Comprehensive Demonstration Study for AES Huntington Beach Generating Station

Final Report, January 2008

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EXECUTIVE SUMMARY

This Comprehensive Demonstration Study (CDS) is submitted by AES Huntington Beach (AES) in compliance with the Huntington Beach Generating Station (HBGS) National Pollution Discharge Elimination System (NPDES) Permit issued in October 2006. The permit provisions imposing Best Technology Available (BTA) reflect to a large extent the Federal Phase II §316(b) Rule (EPA 2004) as modified to a certain extent by the State Water Resources Control Board (SWRCB) Draft §316(b) Policy (SWRCB 2006). Both the Federal Rule and Draft Policy provide for five different compliance alternatives and a number of compliance options. The permit specified that impingement mortality be reduced by 95% and that entrainment be reduced by 90%. The permit compliance alternatives provided that restoration measures could be used to achieve the 90% entrainment reduction if a 60% reduction were achieved through structural and operational measures. Additionally, the permit allows AES to use "site-specific standards" by demonstrating that compliance with the performance standard is not reasonably feasible.

Currently, HBGS has technologies in place that reduce impingement mortality by an estimated 82% through use of an offshore intake with a velocity cap. Additionally, AES has signed a Memorandum of Understanding (MOU) committing to restore over 66 acres of coastal wetland. This acreage was estimated by the California Energy Commission (CEC) Staff as necessary to offset entrainment losses for HBGS Units 3&4 using the habitat production foregone method specified in the permit (CEC 2006).

Seven potential structural and/or operational alternatives for meeting the performance standards were identified by Alden Research Laboratory for more detailed evaluation. Three of these alternatives were initially determined as not feasible either due to physical or generation constraints and/or economic and performance considerations:

- Use of Reclaimed Wastewater for Once-through Cooling – This option was determined as not feasible due to inadequate reclaimed water being available to reliably meet the water supply needs of a single generating unit.
- Reduced Cooling Water Pump Use – This option was determined to be infeasible because HBGS already implements procedures to minimize use of condenser cooling water pumps. Cooling water pump operation is limited to that needed to meet generation needs and protect station equipment. The CDS assumes flows would be required from actual rather than design flow. Since actual flows are currently well below design flow due to operational practices, any additional reduction in flow would be expected to directly impact HBGS generation. Therefore, there is no incremental benefit to be derived from further curtailing pump operation or reducing flow through use of variable frequency drives (VFDs). Since periods of highest entrainment tend to overlap with periods of

highest dispatch requirements for HBGS (i.e. summer periods) additional flow reduction would directly affect generation.

- Extending the Intake to Cooler Water Further Offshore – The cost of this option was determined to be on the same order-of-magnitude as retrofitting with closed-cycle cooling. Because the costs were similar and closed-cycle cooling would automatically comply with the permit while the benefit of the offshore relocation could not be determined, this alternative was deemed infeasible on an economic and performance basis.

Four technologies and operational measures were determined to be feasible and were evaluated in additional detail. The estimated performance and costs associated with these alternatives are summarized as follows:

- Fine-mesh Traveling Screens – This option would be expected to achieve the additional 13% reduction in impingement mortality necessary to meet the impingement reduction standard. However, due to the predominance of very small eggs and larval fish the estimated performance ranges from a 0% reduction for gobies and blennies to a reduction of 15.4% for queenfish and would not meet the entrainment reduction standard. This was one of the lower cost technologies with an estimated capital cost of $6,348,000 and an annual operation and maintenance (O&M) cost of $1,271,952.
- Modular Inclined Screens – This technology would also be expected to achieve the 13% additional reduction to meet the impingement reduction standard but is expected to provide only a minimal reduction in entrainment. This was identified as the lowest cost option with a capital cost of $2,502,000 and an O&M cost of $423,984/yr.
- Narrow-slot Wedgewire Screens – This technology would automatically comply with the impingement mortality reduction standard by reducing the through-screen velocity to less than 0.5 fps. Entrainment reduction performance would be variable by species. For many of the dominant species, the reduction was found to be within the performance standard range (e.g., CIQ gobies 64.1% and northern anchovy 71.7%). However, for some other dominant species it was less than 60% effective (e.g., croaker 58.8%, combtooth blennies 21.8% and diamond turbot 11.3%). The overall performance estimated for this technology is a 61.4% reduction in entrainment. Based on this estimate, this technology would be the best performing alternative fish protection technology. Prior to selection, pilot studies would be required to verify that entrainment would be reduced to within the 60% to 90% reduction required by the Federal Phase II Rule and confirmation that closed-cycle cooling is not determined to be BTA.
- Retrofit with Closed-cycle Cooling – This alternative would meet the performance standards for both impingement and entrainment. However, this alternative had the highest cost with an estimated capital cost of $152,796,000 for wet closed-cycle cooling and almost $200,000,000 for dry cooling.

Based on this review of the alternatives and other important considerations discussed in Section 7, AES determined that on an interim BPJ basis a combination of restoration measures and site-specific standards was the most appropriate approach for complying with the permit provisions at this time. Specifically, AES is providing a Restoration Plan for the coastal wetland restoration project being constructed to generate sufficient larval fish/shellfish production to offset entrainment losses for Units 3&4. This CDS documents the applicability of site-specific standards using the cost-benefit test for reducing entrainment for Units 1&2 by 90% and reducing impingement mortality for all four units by an additional 13%. Veritas Economic Consulting conducted a benefit valuation study using the general approach employed by the Environmental Protection Agency (EPA) in the Phase II Rule. The benefits of achieving an additional 13% reduction in impingement mortality and a 90% reduction in entrainment for Units 1&2 were estimated. Under the above specifications, the mean expected net present value (NPV) is $158,600 and the upper (95%) and lower (5%) bounds on uncertainty are $254,000 and $94,000 respectively. The annualized (NPV/20) benefits associated with impingement mortality and entrainment reductions range from $4,719 to $12,700/yr with a mean estimate of $7,928/yr. This distribution of expected benefits is conditional upon the presumption that reducing I&E leads to increases in local fish populations and corresponding increases in expected commercial and recreational catch. The equilibrium expected change in recreational catch is 543 fish per year. The equilibrium expected change in commercial harvest is 80 pounds per year.

In the context of the technology costs associated with the alternatives, these benefit estimates demonstrate that the cost of each of the four alternatives evaluated were significantly greater than the environmental benefit that would be achieved. The result is that the existing cooling water intake structure is BTA using the Best Professional Judgment (BPJ) criteria in the current permit.

AES recognizes that the Second Circuit Court Decision on the §316(b) Phase II Rule has rejected the use of restoration measures and the cost-benefit test under a revised Phase II Rule and/or California State §316(b) Policy. However, it is important that any final decision regarding requirements for additional fish protection technologies for HBGS be consistent with both the California State Policy and the revised Federal Phase II Rule. Work is currently in progress within the EPA and the SWRCB to issue a proposed Rule/Policy in 2008. Thus, the timing of this CDS effort necessitates an interim approach to a BTA and BPJ determination.

An interim BPJ decision for no additional structural or operational requirements until a revised Phase II Rule or California State §316(b) policy is issued is supported by:

- Previous determinations in the HBGS NPDES permits that the facility is in compliance with §316(b);

- Restoration measures being implemented to offset entrainment losses for Units 3&4 and reduction in impingement mortality of 82% using existing intake technologies; and

- The lack of a BTA determination by either EPA or SWRCB for facilities such as HBGS, particularly in light of the substantial costs and potential to result in significant environmental and social impacts to the community.

- Results of the one year 2003/2004 entrainment studies conducted at HBGS determined that for the geographic areas where the dominant entrained species were vulnerable to entrainment the losses did not exceed 1.2% for any species of finfish and 1.1% for any species of shellfish. The vast majority of these losses occurred to the earliest life stages when natural mortality is highest. Natural mortality in many of these species would be in excess of 99%.

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1
INTRODUCTION

This Comprehensive Demonstration Study (CDS) is being submitted for two key purposes:

1. Satisfying the requirements of Special Provisions VI.C.2(a) and VI.C.7 of Order No. R8-2006-0011, for the Huntington Beach Generating Station (HBGS) National Pollution Discharge Elimination System (NPDES) Permit No. CA0001163, and
2. Providing the Santa Ana Regional Water Quality Control Board (Board) with sufficient data and analysis for decision-making using the Best Professional Judgment (BPJ) criteria in the current permit..

The regulatory context includes the original §316(b) Phase II Rule for large existing power plants (the Rule), the HBGS NPDES permit, the Second Circuit Court Decision on the Rule, the U. S. Environmental Protection Agency's (EPA) withdrawal of the Rule, and the California State Water Resources Control Board's (SWRCB) efforts to develop a State §316(b) Policy.

1.1 HBGS 316(b) NPDES Permit Requirements

Subsequent to the EPA's issuance of the Rule, the Board included Special Provisions VI.C.2(a) and VI.C.7 in Order No. R8-2006-0011, NPDES No. CA0001163 of the HBGS NPDES Permit. These provisions required AES to comply with the Rule by submitting CDS documents by January 7, 2008. As noted in Section II.K of the permit, the §316(b) requirements were issued on a BPJ basis.

Special Provision VI.C.2(a) required that:

As soon as practicable, but no later than January 7, 2008, the Discharger shall submit the Comprehensive Demonstration Study. The Study shall include the following components:

1. Source Waterbody Flow Information, as described at 40 CFR 125.95(b)(2);
2. Impingement Mortality and/or Entrainment Characterization Study, as described at 40 CFR 125.95(b)(3), to support development of a calculation baseline for evaluating impingement mortality and entrainment and to characterize current impingement mortality and entrainment;
3. Design and Construction Technology Plan and a Technology Installation and Operation Plan, as described at 40 CFR 125.95(b)(4);
4. Restoration Plan, as described at 40 CFR 125.95(b)(5);
5. Information to Support Site-Specific Determination of BAT, as described at 40 CFR 125.95 (b)(6); and
6. Verification Monitoring Plan as described at 40 CFR 125.95(b)(6).

Special Provision VI.C.7. also provides:

(a). In accordance with the CWA 316(b) Phase II regulations, as expeditiously as practicable but no later than January 7, 2008, the Discharger shall identify in the Comprehensive Demonstration Study the best technology available for minimizing adverse environmental impact at the Facility site and complying with the performance standards established in VII.C.7.b. below. This shall be accomplished by identifying any one or a combination of the following alternatives:

1. A reduction of cooling water intake flow commensurate with a closed-cycle recirculating system or a reduction of the design intake velocity of the cooling water intake structure to 0.5 feet per second (ft/s) or less; or
2. A demonstration that the existing design and construction technologies, operational measures, and/or restoration measures meet the performance standards and/or restoration requirements; or
3. A demonstration that the facility's existing design and construction technologies, operational measures, and/or restoration measures meet the performance standards and/or restoration requirements. A demonstration that selected new design and construction technologies, operational measures, and/or restoration measures, in combination with any existing technologies, operational measures, and/or restoration measures will meet the performance standards and/or restoration requirements; or
4. A demonstration that the facility meets a pre-approved design and construction technology; or
5. A site-specific demonstration, based on cost considerations, of best technology available to minimize adverse environmental impact.

(b). Implementation of any or a combination of the actions specified in VII.C.7.a. above shall meet the following unless a site-specific demonstration (7.a.5 above) demonstrates that compliance with the numeric limits in 1) and 2), below are not reasonably feasible:

1. Reduce impingement mortality for all life stages of fish and shellfish by at least 95% from the calculated baseline by any combination of operational or structural controls.
2. Reduce entrainment by at least 90 % from the calculation baseline. If the Discharger demonstrates that achieving a 90% reduction in entrainment via any combination of structural or operational controls is infeasible, then the Discharger may use restoration measures to achieve the required 90% reduction as follows:
    a) The Discharger must reduce entrainment of all life stages of fish and shellfish by a minimum of 60% from the calculated baseline by any combination of operational or structural controls, and
    b) Restoration measures (i.e., mitigation) must be employed to achieve the remaining percent reduction in entrainment over the minimum achieved above, up to 90%, of all life stages of fish and shellfish from the calculated baseline. If restoration measures are to be used as the compliance alternative, this Order will use the habitat production foregone methodology in assessing entrainment losses and then apply that information to a restoration project.

These permit requirements were more stringent than the Federal Rule requirements in that they required meeting the upper end of the performance standard range.

The PIC was submitted to the Board in July 2005 followed by a meeting with the Board to discuss PIC studies and address questions in August 2005.

The NPDES Permit also required that quarterly public stakeholder meetings be conducted to keep the public informed of progress on the CDS. Quarterly meetings were held at HBGS on:

- January 18, 2007
- June 20, 2007
- September 13, 2007
- December 18, 2007

1.2 The Phase II Rule Regulatory Provisions

EPA promulgated new regulatory provisions for existing electric power generating facilities to comply with Section 316(b) of the Clean Water Act on July 9, 2004. These regulations became effective on September 7, 2004 and were based on numeric performance standards[1]. The Rule at 125.94(a) (1-5) provided facilities with compliance flexibility by incorporating five alternatives as follows:

1. *A facility can demonstrate it has or will reduce cooling water flow commensurate with wet closed-cycle cooling and be determined to be in compliance with all applicable performance standards. A facility can also demonstrate it has or will reduce the maximum design through-screen velocity to less than 0.5 ft/s in which case it is deemed in compliance with the impingement mortality (IM) performance standard (the entrainment standard still applies).*
2. *A facility can demonstrate that it has technologies and/or operational measures and/or restoration measures in place that will meet the applicable performance standards.*
3. *A facility can propose to install new technologies and/or operational measures and/or restoration measures to meet applicable performance standards.*
4. *A facility can propose to install, operate and maintain an approved design and construction technology.*
5. *A facility can request a site-specific determination of BTA by demonstrating that either the cost of installing technologies and/or operational measures and/or restoration measures are significantly greater than the cost for the facility listed in Appendix A of the rule or that the cost is significantly greater than the benefits of complying with the applicable performance standards.*

All facilities that use compliance alternatives 2, 3 and 4 were required to demonstrate a minimum reduction in impingement mortality (IM) of 80% (125.94(b) (1)). Facilities with a capacity factor that is greater than 15% that are located on oceans, estuaries, or the Great Lakes, or on rivers and have a design intake flow that exceeds more than 5% of the mean annual flow, were also required to reduce entrainment by a minimum of 60% (125.94(b)(2)).

The Rule further provides that facilities using compliance alternatives 2, 3, and 5 prepare a CDS as described at 125.95(b). There were seven components of a CDS and all facilities were required to submit the following: 1) Proposal for Information Collection (PIC); 2) Source

[1] Performance standards are found at 125.94(b)

Waterbody Information (if facility is on a river or reservoir); 3) Impingement Mortality and Entrainment (IM&E) Characterization Study; and 7) Verification Monitoring Plan. Facilities using compliance alternative 1 were not required to submit a CDS and those using compliance alternative 4 are only required to submit the Technology Installation and Operation Plan (TIOP) and Verification Monitoring Plan. All facilities that used compliance alternatives 2, 3 and 5 were required to prepare and submit components 1, 2, 3, and 7, but depending on the compliance alternative(s) selected would submit one or more of the following three components 4) Design and Construction Technology Plan and Technology Installation and Operation Plan, 5) Restoration Plan or 6) information to support a site specific BTA determination. Only one or any combination of these components might be required depending on which one (or more) of the three alternatives was selected for compliance.
The first CDS document required for submittal was the PIC. The Rule at 125.95(b)(1) required that the PIC include:

1. *A description of the proposed and/or implemented technologies, operational measures, and/or restoration measures to be evaluated in the Study.*
2. *A list and description of any historical studies characterizing impingement mortality and entrainment (IM&E) and/or the physical and biological conditions in the vicinity of the cooling water intake structures (CWIS) and their relevance to this proposed Study. If you propose to use existing data, you must demonstrate the extent to which the data are representative of current conditions and that the data were collected using appropriate quality assurance/quality control procedures.*
3. *A summary of any past or ongoing consultations with appropriate Federal, State, and Tribal fish and wildlife agencies that are relevant to this Study and a copy of written comments received as a result of each consultation.*
4. *A sampling plan for any new studies you plan to conduct in order to ensure that you have sufficient data to develop a scientifically valid estimate of IM&E at your site. The sampling plan must document all methods and quality assurance/quality control procedures for sampling and data analysis. The sampling and data analysis methods you propose must be appropriate for a quantitative survey and include consideration of the methods used in other studies performed in the source waterbody. The sampling plan must include a description of the study area (including the area of influence of the CWIS(s)), and provide a taxonomic identification of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish).*

An important feature of the Rule was use of the calculation baseline. The calculation baseline was defined as follows:

Calculation baseline means an estimate of impingement mortality and entrainment that would occur at your site assuming that: the cooling water system has been designed as a once-through system; the opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment. You may also choose to use the current level *of impingement mortality and entrainment as the calculation baseline. The calculation baseline may be estimated using: historical impingement mortality and entrainment data from your facility or another facility with comparable design, operational, and environmental conditions; current biological data collected in the waterbody in the vicinity of your cooling water intake structure; or current impingement mortality and entrainment data collected at your facility. You may request that the calculation baseline be modified to be based on a location of the opening of the cooling water intake structure at a depth other than at or near the surface if you can demonstrate to the Director that the other depth would correspond to a higher baseline level of impingement mortality and/or entrainment.*

1.3 Second Circuit Court Decision

Shortly after the final Rule was issued, a number of northeastern states and stakeholders (including environmental organizations and industry) filed lawsuits on various aspects of the new §316(b) regulations. The Second Circuit Court of Appeals (the Court) issued its §316(b) Phase II Rule decision (Decision) on January 27th 2007. The Decision remanded significant portions of the Rule back to EPA. The Court determined that use of restoration measures and the Cost-Benefit Test could not be used as compliance options. Two Rule provisions, the Cost-Cost Test and the Technology Installation and Operation Plan (TIOP) were remanded back to EPA for failure to provide adequate opportunity for public review and comment. Perhaps most importantly, the Court remanded to EPA the determination of Best Technology Available (BTA). Relative to BTA, the Court raised a number of issues that EPA will have to address in the promulgation of a revised Rule that included:

- Closed-cycle Cooling as BTA – The Court said that EPA may have based its determination that closed-cycle cooling was not BTA for existing facilities at least in part on the cost of the technology relative to the environmental benefits. The Court pointed out that consideration of the environmental benefits is not allowed. The Court remanded this determination back to EPA for clarification. The Court clarified that EPA could consider factors that included industries' ability to bear the cost, impacts to energy production and supply and adverse impacts associated with retrofits in making this determination.

- Use of "Best Performing" Technology – The Court upheld EPA's use of performance standard ranges. However, the Court determined that facilities must use the "best performing" technology in the performance standard range rather than the most cost-effective technology.

- Consideration of Cost – The Court ruled that EPA could consider the cost of technologies to a limited extent in the BTA determination. The first issue is whether or not facilities can bear the cost of the technology. The second was limited to the use of cost-effectiveness. On this point the Court ruled that if there was an overlap in the expected environmental performance ranges of two best performing technologies, the facility could select the most cost-effective option rather than the one that had the potential for higher performance.

1.4 EPA Withdrawal of the §316(b) Phase II Rule

In response to the Decision, EPA issued a memorandum to EPA's Regional Offices dated March 20, 2007 announcing withdrawal of the §316(b) Phase II Rule. This was followed by a notice in the Federal Register on July 9, 2007. Specifically, the memorandum and Federal Register notice stated the withdrawal of the Rule was a result of the Decision's impact on the overall compliance approach. EPA determined that so many of the Rule's provisions were affected by the Decision that the overall Phase II approach was no longer workable for compliance. The memorandum and Federal Register notice further directed EPA Regional Offices and delegated states to implement §316(b) in NPDES permits on a BPJ basis until the Decision issues are resolved. EPA is currently considering alternatives for responding to the Decision and is engaged in making revisions to the Rule (EPA personal communication with EPRI).

In response to the March 2007 EPA memorandum, AES met with the Board in April 2007 to discuss the §316(b) NPDES permit requirements as a result of EPA's withdrawal of the Rule. It was agreed that AES would continue to prepare and submit the CDS in January 2008 as specified in the permit, since the information contained in the PIC and CDS could be used as a basis for the Board to make a BPJ determination.

1.5 California SWRCB §316(b) Policy Development

After holding two public stakeholder meetings for input, the SWRCB issued a proposed Statewide 316(b) Policy in June 2006 (Draft Policy). The Draft Policy set requirements for 316(b) in California that went beyond the requirements in the §316(b) Phase II Rule. There were a number of significant deviations that included requiring facilities to meet the Rule's maximum performance standards for reduction of impingement mortality and entrainment rather than the performance standard range provided for in the Rule. Other deviations from the Rule included:

- Including consideration of zooplankton as an entrainable life stage.
- Only allowing the use of restoration measures for achieving the maximum 90% entrainment reduction after reducing entrainment by a minimum of 60% from the calculation baseline by any combination of operational or structural controls.
- Not allowing facilities to use restoration measures for compliance with the impingement reduction performance standard.
- Basing the "calculation baseline" on actual average flow and including reference stations as part of the calculation baseline.
- Not allowing facilities to use the Rule's Compliance Alternative 5 by demonstrating that the cost of meeting the performance standards would be significantly greater than the environmental benefit or costs considered by EPA.
- Requiring that facilities use the "habitat production foregone" method to determine the amount of restoration for compliance.
- Requiring some facilities to conduct studies to evaluate cumulative impacts.
- Requiring detailed monitoring studies including:

- Quantification of all species and life stages
- Quantification of impacts to zooplankton in addition to fish and shellfish
- Requiring use of specific performance assessment models (FH, AEL and ETM)

SWRCB has not yet finalized the Draft Policy. However, it is AES's understanding that they are still contemplating a State §316(b) Policy and that such a Policy may be forthcoming in 2008.

1.6 Supreme Court Review of Second Circuit Decision

The Utility Water Act Group (UWAG), Entergy Corporation, and Public Service Gas and Electric Company filed a timely petition for Certiorari with the Supreme Court to review the Decision. At this point it is not yet know if the Court will hear this case. The Court has extended the deadline for filing responses to the three petitions filed to February 1, 2008.

1.7 Comprehensive Demonstration Study Organization

AES's CDS approach for HBGS is submitted in conformance with the NPDES requirements laid out in Section 1.2. Section 2 provides a description of HBGS and the overall compliance approach is discussed in Section 3. Section 4 provides a summary of the results of the Impingement Mortality and Entrainment Characterization Study. Section 5 provides a summary of compliance using restoration measures for Units 3&4 entrainment mitigation, while Section 6 provides a summary of compliance for Units 1&2 entrainment and the additional 13% impingement reduction needed for all four units. Section 7 provides an overall summary of compliance for the CDS and BPJ requirements and considerations for compliance decision-making.

2 FACILITY DESCRIPTION

A description of the HBGS was presented in the PIC. That information is also provided in this section to provide readily available context for other portions of the CDS.

2.1 Location and Physical Description of Cooling Water Intake Structure and Cooling System

HBGS is located on the shore of the Pacific Ocean in Huntington Beach, California (Figure 1). The station consists of four units. Units 1 through 4 are each a nominal 225 MWe for a total of approximately 900 MWe. All four of these units rely on ocean water withdrawn by a once-through system for cooling. The capacity utilization between 2001 and 2006 averaged 31.5% for Unit 1 and 31.0% for Unit 2. Capacity utilization for Units 3&4 between 2003 and 2006 (when these Units returned to operation) was 14.4% and 12.7%, respectively.

In December 2000, AES Huntington Beach L.L.C filed an Application for Certification for the HBGS Re-tool Project (Re-tool Project). The project consisted of re-powering and operating Units 3&4 which were retired from service in 1995. The Re-tool Project was approved in May 2001. The Units 3&4 steam turbine generators were rebuilt with new natural gas burners and emissions control technologies. Unit 3 came on-line in summer 2002 and Unit 4 in summer 2003.

The HBGS offshore intake is located approximately 1,500 ft offshore and is fitted with a velocity cap (Figure 2). The velocity cap is submerged approximately 17.5 ft below mean sea level and is approximately 5 ft above the intake riser. The velocity cap is 33 ft by 28 ft, and provides the benefit of fish protection by changing the direction of cooling water flow from vertical to horizontal. The horizontal velocity at the opening of the velocity cap is 2.8 fps. The velocity cap and pipes are made of concrete and are fitted with barriers to prevent marine mammals, large fish, and sea turtles from entering the offshore intake pipe. After entering the velocity cap, the water flows down 21 ft into a 14 foot diameter intake pipe that is used to transport the water to an onshore intake structure.

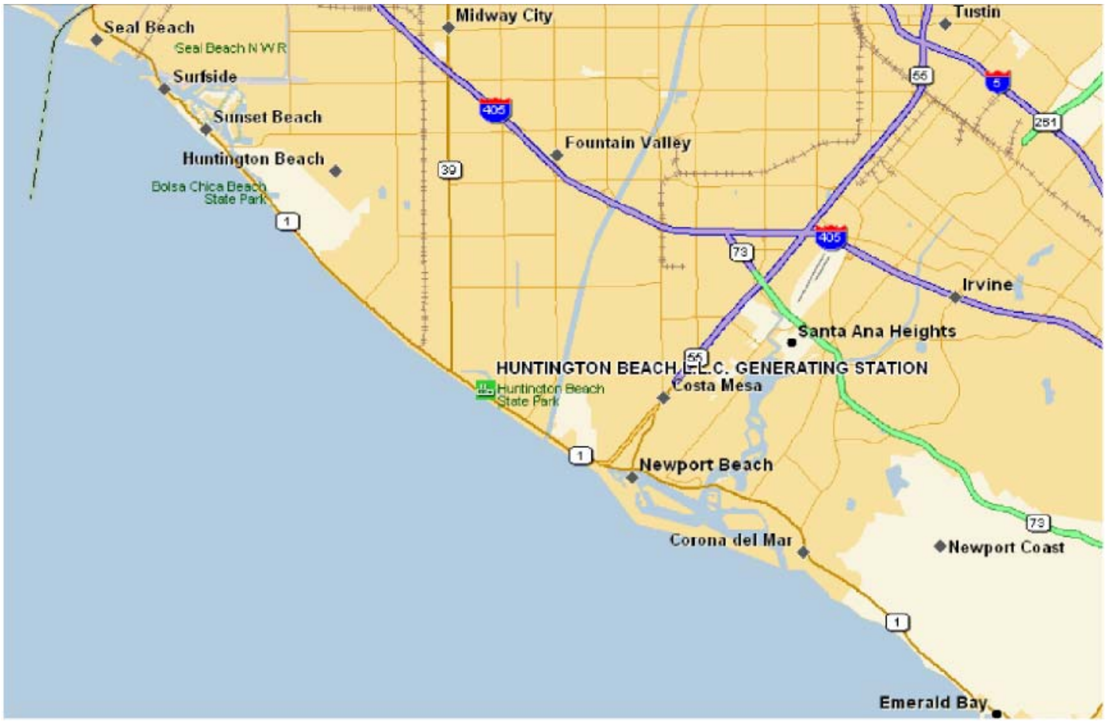


Figure 1 – Vicinity Map of Huntington Beach Generating Station

Once the water reaches the onshore intake forebay it is directed by guiding vanes to three wider screen bays. These three screen bays then merge into two trash rack bays. The trash racks are made of vertical steel bars spaced 3 inches apart to prevent large debris or objects from reaching and damaging the traveling screens. After passing through the trash racks the intake channel expands slightly and splits into four 11 ft wide channels, each containing traveling water screens. The approach velocities to the four traveling screens vary slightly and are 0.80, 0.96, 1.04 and 0.98 fps for Units 1, 2, 3, and 4 respectively. The screens are equipped with a high-pressure spraywash system that washes any debris and impinged organisms into a screenwash trough where washwater and material removed from the screens are discharged into a trash basket. The traveling screens are normally operated twice per shift for a period of approximately 20 minutes.

After passing through the traveling screens, cooling water enters a box culvert 14 ft wide and 11 ft high. The culvert is 236 ft long with a slight grade leading to the circulating water pumps. Due to the increased size in the channel, velocity decreases slightly. There are eight cooling water pumps, two for each of the four units. The six pumps used by Units 1-3 are each rated at 98 cfs, with the two pumps for Unit 4 rated at 103.2 cfs. The combined cooling water flow for all four units is 794.4 cfs. After passing through the condensers the cooling water is discharged through a 14 foot diameter concrete pipe that runs parallel to the intake pipe. The discharge point is approximately 1,200 ft offshore, 300 ft south of the intake at a depth of 21.3 ft. The discharged waters are directed vertically toward the surface by a riser that is similar in design to that at the intake structure.

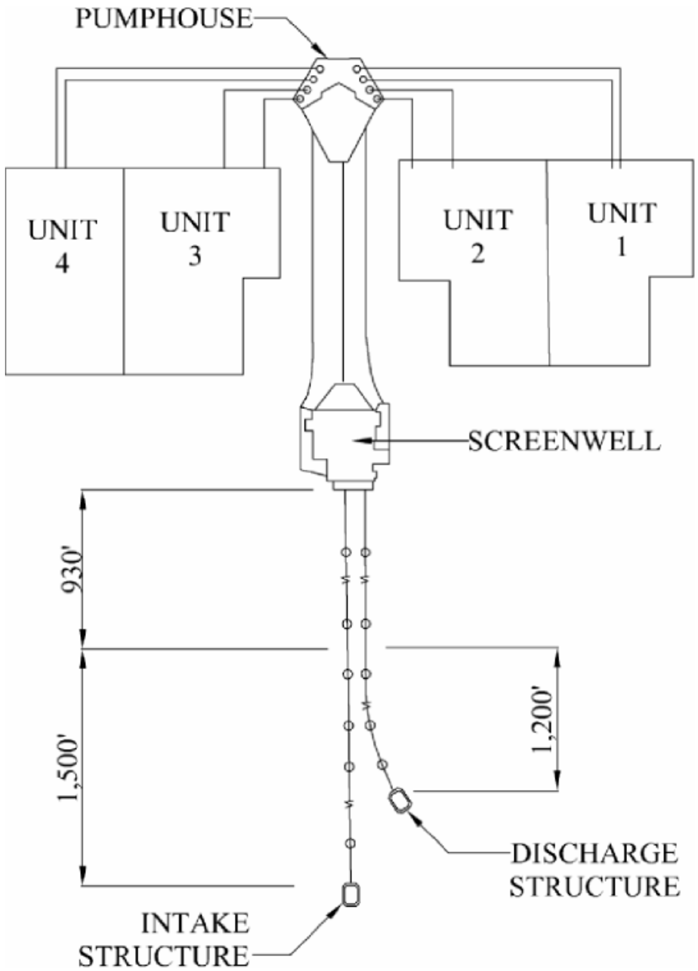


Figure 2 – HBGS Cooling Water Intake System

As is the case with many other California facilities, HBGS uses a combination of sodium hypochlorite and heat treatment to control biofouling. The sodium hypochlorite is used to control microfouling organisms in the condenser tubes that adversely affect the efficiency of the heat transfer. Biofouling in the forebay, cooling water conduits, and on the traveling screens is controlled by heat treatment. In this procedure, some of the heated water that has passed through the condensers is recirculated to the intake forebay for approximately one hour, which is sufficient to control mussels, barnacles and other attached organisms that might clog or impede normal operation of the cooling system.

2.2 §122.21(r)(2),(3), and (5) Information

Attachment 1 contains the §122.21(r)(2),(3), and (5) information required by 40 Code of Federal Regulations (CFR). The information is required to be submitted by all Phase II facilities regardless of the compliance alternative selected. Specifically, information in Attachment 1 provides additional information on the source waterbody, cooling water intake structure, and cooling water system to assist the Board in making its BPJ determination.

3 §316(B) COMPLIANCE APPROACH FOR HBGS

As discussed in the Introduction, EPA has remanded the Rule in its entirety. The result is that from a federal perspective the requirements to meet specific numeric performance standards, submit a CDS, submit the 122.21(r)(2),(3), and (5) information, and meet the associated §316(b) compliance schedules are no longer applicable. However, until the HBGS permit is re-opened and modified with BPJ requirements, AES is required to prepare a CDS in conformance with the NPDES requirements and schedule. The compliance approach selected, based on the permit requirements for the CDS, is discussed in the following sections:

3.1 Source Waterbody Information

The Source Waterbody Information CDS document is required only for facilities located on freshwater rivers or reservoirs. Since HBGS withdraws its condenser cooling water from an ocean this CDS document is not required.

3.2 Impingement Mortality and Entrainment Characterization Study

This document is provided and was prepared in a manner consistent with the studies described in the PIC. Section 4 provides a summary of the impingement and entrainment study results and the complete IM&E Characterization Study Report is provided as Attachment 2. The approach used in the study and CDS are fully consistent with the requirements of §125.95(b)(3) of the Rule and the NPDES permit.

3.3 Use of Compliance Alternative 3 to Meet Entrainment Reduction Standard for Units 3&4

AES has signed a memorandum-of-understanding (December, 2006) to implement restoration measures to offset entrainment losses for Units 3&4. Use of restoration measures under Compliance Alternative 3 requires that a Restoration Plan be submitted. The Restoration Plan has been prepared in a manner that complies with the requirements of §125.95(b)(5) of the Federal Phase II Rule and Special Provision VI.C.2(a)(4) of the Permit. A more detailed summary of those requirements, the restoration measures being used, verification monitoring, and other requirements are summarized in Section 5 and fully discussed in the Restoration Plan (Attachment 3).

3.4 Use of Site-Specific Standards to Meet the Impingement Mortality Reduction Standard and Entrainment Reduction Standard for Units 1&2

Section 6 provides AES's compliance analysis for HBGS for impingement mortality reduction for Units 1-4 and entrainment reduction for Units 1&2. While the HBGS cooling water intake structure can comply with the impingement mortality reduction standard of the Federal Rule, it falls short of the 95% reduction standard specified in the permit. Similarly, while entrainment losses of Units 3&4 will be fully mitigated using habitat restoration measures, additional compliance measures are necessary for Units 1&2. AES conducted a Comprehensive Cost Evaluation Study to evaluate the costs of technologies and operational measures to comply with the NPDES permit. Based on those costs, AES also conducted a Cost-Benefit Test as specified in Sections VI.C.2(a)5 and VI.C.7(a)5 of the NPDES permit. The specific CDS documents required for this approach include a Comprehensive Cost Evaluation Study, Benefit Valuation Study, Site-specific Technology Plan, and a Verification Monitoring Plan. These CDS documents are summarized in Section 6 and provided as Attachment 4 (Comprehensive Cost Evaluation Study), Attachment 5 (Benefit Valuation Study) and Attachment 6 (Site-Specific Technology Plan and Verification Monitoring Plan).

3.5 Best Professional Judgment Compliance Considerations

The EPA has withdrawn the Rule and directed EPA regions and NPDES delegated states to implement §316(b) in individual NPDES permits on a BPJ basis. AES provides a discussion of key factors for consideration by the Board in developing its final BPJ determination for HBGS. A discussion of these considerations is provided in Section 7 along with an overall compliance summary.

4 IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY

AES performed an IM&E study to satisfy the California Energy Commission Conditions of Certification for BIO-4 and BIO-6 of the AES HBGS Re-tool Project. Impingement sampling began in late July 2003, and entrainment and source water sampling began in September 2003. Field studies were completed in late-August 2004. This study was conducted in a manner that satisfied all of the requirements for an Impingement Mortality and Entrainment Characterization Study required by §129.95(b)(3) of the Rule.

Thirty-two entrainment surveys and twelve combined entrainment/source water surveys were done between September 2003 and August 2004. Fish larvae from 57 different taxonomic groups were collected during the entrainment surveys. A three-species complex of gobies were the most abundant fish larvae in the entrainment samples and made up 37% of the total estimated entrainment. This species complex (CIQ gobies) is comprised of one or more of the following nearshore gobies that cannot be distinguished during early larval stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*). Other abundant larval fish taxa included: northern anchovy (*Engraulis mordax*; 18%), spotfin croaker (*Roncador stearnsii*; 14%), white croaker (*Genyonemus lineatus*; 7%), and queenfish (*Seriphus politus*; 5%). Seventy-nine larval fish taxa were collected during the source water surveys but only six taxa made up 80% of the total fish larvae collected from the source water samples: CIQ gobies (37%), northern anchovy (18%), queenfish (10%), white croaker (9%), unidentified croakers (4%), and combtooth blennies (*Hypsoblennius* spp.; 3%).

Of the five proposed target invertebrate taxa, only two were collected in entrainment samples: sand crab (*Emerita analoga*) and rock crab (*Cancer* spp.). Sand crab larvae comprised nearly 99% of the entrained target invertebrates. Almost all of the sand crab larvae were in the earliest stage of their larval development (zoea stage I). No California spiny lobster (*Panulirus interruptus*), market squid (*Loligo opalescens*), or ridgeback prawn (*Sicyonia ingentis*) larvae were collected.

Potential impacts to CIQ gobies, northern anchovy, and combtooth blennies were analyzed using:

- demographic modeling (Adult Equivalent Loss [*AEL*]), and/or Fecundity Hindcasting [*FH*]), and
- Empirical Transport Model (*ETM*)

An additional six larval fish taxa, as well as rock crabs (*Cancer* spp.), were assessed using only the *ETM*. Impact assessment modeling could not be performed for salema (*Xenistius californiensis*) due to lack of life history parameters and the lack of sufficient larvae at both entrainment and source water stations during surveys. For fishes, *AEL* estimates (assuming maximum flow) were 304,125 individuals (northern anchovy) and 147,493 individuals (CIQ gobies) (Table 1). *FH* estimates ranged from 3,233 adult females (combtooth blennies) to 101,269 adult females (CIQ gobies).

Table 1 - Summary of entrainment modeling and impingement estimates for target taxa assuming maximum cooling water flow. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate.

Taxon	Estimated Annual Entrainment	2·*FH*	*AEL*	P_m Alongshore	P_m Alongshore + Offshore	Impingement No.	Impingement Weight (kg)
Finfish							
CIQ gobies	113,166,834	202,538	147,493	1.0%	1.0%	0	0.0
N. anchovy	54,349,017	53,490	304,125	1.2%	0.7%	2,193	14.9
spotfin croaker	69,701,589	NA	NA	0.3%	0.3%	49	1.8
queenfish	17,809,864	NA	NA	0.6%	0.5%	35,847	648.2
white croaker	17,625,263	NA	NA	0.7%	0.4%	4,903	95.4
black croaker	7,128,127	NA	NA	0.1%	0.05%	65	7.0
salema	11,696,960	NA	NA	NA	NA	46	0.5
blennies	7,165,513	6,466	NA	0.8%	0.3%	3	0.02
diamond turbot	5,443,118	NA	NA	0.6%	0.3%	0	0.0
California halibut	5,021,168	NA	NA	0.3%	0.08%	21	9.9
shiner perch	-	-	-	-	-	4,045	51.8
Shellfish							
sand crab megalops	69,793	NA	NA	NA	NA	-	-
Calif. spiny lobster	0	NA	NA	NA	NA	32	19.6
ridgeback rock shrimp	0	NA	NA	NA	NA	0	0.0
market squid	0	NA	NA	NA	NA	7	0.4
rock crab	6,411,171	NA	NA	1.1%	0.8%	5,820	42.1
D. frondosus-nudibranch	-	NA	NA	-	-	65,150	15.0
two-spotted octopus	-	NA	NA	-	-	61	25.4
purple-striped jelly	-	NA	NA	-	-	53	21.7

NA = Not available due to insufficient life history information or low abundance in entrainment samples.
- = Not analyzed.

Two probability of mortality (P_m) estimates (assuming maximum cooling water flow at the HBGS) were calculated for each of the target taxa: one based solely on alongshore current movement and the other on alongshore current movement and an extrapolation of aerial density of larvae offshore to a distance bounded by either the extrapolated densities or onshore current movement. Larval durations of target fish taxa ranged from five days (spotfin croaker) to 38 days (northern anchovy). The P_m estimates based on alongshore current displacement ranged from 0.1% to 1.2% (Table 1). An estimate of the area of larval production lost due to entrainment (area of production foregone, or habitat production foregone) was estimated by multiplying the P_m estimates by the alongshore source water length and the width of the source water area sampled (5 km). Estimates of the area of production foregone ranged from 0.12 to 4.47 km^2, and averaged 1.50 km^2 (Table 2).

Table 2 - Summary of entrainment modeling estimates for target taxa and estimation of area of production foregone. The shoreline distance (km) used in the alongshore extrapolation of P_m is presented in parentheses next to the shoreline distance estimate. Estimates assume maximum cooling water flow at the HBGS.

Taxon	Estimated Annual Entrainment	P_m Alongshore Extrapolation	Shoreline Distance (km) of Production Foregone	Area of Production Foregone (km^2)
CIQ gobies	113,166,834	1.0% (60.9 km)	0.604	3.024
northern anchovy	54,349,017	1.2% (72.0 km)	0.894	4.471
spotfin croaker	69,701,589	0.3% (16.9 km)	0.050	0.248
queenfish	17,809,864	0.6% (84.9 km)	0.531	2.657
white croaker	17,625,263	0.7% (47.8 km)	0.340	1.699
black croaker	7,128,127	0.1% (19.4 km)	0.023	0.115
salema	11,696,960	NA	NA	NA
blennies	7,165,513	0.8% (12.8 km)	0.098	0.492
diamond turbot	5,443,118	0.6% (16.9 km)	0.098	0.488
California halibut	5,021,168	0.3% (30.9 km)	0.077	0.386
rock crab	6,411,171	1.1% (26.5 km)	0.284	1.418

A total of 52 normal operation impingement surveys were conducted from July 2003 to July 2004, and six heat treatment impingement surveys were conducted through July 2004. Results from the weekly normal operation surveys were extrapolated based on cooling water flow and summed with heat treatment results to estimate total annual impingement. A total of 51,082 fishes representing 57 species and weighing 1,292 kg was impinged, with most (75%) of the losses attributable to heat treatments. Queenfish was the most abundant species impinged, accounting for 70% of total abundance. Other abundant impinged fish species included white croaker, shiner perch (*Cymatogaster aggregata*), and northern anchovy. A total of 70,638 macroinvertebrates representing 37 species and weighing 168 kg was impinged, with most (98%) of the losses attributable to normal operations. The most abundant species were a nudibranch (*Dendronotus frondosus*), yellow rock crab (*Cancer anthonyi*), slender rock crab (*Cancer gracilis*), and brown rock crab (*Cancer antennarius*).

"Calculation Baseline" estimates were made for both impingement mortality and entrainment at the HBGS assuming (1) design cooling water flow, and (2) actual cooling water flow during 2004-2005. The 2004-2005 period was considered to be a representative period of facility operations since Units 3&4 were refurbished. The results of the calculation baseline analysis are discussed further in Section 6 of this document and can also be found in the Impingement Mortality and Entrainment Characterization Study (Attachment 2).

5 USE OF RESTORATION MEASURES UNDER COMPLIANCE ALTERNATIVE 3 FOR UNIT 3&4 ENTRAINMENT REDUCTION

Special Provision VI.C.2(a)(4) of the NPDES permit specifies that a Restoration Plan shall be submitted as described at 40 CFR 125.95(b)(5) of the Rule. As a result of a re-tool project to restore Units 3&4 operation, the California Energy Commission (CEC) issued the final Order for Compliance with Condition of Certification for BIO-5 (CEC 2006). This Order required mitigation of significant adverse impacts due to entrainment as a result of Units 3&4 condenser cooling water flow. The Order was based on the "Huntington Beach Units 3&4 Entrainment and Impingement Study Results, Mitigation Options, Staff and Working Group Recommendations, and AES's Response and Objections to the Recommendations" report issued by the CEC (CEC 2006).

The CEC staff determined that use of coastal wetland habitat restoration was the most appropriate option for offsetting entrainment losses. CEC staff and their consultants used the habitat production foregone model to scale the amount of coastal wetland that must be restored to offset Units 3&4 entrainment losses. The scaling of the wetlands project was based on on the actual forecasted operations of the units (rather than design flow). The maximum projected operations of Units 3&4, calculated by AES for HBGS was estimated to be 25% operation during the first quarter of each year, 50% during the second, 80% during the third, and 45% during the fourth quarter. This estimated 50% annual operation was considered conservative by AES for HBGS. Based on this estimate CEC staff determined that restoration of 66.8 acres of coastal wetland would be needed to offset entrainment losses.

It was pointed out in the CEC staff analysis that in California more than 90% of the coastal wetlands have been lost due to human activity, and there are state and federal efforts underway to accelerate the pace of coastal wetland restoration. In addition to increasing the net production of fish and shellfish by enhancing existing habitat or creating new habitat, restoration of coastal wetlands would provide multiple benefits. These benefits include: improvements in water quality by trapping pollutants before they enter coastal waters; providing foraging, resting, and nesting habitat for seabirds and shorebirds, including sensitive species; physical improvements in terrestrial and avian habitats; improved aesthetics; added recreational and/or viewing opportunities (CEC 2006). Tidal wetlands provide nursery habitat for many nearshore fish species and also export organic matter that enhances coastal food chains.

AES and its scientific experts had significant disagreements with the CEC staff on the need for restoration and the methods used for determining the appropriate scale of the restoration project including the need to consider the added environmental benefits of wetlands restoration. The basis for the need for restoration was entrainment losses that were estimated to result in losses of less than 1.2% to larval fish populations that extend along miles of coastline. At the request of the CEC, AES estimated that the restoration of 12.5 acres of wetlands would compensate for entrainment losses to gobies, which primarily occur in wetland habitats and comprised the greatest percentage of the entrained fish larvae. Instead the CEC staff scaled the wetlands restoration using nearshore ocean fishes that occur over miles of coastline grossly exaggerating the estimate and resulting in a negotiated project that more than compensates for any losses due to the HBGS.

The HBGS NPDES permit at VI.C.7(b) requires that unless a site-specific demonstration required by VI.C.7(a)(5) demonstrates that compliance with the numeric limits in VI.C.7(b)(1) and (2) are not reasonably feasible then use of restoration measures would be limited to 30% of the overall 90% reduction required. A site-specific demonstration of §316(b) compliance is provided in Section 6 below and CDS Attachments 4, 5 and 6.

The Conceptual Restoration Plan for the Huntington Beach Wetlands was prepared in April 2006 (Moffatt & Nichol 2006). The Huntington Beach Wetlands occupy approximately 191 acres (0.773 km^2) of the remnants of coastal salt marsh habitat associated with the Santa Ana River in Huntington Beach, California. The entire wetland complex was once the lower Santa Ana River mouth wetland area and now consists of four recognized marshes that include Talbert Marsh, Brookhurst Marsh, Magnolia Marsh, and Newland Marsh.

These marshes are hydraulically connected but now separated by roads. Talbert Marsh was restored in 1990 by the Huntington Beach Wetland Conservancy and resulted in increased tidal flushing and circulation, establishment of sensitive salt marsh habitat, and improved flood control. Besides Talbert Marsh, the other marshes are non-functional salt marshes isolated from tides by flood control levees along their northern boundaries and other infrastructure. The sites have degraded over time and serve as seasonal wetlands during the rainy season only. The marshes are habitat for the state-listed endangered Belding's savannah sparrow *(Passerculus sandwichensis beldingi)* and other coastal wetland species.

Wetland restoration construction is scheduled to begin in September 2008 contingent upon acquisition of necessary permits. The conceptual plan proposes an implementation timeline that is phased to ensure that some marsh habitat is available during construction. The approach is also designed to avoid site flooding or modification of vegetation during the avian nesting season within the marshes (April through September).

Further details of the project are provided in the Restoration Plan (Attachment 4). This includes details regarding scaling for entrainment mitigation, discussion of uncertainty, an adaptive management plan, and a verification monitoring plan.

6 USE OF SITE-SPECIFIC STANDARDS FOR IMPINGEMENT MORTALITY AND ENTRAINMENT REDUCTIONS FOR UNITS 1&2

Special Provision VI.C.2(a)(5) of the NPDES permit requires submittal of information to support a Site-specific Determination of BTA, as described at 40 CFR 125.95 (b)(6) of the Rule. AES conducted an evaluation of the feasibility, performance and cost of alternative fish protection technologies and operational measures. Based on the results of that analysis and other considerations discussed in Section 7 of this report use the Cost-Benefit Test for compliance with Units 1&2 for entrainment and for Units 1, 2, 3 & 4 to make up the difference between estimated 82% reduction in impingement mortality currently in place and the 95% reduction required by the permit were chosen for interim BPJ compliance. In addition, since Units 1&2 have approximately the same design flow as Units 3&4, this analysis also provides the necessary site-specific demonstration required by Section VI.C.7(b)(1) and (2) that structural and operational controls are not feasible on an economic and/or performance basis in order to use restoration measures for more than 30% for compliance for Units 3&4.

6.1 Technologies Selected for Evaluation and Technology Performance

Alden Research Laboratory, Inc. (Alden) conducted a comprehensive cost evaluation study of alternative fish protection technologies and operational measures for the HBGS. The details of the process used by Alden to identify the alternatives are provided in Attachment A of the Comprehensive Cost Evaluation Study (Attachment 4). Additionally, Dr. John Maulbetsch conducted an evaluation of closed-cycle cooling for HBGS. The following seven alternatives were evaluated:

1. Fine-mesh modified traveling screens;
2. Modular inclined screens;
3. Offshore, narrow-slot cylindrical wedgewire screens;
4. Reduced circulating pump flow using variable frequency drives;
5. Use of reclaimed water for cooling water;
6. Relocation of the intake farther offshore to a point below the thermocline; and
7. Closed-cycle cooling.

Three of the alternatives were determined not to be feasible on the following basis:

- Reduced Use of Cooling Water Pumps -.The Federal Phase II Rule assumed a proportional relationship between flow and entrainment. AES for HBGS has developed operational measures to reduce use of condenser cooling water pumps well below design flow for economic reasons. The California Draft Policy required use of actual flow for the calculation baseline and the EPA was considering issuing guidance specifying actual flow for the calculation baseline. Therefore, for any flow reduction credit for HBGS, it is assumed the reduction would be required from current actual flows. Because flows have already been reduced for economic reasons further reductions would directly affect facility revenue and/or limit the ability of HBGS to meet electric power generation dispatch needs. Therefore this option is not considered feasible for use at HBGS.

- Use of Reclaimed Water – Use of wastewater sewage effluent from the Orange County Sanitation District (OCSD) was evaluated as a potential source of condenser cooling water. OCSD discharges about 240 MGD (371.3 cfs) of water to the Pacific Ocean. This water is a 1:1 ratio of secondary and primary treated sanitary wastewater. By 2012, all water discharged by OCSD will have received secondary treatment. Some 70 MGD of this water has been allotted for other re-use and reclamation projects leaving approximatly170 MGD (263 cfs) potentially available for use by HBGS. Unfortunately, the analysis determined that available flow tends to be variable and that during warmer months (when electric power generation is highest) the available flow could be as low as 30 MGD (53 cfs). This flow would not be adequate to supply the cooling water needed for even one unit at HBGS. Due to lack of a consistent flow necessary to meet the needs of a single unit, this option was considered infeasible. A discussion of the details regarding the evaluation of this alternative can be found in the Comprehensive Cost Evaluation Study (Attachment 4) and Attachment D of that document.

- Relocation of the Intake Farther Offshore – This option was suggested at the first public stakeholder meeting. The suggestion was to extend the intake pipe farther offshore to a location where much cooler water could be withdrawn resulting in improved heat rate and a reduction in overall cooling water withdrawals. Extending the intake to 5 miles offshore would result in an intake depth of approximately 100 ft and cooler water. However, the cost of extending the intake to this distance and depth was estimated to be on the same order-of-magnitude as closed-cycle cooling. Further, in the absence of data on entrainable life stages in this area of the ocean, it is not clear to what extent, if any, there would be a significant reduction in impingement mortality and entrainment. Due to the high cost and lack of a clear entrainment reduction benefit this option was considered infeasible. A more detailed discussion of this alternative is provided in the Comprehensive Cost Evaluation Study (Attachment 4) and Attachment C of that document.

This evaluation left four feasible options for further consideration. Summaries of these four options and the estimated fish protection benefit of each are provided below and a more detailed discussion is provided in the Comprehensive Cost Evaluation Study (Attachment 4) and Attachment B of that document.

Fine-mesh (0.5 mm) Traveling Screens

This technology is designed to reduce impingement mortality and entrainment by collecting fish off fine-mesh screens and transporting them back to the ocean offshore in a manner that maximizes survival. This is achieved by use of design components that include:

- Low-pressure Screen Spraywash – A low-pressure screenwash spraywash system is installed to gently wash larvae off screens into a return trough.

- Fish Collection Buckets – Buckets are installed at the bottom of each screen panel to hold collected fish and shellfish in water for release into the return trough.

- Continuous Screen Rotation – The screens are rotated continuously to minimize the time that eggs and larvae are exposed to the system and increase survival.

- Fish Return – A return pipe or sluice is installed to transport collected fish and shellfish back to the Pacific Ocean. The San Onofre Nuclear Generating Station is an example of a facility with such a system in California.

Since almost none (i.e. occasionally Pacific electric rays are returned) of the fish currently impinged on the HBGS traveling screens survive, such a system would be expected to provide a survival rate sufficient to make up the additional 13% needed to meet the 95% impingement mortality performance standard required by the permit. However, the benefit for entrainable life stages is less clear.

In the technology assessment, Alden assumed that the screenhouse would need to be expanded to reduce the screen approach velocity to 0.5 fps. Estimates of retention based upon the size of organisms typically entrained at HBGS indicate that few would be prevented from being entrained with 0.5 mm screens. In addition, the survival of the impinged ichthyoplankton that were previously entrained, but would become impinged on 0.5 mm screens, is expected to be low for some species. Therefore, there is expected to be no benefit associated with expanding the intake. Fine-mesh screens (0.5 mm mesh) at HBGS would decrease the entrainment of some larval fish through the circulating water system. The effectiveness of a fine-mesh screening system is measured in two ways: exclusion/retention and survival. Fine-mesh screens prevent the entrainment of some organisms; however, the number is dependent upon the size of the organisms exposed to the system and the mesh size considered. The survival of organisms removed from the screens is highly variable and depends on species, intake velocity, and the return system.

With this option, fish and debris removed from the screens would have to be transported back to the ocean. The discharge location would have to be carefully selected in order to increase the likelihood of survival. Transporting the fish back to the ocean at HBGS would be exceptionally difficult as the fish return line would need to be routed under the Pacific Coast Highway, across a public beach and out beyond the surf zone.

Although the finer mesh may result in an increased rate of biofouling of the screen mesh, this should not be an issue if HBGS continues to use the same cleaning method currently used to reduce biofouling of the existing screens.

Although the system is designed to minimize stress to aquatic organisms, the process of collection and transfer will impart a stress to the organism that would not be experienced if they were not impinged. This is especially true for the earliest lifestages (e.g. yolk-sac larvae). Generally, survival will increase as a fish grows. For those fish that come in contact with the screen, collecting them on a fine-mesh screen and returning them to the ocean rather than allowing them to be entrained should result in some reduction in losses.

A detailed discussion of this option is provided in the Comprehensive Cost Evaluation Study (Attachment 4) and Attachment B of that CDS document. The use of this technology will not meet the entrainment reduction performance standard.

Modular Inclined Screens

Modular inclined screens are another form of fish collection and transport technology. The advantage of this system over fine-mesh screens is that fish and shellfish eggs and larvae remain in the water at all times which reduces a major source of stress associated with fine-mesh traveling screens. Fish collected would be returned offshore to the Pacific Ocean using a fish-friendly pump and a 2 ft diameter fish return pipe. However a significant disadvantage of this system is that existing designs are all based on a minimum 2.0 mm slot width. At this point, it is not clear if use of a narrower slot width is feasible. Further, even if a narrower slot width were used it is not clear that any significant survival would result. Alden assumed survival of eggs and small early life stages would be negligible. A 2.0 mm slot width would be quite effective for impingeable-sized fish and this option would be expected to easily achieve the 13% impingement mortality reduction needed to meet the permit standard. However, as discussed this slot size would retain significantly fewer entrainable fish than the fine-mesh screen option. Alden estimated an entrainment reduction of the most dominant fish species between 0% - 1.5% (i.e. significantly less than the minimum 60% reduction required for structural modification and operations required by the permit for entrainment). Due to an installation design upstream of the existing screens wells, no significant environmental impacts are assumed with this option.

Additionally there are ancillary issues associated with this option that would need to be addressed prior to deployment that include biofouling control and the location for the fish return. This option would require pilot study testing to establish performance and ancillary design solutions.

Narrow-slot Wedgewire Screens

This technology provides fish protection through a combination of exclusion from the cooling system and low through-slot design velocities. EPRI has previously provided the results of jointly funded EPA/EPRI studies that evaluated these screens. While used in freshwater and estuarine systems, experience with these systems is very limited in marine environments; there are no existing installations for electric generating stations in marine waters.

Alden's final design proposes use of twenty T-120 (10 ft diameter) screens with 0.5 mm slot openings. Using 20 screen modules would reduce the through-slot velocity to about 0.35 fps; which is similar to the minimum ambient current in the area. This would provide the benefit of some small amount of sweeping velocity although flow conditions are expected to be variable. In addition, this design would allow a screen to be out of service without increasing the through-slot velocity above 0.5 fps (manufacturer's design velocity for wedgewire screens). The result is complete exclusion for impingeable-sized organisms and this option would have qualified for use of Compliance Alternative 1 under the Federal Phase II Rule and no CDS would be required for impingement.

Since there are no biological efficacy data for a wedgewire screen installation for the species entrained at HBGS, head capsule depth data developed for the fine-mesh screen option above were used to estimate the physical exclusion that could be achieved with narrow-slot wedgewire screens. Based on the results of this analysis, entrainment reduction performance was found to be variable by species. For many of the dominant species, the reduction was found to be within the performance standard range (e.g., CIQ gobies 64.1% and northern anchovy 71.7%). However, for some other dominant species it was less than 60% effective (e.g., croaker 58.8%, combtooth blennies 21.8% and diamond turbot 11.3%). The overall performance estimated for this technology is a 61.4% entrainment reduction. Based on this estimate this technology would be the best performing alternative fish protection technology. Prior to selection, pilot studies would be required to verify that entrainment would be reduced to within the 60% to 90% reduction required by the Federal Phase II Rule and confirmation that closed-cycle cooling is not determined to be BTA.

As with the previously discussed technologies, there are a number of ancillary issues that would need further study prior to full-scale deployment. Key issues would be quantification of performance and ensuring that marine biofouling can be controlled. Also, this option would have significant environmental impacts due to the size of the structure (loss of habitat) and its visibility (large offshore platform).

Closed-cycle Cooling

Reducing flow commensurate with closed-cycle cooling qualifies for use under Compliance Alternative 1 for both impingement mortality and entrainment reduction and was listed as compliance alternative IV.C.7(a)(1) in the HBGS NPDES permit. Since a reduction in flow achieves a proportionate reduction in entrainment, use of this alternative would meet the 90% entrainment reduction required by the permit. This option, however, would be expected to result in potentially significant environmental and social impacts. Such impacts could include:

- Human health impacts associated with increased emissions of fine particulates;
- Terrestrial impacts to nearby wetlands or structural impacts to materials due to salt drift;
- Potential water quality issues due to concentration of ambient source water pollutants in blowdown;

- Public safety issues due to fogging and nearby roads;
- Noise; and
- Aesthetics.

There are likely to be permitting issues associated with these impacts that could delay or prevent permitting of this option.

6.2 Technology Costs

For each of the three feasible alternative fish protection technologies, Alden prepared cost estimates based on deployment designs for HBGS. Cost estimates for a closed-cycle cooling retrofit were prepared by Dr. John Maulbetsch as part of an EPRI retrofit study for each of California's once-through cooling facilities.

Table 3 provides cost estimates for each of the four alternatives. For the three fish protection technologies (fine-mesh traveling screens, MIS, and narrow-slot wedgewire screens) the cost estimates are based on costs for Units 1-4 rather than just for Units 1&2 for entrainment. The rational for providing costs in this manner are:

1. The additional 13% reduction in impingement mortality is required for all units;
2. The Board requested cost estimates for the entire facility in the report; and
3. The existing design's use of a common offshore intake, traveling water screens that are common to all units, and the circulating water pumps being located in a common plenum preclude consideration of technologies for only Units 1&2.

Retrofitting HBGS with closed-cycle cooling had the highest estimated cost. AES recently participated in an EPRI study to estimate retrofit costs for all once-through cooling facilities in California. The report titled "Issues Analysis Associated with Retrofitting Once Through Cooling Plants with Closed-Cycle Cooling" included a site-specific cost estimate for HBGS as Attachment B-6. The retrofit analysis for HBGS from that report is provided as Attachment F of the enclosed Comprehensive Cost Evaluation Study (Attachment 4). Peer reviewers for this report included the CEC and Tetra Tech who is performing a similar project for the California Ocean Protection Council. The report estimated that the cost of retrofitting HBGS Units 1–4 would be in the range of $150 million for wet closed-cycle cooling and nearly $200 million for dry cooling. These estimates did not include lost revenue that would result during the retrofit outage which could also be significant. The estimated cost to retrofit Units 1&2 only for the purpose of the Cost-Benefit analysis used in this CDS was $76,398,000. This is half the cost of a full facility retrofit as discussed in Attachment F of Attachment 4, Table B-59.

Table 3 – Estimated costs of feasible fish protection technologies.

Technology	Capital Cost(1) ($)	Capital Cost ($) with Replacement Power Needed During Installation (2)	O&M Cost ($)	Total Annualized Cost ($) (Capital & O&M)
Fine-mesh Traveling Screens	6,348,000	69,946,000	357,000	6,393,000
Modular Inclined Screens	5,984,000	27,183,000	133,000	2,648,000
Narrow-slot Wedgewire	36,003,000	57,202,000	676,000	7,467,000
Closed-cycle Cooling	76,398,000	0	2,291,940	13,900,000

(1) Note that the capital costs for fine-mesh traveling screens, modular inclined screens, and narrow-slot wedgewire screens are for all four units. The cost for closed-cycle cooling is for a Unit 1&2 retrofit, only. The cost of retrofitting all four units is approximately twice the cost shown.

(2) It is entirely possible that a closed-cycle cooling retrofit could also require replacement power. At this point it is not clear whether or not the tie-in could be accomplished during a scheduled outage or would require an extended outage in which case the replacement power cost could be for the 6 month period estimated for installation of fine-mesh traveling screens (i.e. ~$60,000,000).

6.3 Environmental Benefit Analysis

The HBGS NPDES permit requires that use of site-specific standards be consistent with the requirements of 40 CFR 125.95 (b)(6) of the Federal Phase II Rule. Those requirements specify that for use of the Cost-Benefit Test that a Benefit Valuation Study be provided. The complete Benefit Valuation Study is provided as Attachment 5 and is summarized in this section.

A four-step model was used in the benefit valuation study and is generally consistent with the methodology used by EPA in development of the Phase II Rule. The four steps are shown in Figure 3 below and consisted of:

1. Developing dynamic population models from the HBGS impingement and entrainment data using the best available information on life stages, natural and fishing mortality rates, and fecundity to develop population increases for the impinged and entrained species. Note the approach used tends to be conservative in that no compensation is assumed.
2. Determining catch using a methodology that entails determining forgone yield, production, and species categorization (i.e., the percentage of impinged and entrained organisms that would have been caught, uncaught, or are forage). The determination of harvested versus forage species is based on the best available information, including consultation with local fishery experts, EPA's regional case study for California (2004), and local catch data. The analysis calibrated natural and fishing mortality parameters to determine the forgone yield and forgone production for each species.
3. Determining the value of fish produced as a result of impingement mortality and entrainment reductions. There are three key aspects to this analysis that include:

- Estimating Recreational Benefits – This analysis is based on a simulation of angler behavior and changes in social welfare resulting from reductions in impingement mortality and entrainment and the associated increases in expected catch. Important factors accounted for include the number and quality of substitute fishing sites, the geographic range of impacted species, the number of trips with improved catch rates, and the number of anglers associated with those trips. This was accomplished using a random utility analysis to value impingement mortality and entrainment reductions on recreational fishing.

- Estimating Commercial Benefits – Estimating the commercial benefits of impingement and entrainment reductions based on consideration of the fishery's relevant market conditions to determine the underlying relationship between the reductions and changes in commercial fishing benefits for alternative market conditions. These were based on an analysis for the species impinged and entrained at HBGS to evaluate changes to the fishery resulting from those losses.

- Estimating Non-use Benefits – Non-use benefits associated with the loss of threatened and endangered and protected species are discussed qualitatively since no species of fish and shellfish in these categories were impinged or entrained.

4. Quantifying uncertainty associated with the analysis was performed using the approach recommended by EPA. This approach uses a Monte Carlo analysis to quantify the effects of uncertainty on benefits. The Monte Carlo analysis combines uncertainty in input parameters with the benefits-estimation model to quantify uncertainty in 316(b) compliance benefits. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and then combines the estimates. The resulting combination of the various inputs creates an estimate of compliance benefits.

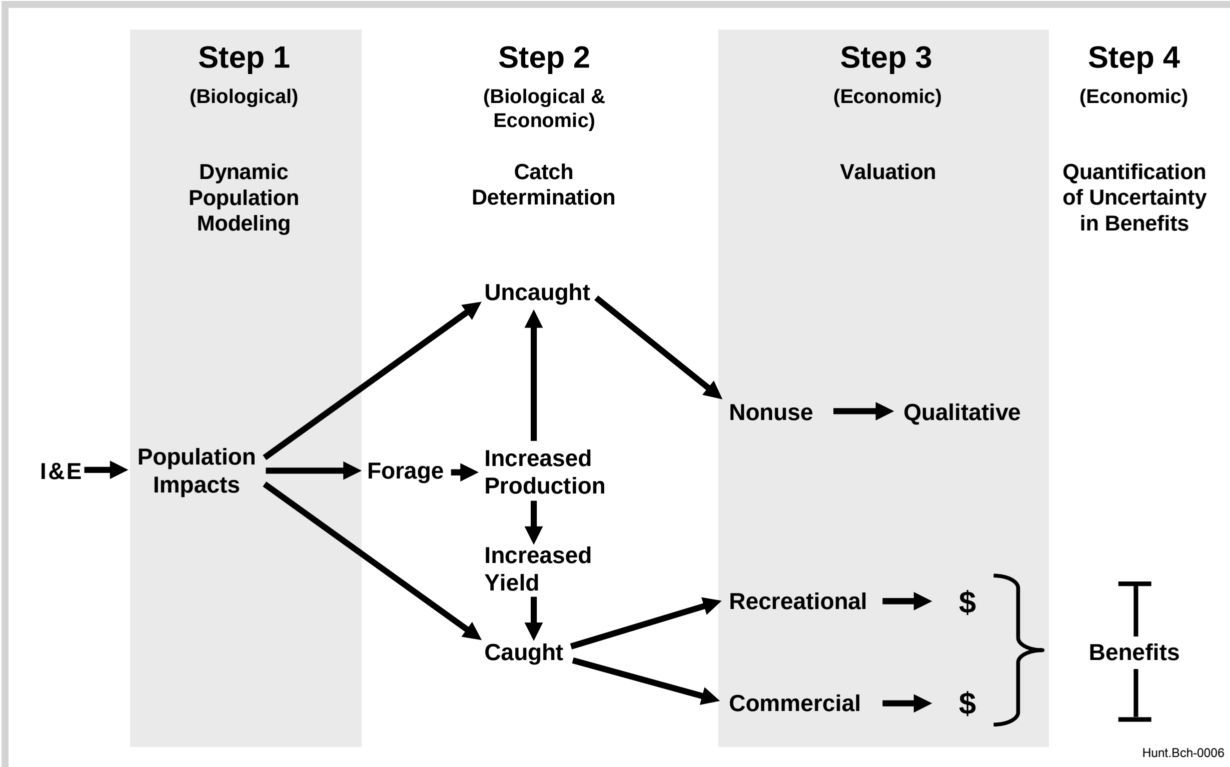


Figure 3 - Overview of Methodology for Estimating the Benefits of IM&E Reductions

Using the dynamic fishery modeling and economic impact methodologies described in the four step approach (Figure 3), the annual economic benefits of reducing impingement at all units by 13% and entrainment at Units 1&2 by 90% were estimated. Both economic theory and requirements of the Phase II Rule indicate that the type (recreational, commercial, use) and timing of IM&E reductions will offset the benefit estimates. Consistent with Phase II Rule requirements, recreational benefits are discounted at 3% and commercial benefits (including that generated from recaptured forgone productivity attributable to forage loss) are discounted at 7%. Impacts are quantified assuming the impingement mortality and entrainment reductions began in 2007 and continued for 20 years.[2]

It is also assumed that the timing of biological impacts exhibits an appropriate lag.[3] This feature is common to dynamic population models and reflects the time taken to transition between life stages. Economic benefits associated with the change in catch do not occur with a lag. Thus, the analytical approach assumes that commercial and recreational anglers adjust their behavior in the same year catch changes. The extent to which this assumption is incorrect and resultant estimates are biased has not been evaluated. However, there are mitigating relationships that could affect this source of uncertainty. Examples include:

[2] In dynamic models, impacts can persist for a limited period. The 25-year cut-off is computationally tractable and viewed as offsetting to the start specification as instantaneous.
[3] For a more detailed discussion and numerical example of catch timing impacts on value, see Bingham, Desvousges, and Mohamed (2003).

1. Relatively small behavioral changes (i.e., changes in trips) associated with relatively small changes in catch such as those seen here mean that much of the value comes from current trips where a behavioral response is not required.

2. Conversely, large changes in expected commercial and recreational catch in particular areas are likely to be communicated rapidly. The public nature of 316(b) proceedings would tend to enhance this effect.

Under the above specifications, the expected value (mean) of the NPV is $158,600 with upper (95%) and lower (5%) bounds of $254,000 and $94,000 respectively. The annualized (NPV/20) benefits associated with IM&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928.

Complete details of the analysis are provided in the Benefit Valuation Study CDS document (Attachment 5).

6.4 Cost-Benefit Analysis

The Cost-Benefit analysis provides a comparison of the estimated costs of the feasible structural and operational alternatives to the economic benefits that would be achieved if they were implemented to determine if the costs are significantly greater than the benefits. Sub-section 6.4.1 provides a summary of the methodology used to determine "significantly greater" costs and sub-section 6.4.2 provides the comparisons and summary of the results.

6.4.1 Approach for Determination of "Significantly Greater"

In the Rule, use of site-specific standards under the Cost-Cost and Cost-Benefit Test are based on a determination of whether those costs are "significantly greater" than the associated economic environmental benefits. In developing the Rule, EPA did not provide specific guidance as to the basis of this comparison. However, the EPA evaluation of the economic benefits of the Rule was based on measuring economic benefits based on economic theory. Further, EPA's requirement that a sensitivity analysis of the benefit valuation be performed in addition to use of the phrasing "significantly greater," indicate that the decision-making be based on statistical criteria. The second component used in the "significantly greater" determination is decision theory.

Using statistical significance allows a determination based on the probability that the estimated quantity (i.e. economic value of fish protection) is significantly greater than zero. Such an outcome indicates that the likelihood that the estimated quantity is below zero is less than 5%, giving the analyst a great deal of confidence that the actual (not estimated) quantity is indeed larger than zero. Using a statistical approach also provides a methodology for appropriately capturing the uncertainty in cost and benefit estimates.

The second key component of the approach to determine if costs are significantly greater than benefits is decision theory. Decision theory is used to provide a framework for the evaluation. For example decision theory provides additional analytical capabilities such as helping to minimize the probability that a meaningful impact is not mitigated or conversely to minimizing the probability that funds may be spent over-mitigating minor impacts.

In assessing the determination of “significantly greater” the assumption is that protection of the environment is preferred in the Cost-Benefit comparison. The determination will be based on a calculation of net benefits (benefits of compliance minus lowest costs of compliance) with simultaneous consideration of costs, benefits, and uncertainty in a Monte Carlo simulation. This approach will provide a distribution of net benefits, and a determination of “significantly greater” based on the estimated range of net benefits.

6.4.2 Comparing Technology Costs with Environmental Benefits

The benefits in each of these evaluations reflect the effectiveness associated with the technology. Table 4 below contains the detailed comparisons of benefits to costs.

To make the significantly greater determination, expected costs were compared to the expected benefits. The benefit estimates included uncertainty, as instructed by the EPA in the Federal Phase II Rule. Specifically, a Monte Carlo analysis was conducted that makes one draw from the distribution of benefits and subtracts from it the point estimate of costs to develop a single estimate of net benefits. The analysis repeated this Monte Carlo process one thousand times to develop a distribution of net benefits (benefits minus costs).

In all cases, the benefit-cost comparisons reveal that the costs of achieving compliance are significantly greater than the benefits, indicating that a site-specific determination of BTA (Alternative 5) is appropriate for Units 1&2 of the HBGS. Not only were differences determined to be significantly different they were in fact different by well over an order of magnitude in all cases. In addition, closed-cycle cooling, which was the only technology that would reduce entrainment to the 90% reduction level required by the permit, also has additional environmental and social disamenities. While these environmental disamenities were not quantified in this analysis they are being quantified in an EPRI research project currently in progress to inform the Phase II Rule revision.

Table 4 - Estimates of Net Benefits and Significantly Greater Determination with Benefit-Cost Comparisons

Technology Alternative	Total Annualized Costs ($)	Range of Annualized Benefits ($)	Range of Annualized Net Benefits ($1,000,000)	Costs Significantly Greater
Fine-mesh modified traveling screens	6,393,000	1,200 - 42,750	-3.243 - 3.287	Yes
Narrow-slot cylindrical wedgewire	7,467,000	1,500 - 53,720	-2.231 - 2.284	Yes
Modular inclined screens	2,648,000	1,000 - 39,550	-2.608 - 2.647	Yes
Closed-cycle cooling (wet cooling)	13,900,000	1,700 - 64,190	-7.912 - 7.975	Yes

The details of the cost-benefit analysis are found in the Comprehensive Cost Evaluation Study (Attachment 4) of the CDS.

6.5 Site-specific Technology Plan and Verification Monitoring

Based on the results of the cost-benefit analysis, the existing cooling water intake structure is determined to be BTA. Therefore the site-specific technology plan is based on this outcome. Similarly, the verification monitoring plan is based on the existing cooling water intake structure as BTA. Since the efficacy of the existing velocity cap is estimated and entrainment would not be expected to change from that established in the calculation baseline, monitoring of the existing design and operation is proposed rather than biological verification monitoring.

7 BPJ COMPLIANCE SUMMARY AND CONSIDERATIONS FOR COMPLIANCE DECISION MAKING

AES has prepared this CDS in conformance with the NPDES permit and the Federal Phase II Rule. To meet the 95% reduction in impingement required by the permit, AES has provided documentation for the 82% reduction achieved by the velocity cap and used a Site-Specific Standard Cost-Benefit analysis to demonstrate that the costs of achieving an additional 13% reduction to meet the NPDES permit limit are significantly greater than the environmental benefit. AES is using restoration measures to offset entrainment losses for Units 3&4. These restoration measures are in the form of restoration of over 66 acres of coastal wetlands, an amount determined based on habitat production foregone calculations to produce sufficient habitat to offset Unit 3&4 entrainment losses. It is important to note that AES and its scientific experts had significant disagreements with the CEC staff on the need for restoration and the methods used for determining the appropriate scale of the restoration project including the need to consider the added environmental benefits of wetlands restoration. The basis for the need for restoration was entrainment losses that were estimated to result in losses of less than 1.5% to larval fish populations that extend along miles of coastline. At the request of the CEC, AES estimated that the restoration of 12.5 acres of wetlands would compensate for entrainment losses to gobies, which primarily occur in wetland habitats and comprised the greatest percentage of the entrained fish larvae. Instead the CEC staff scaled the wetlands restoration using nearshore ocean fishes that occur over miles of coastline grossly exaggerating the estimate and resulting in a negotiated project that more than compensates for any losses due to the HBGS.

For Units 1&2 entrainment losses, AES conducted an evaluation of structural and operational controls to achieve the 90% reduction required by the permit. The estimated costs were determined to be well over an order-of-magnitude greater than the estimated environmental benefit.

AES acknowledges that the Second Circuit ruled that two of the compliance alternatives (i.e. restoration measures and Cost-Benefit analysis) used should not be allowed in the remand of the Federal Phase II Rule back to EPA. AES further recognizes that additional fish protection technologies and operational measures are likely to be required, but point out a number of important considerations for the Board in making the final BPJ compliance determination for HBGS.

1. HBGS provides reliable generation of electricity in an urban setting. The four generating units produce enough electricity to light nearly one million homes. To help support California's growing energy needs, HBGS recently invested in refurbishing Units 3&4 so that they could be returned to service. Thus, HBGS is a critical component of the southern California power generation strategy and plays an important role in stabilizing

the electrical system within Orange County. Moreover, AES's generating assets in California produce 10% of the state's peak electricity demand.

HBGS produces clean power generation through the use of selective catalytic reduction (SCR) technology, which is designed to reduce atmospheric emissions. This technology reduced emission of NO_x by more than 90%. AES is also one of the only generators in the state with carbon monoxide reduction catalyst technology in use.

HBGS contributes to the local economy and the quality of life in Orange County. It provides employment for 50 people and a source of revenue for the City of Huntington Beach.

2. AES has paid over $5.5 million dollars for the construction and maintenance for restoration of coastal wetlands to offset Units 3 &4 entrainment losses. These wetlands will continue to provide benefits to entrainable lifestages after compliance with the revised Federal Phase II Rule and/or California State §316(b) Policy goes into effect. Aside from increasing the production of fish and shellfish, there are also multiple environmental benefits from implementation of the restoration project. Additionally, while a 95% impingement mortality reduction is not yet achieved, impingement mortality has been reduced by 82%.

3. Results of the one year 2003/2004 entrainment studies conducted at HBGS determined that for the geographic areas where the dominant entrained species were vulnerable to entrainment the losses did not exceed 1.2% for any species of finfish and 1.1% for any species of shellfish. The vast majority of these losses occurred to the earliest life stages when natural mortality is highest. Natural mortality in many of these species would be in excess of 99%.

4. A petition for a re-hearing of the Second Circuit Court of Appeals has been filed to the Supreme Court that could alter the Decision. In addition, the Second Circuit Decision does not overrule and is inconsistent with the prior §316(b) Decision by the First Circuit Court in Seacoast Anti-pollution League vs. Costle. In that Decision the First Circuit ruled that cost and benefits could be considered using the wholly disproportionate standard. It is therefore up to the Board to determine whether or not this interpretation is appropriate unless and until authoritative action is taken by EPA or the SWRCB.

5. EPA has initiated work to revise the Federal Phase II Rule in a manner that addresses issues raised by the Second Circuit Court. EPA is scheduled to issue a proposed Rule by the end of 2008 and a final Rule in 2009. At this point, it is anticipated that the Rule will be limited to use of technologies and operational measures and if performance standard ranges are used, the use of the best performing technology in the performance standard range will be required.

   It is not clear whether or not closed-cycle cooling will be identified as BTA. The Second Circuit Court determined that EPA could consider three factors as a basis for not identifying closed-cycle cooling as BTA. These three factors included:

a. The industry cannot reasonably bear the cost of retrofits;

b. Impacts to energy production and supply; and

c. Adverse impacts associated with retrofits.

AES Southland is one of 25 companies funding a large scale EPRI research project to provide technology information relative to retrofits. The scope of the project will provide quantitative estimates of:

i. the national cost of retrofits;

ii. the reduction in generation as a result of generation unit retirements and energy penalties associated with retrofits;

iii. environmental and social impacts resulting from retrofits; and

iv. impacts to electric system reliability.

6. The EPRI research project is national in scope and will provide information for California's facilities including HBGS. EPRI has met with EPA Staff working on the Rule to discuss the schedule, scope, and approach for the research program and EPA has expressed a strong interest in making use of this information in developing the proposed Rule.

7. The SWRCB continues to consider development of a State §316(b) Policy.

8. Due to points 3, 4, 5 and 6 it is important to consider that the final determination of BTA for HBGS be consistent with both the revised Federal Phase II Rule and the final California State §316(b) Policy.

9. The previous HBGS NPDES permit waste discharge requirements issued in July 2000 stated the following:

   "Pursuant to regulations established by Section 316(b) of the Clean Water Act, the discharger was required to submit a proposal to the Board for the conduct of a study to determine whether the location, design, construction, and capacity of the existing cooling water intake structures reflect the best technology available for minimizing adverse environmental impacts."

   "The 316(b) study was duly executed and a final report was submitted to the Executive Officer. The report adequately addressed the important ecological and engineering factors specified in the 316(b) guidelines, demonstrated that the ecological impacts of the intake system are of an environmentally acceptable order, and provided sufficient evidence that no modification of the location, design, construction, or capacity of the existing systems is required."

For these reasons AES believes that a final BTA determination that requires additional technologies be deferred until after the final revised Phase II Federal Rule or final State §316(b) Policy are issued.

8 REFERENCES

Bingham, M. F., W. H. Desvousges, and A. F. Mohamed. 2003. Comments on Benefit Estimation of EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability: Final Report. Prepared for The Utility Water Act Group. June. Triangle Economic Research, Durham, NC.

California Energy Commission (CEC). 2006. Huntington Beach Units 3&4 Entrainment and Impingement Study Results, Mitigation Options, Staff and Working Group Recommendations, and AES's Response and Objections to the Recommendations July, 2006.

Environmental Protection Agency (EPA). 2004. National Pollution Discharge Elimination System-Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities; Final Rule. July, 2004 U.S. Environmental Protection Agency. 2004b. California Regional Analysis. Available at http://www.epa.gov/waterscience/316b/phase2/casestudy/final/chb2.pdf. Retrieved on October 12, 2007.

Moffatt & Nichol. 2006. Huntington Beach Wetlands Conceptual Restoration Plan: Revised Final Report. Prepared for the Huntington Beach Wetlands Conservancy and the California State Coastal Conservancy for the Wetlands Recovery Project. April 10, 2006.

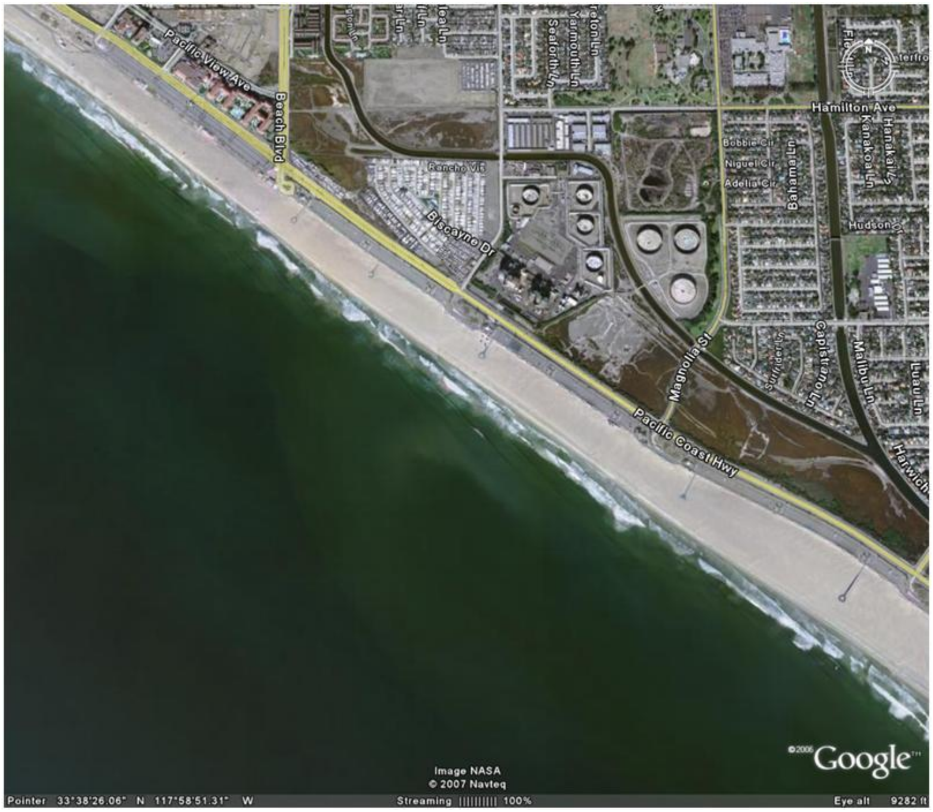
State Water Resources Control Board (SWRCB). 2006. Scoping Document: Proposed Statewide Policy on Clean Water Act Section 316(b) Regulations. June, 2006.

ATTACHMENT 1

§122.21(r)(2)(3)&(5) Information

ATTACHMENT 1

§122.21 (r) (2), (3), (5) INFORMATION FOR HUNTINGTON BEACH GENERATING STATION



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1.0 Introduction

This report is submitted in response to the requirements of 40 CFR §122.21(r) (2), (3), and (5) (USEPA 2004) by providing the Source Water Physical data, the Cooling Water Intake Structure (CWIS) data, and the Cooling Water System (CWS) data, respectively.

2.0 Source Water Physical Data (40 CFR 122.21(r) (2))

The following source water physical data are being provided to characterize the waterbody in the vicinity of Huntington Beach Generating Station (HBGS) cooling water intake structure (CWIS). This information is used, in part, to evaluate the various measures being considered for reducing impingement mortality and entrainment at HBGS. The following sections describe the waterbody's key physical and chemical characteristics in the vicinity of HBGS and provide figures and maps for reference.

2.1 Narrative Description of Source Waterbody

HBGS is located on the shore of the coastline of the Pacific Ocean in the City of Huntington Beach, California (Figure 1). The HBGS CWIS is located within the nearshore zone (defined as the zone between the shoreline and 1,000 ft from shore or the 30-foot depth contour, whichever is farther). Tides in the region are semi-diurnal, with two high and two low tides of unequal heights during each 25-hour tidal period. Flood tides flow up-coast while ebb tides flow down-coast. The extreme low water level is El. -4.0 ft; while the mean tidal range is approximately 3.7 feet (all elevations refer to Mean Sea Level, El. 0.0 ft).

2.2 Aerial Dimensions

For reference, an aerial view of HBGS is shown in Figure 2. The approximate location of the velocity cap is included in this figure.

2.3 Depths

The water depth at the HBGS intake, which is located approximately 1,500 ft offshore, is about 23 ft. Depths in the vicinity of the e intake vary from less than 30 ft along inshore areas to over 650 ft, 3.5miles from the shoreline. The depths for the area surrounding the HBGS intake are shown in Figure 3.

2.4 Flow

A detailed analysis of the currents in the area surrounding the HBGS intake was conducted for the Huntington Beach Shoreline Contamination Investigation-Phase III (USGS 2004). The purpose of the USGS investigation was to determine the coastal circulation and transport patterns surrounding the Orange County Sanitation District's (OCSD) wastewater outfall. This study was initiated because it was believed that the OCSD outfall plume resulted in reduced water quality on the Huntington Beach shoreline.

The USGS study looked at a myriad of temporal and spatial data, including currents, wind, tides, waves, and upwelling to evaluate the transport processes in the region. Multiple fixed-moorings were used to measure the currents, waves, temperature, and conductivity. The locations of these moorings are provided on Figure 3 and Figure 4.

The report indicated the along-shore currents (parallel to the shoreline) are the dominant currents in the nearshore region near the HBGS intake. This current is typically down-coast but occasionally switches direction. In general, these currents are not wind-driven; but, over short periods of time the wind can result in fluctuations in the nearshore flow. Typically, the magnitude of these currents range from about 0.3 ft/sec to 0.7 ft/sec (5 cm/sec to 20 cm/sec). A plot of the along-shore currents is provided on Figure 5.

Based on the depth and location of the velocity cap, Alden selected data collected from location AES3 to represent conditions that can be expected at the HBGS intake. Cross-shelf currents, perpendicular to the shore, are also present near the HBGS intake but they are about an order-of-magnitude less than the along-shore currents. Velocity and directions of both the along-shore and cross-shore currents offshore are shown on Figure 6.

2.5 Salinity

Salinity in the southern California region of the Pacific Ocean where HBGS is located ranges from 32.1 ppt to 35.3 ppt with a mean of 33.8 ppt (Operational Oceanography Group 2006).

2.6 Temperature

Water temperatures in the vicinity of HBGS are coolest during the winter months and warmest in the summer. Air temperatures range from approximately 53º F in winter to 88º F in summer. During the summer there is a diurnal temperature change of about 2° F to 4^{o} F (AES 2000).

2.7 Geomorphological Features

HBGS is located on the coastline of the Southern California Bight in Huntington Beach, California (Figure 1). This region experiences a Mediterranean climate regime that is characterized by short, mild winters and warm, dry summers. Annual precipitation near the coast averages about 11 inches (AES 2000).

The general orientation of the coastline tends to be from northwest to southeast. The Bight has slowly emerged over a long geological period, resulting in a coastline with numerous cliffs that are broken by coastal planes. The region has many small streams that normally flow only during rain events. These streams produce a considerable amount of sediment that enters the nearshore environment. The net transport of this sediment along the coast is towards the south.

3.0 122.21 (r) (3) Cooling Water Intake Structure Data

HBGS uses a once-through cooling water system. The cooling water intake structure (CWIS) at HBGS serves Units 1–4. The CWIS includes a single, offshore intake pipe with velocity cap, as shown on Figure 7, and a single screenwell structure with trash racks and four traveling water screens that are used to keep fish and debris out of the circulating water system. Circulating water pumps, located downstream of the screens, supply ocean water to the steam turbine condensers and the closed-loop cooling system that serves the auxiliary equipment. A summary of pertinent plant data is presented in Table 1.

The intake structure, a velocity cap, is located approximately 1,500 ft offshore of Huntington Beach at a bottom elevation of -23.3 ft. The velocity cap is 33 ft by 28 ft with the top located at El. -17.5 ft; approximately 5 ft above the intake riser pipe. The velocity cap (Figure 8) redirects the intake flow from a vertical direction to a horizontal direction, which is believed to be easier for fish to sense and avoid. Water flows down a 21 ft vertical riser pipe into a 14 ft diameter intake pipe that conveys the water to the onshore screen structure. Both the pipes and the velocity cap are made out of concrete. Mammal bar rack barriers are mounted around the cap to help prevent aquatic mammals, large fish, and turtles from entering the intake. The barrier consists of bars spaced approximately 18 in. on center.

Water enters the onshore screenwell structure at a rectangular forebay (13 ft x 50 ft) and is redirected by guide vanes to three wider screenbays (Figure 9). The three channels then merge into two trash rack bays, each of which are 20 ft wide by 18 ft deep. The trash racks are vertical steel bars with 3 inch slot openings.

Downstream from the trash racks, the intake channel expands slightly and splits into four, 11 ft wide screenbays, each containing a traveling water screen. The traveling screens are located 19.5 ft downstream of the trash racks. A plan and section of the screenwells appear on Figure 9 and Figure 10, respectively. Debris is deposited into a screenwash trough that leads to a trash basket located on the east side of the screenwell structure. The traveling screens are removed and cleaned twice a year.

Immediately downstream of the traveling screens, the cooling water flow combines before entering a box culvert that is 14 ft wide and 11 ft high. The culvert is 236 ft long and slopes down slightly toward the intake pump structure. The increased size of the pump structure decreases the velocity of the water before it enters the suction of the eight circulating pumps. Stoplog slots in each pump bay allow the pump bays to be dewatered. Units 1–4 each require two circulating water pumps. The six pumps for Units 1–3 are each rated at 98 cfs, while the two pumps for Unit 4 are each rated at 103.2 cfs. The total system flow for HBGS is 794.5 cfs. Condenser flow accounts for 756.2 cfs, while the remaining water (38.3 cfs) is used for the auxiliary flow. The City of Huntington Beach supplies additional water that is used as potable and make-up water for the boilers. Section and plan views of the pumphouse structure are provided on Figure 11 and Figure 12, respectively. A water balance diagram for HBGS is provided on Figure 13.

The average horizontal velocity in the velocity cap opening is approximately 1.3 ft/sec. Velocities in both the intake and discharge pipes are estimated to be 5.2 ft/sec. Velocities immediately upstream from the traveling screens at HBGS were calculated in a study performed in 1978. The mean screen approach velocities ranged from 0.80 to 1.04 ft/sec at an assumed design flow of 795 cfs. The average velocity in the screenbays, as calculated by Alden, at this design flow and mean low water level (El. 0.0 ft) is 1.0 ft/sec in each bay, which is consistent with the 1978 study.

4.0 122.21 (r) (5) Cooling Water System

As described above, the cooling water system for the station is combined to a single CWIS. That is, all cooling water is withdrawn through the common offshore intake, the trash racks, traveling water screens, and a common plenum for circulating water pump withdrawal to the individual units.

HBGS operates eight (8) circulating, ocean-water pumps. The circulating pumps provide boiler cycle cooling, as well as bearing and machinery cooling. Running equipment within proper temperature ranges is necessary to protect and extend the life of equipment. Running the circulating pumps entails a large electrical energy cost and the pumps are run as little as necessary.

One (1) circulating pump must be run at all times, even when no generator units are operating. This pump maintains the operating temperatures of equipment that must stay operative, such as air compressors, and keeps the unit ready for operation when called. For any of the units, when they initiate startup, a minimum of two circulating pumps are needed. Therefore, the first unit called up will require a second circulating pump to start. If an additional unit is required, two (2) more circulating pumps must start. When a unit has been running and then is shutdown, both associated circulating pumps must run for approximately 4 additional hours to keep temperatures from overheating. After the first pump is shutdown, assuming the unit does not restart, its 2nd circulating pump can be shut off (typically 24 hours after the unit comes offline). The 2nd circulating pump stays operating during this period to get the equipment/housings cooled in order to reduce any hazard for maintenance and to allow preparations for restart.

Cooling water is discharged through a 14 ft diameter concrete pipe that is located parallel to the intake pipe. The discharge location is about 1,200 ft offshore, slightly to the south of the intake and at a depth of 21.3 ft. The transit time between intake and discharge is 21.5 minutes. The NPDES permit for HBGS allows a maximum delta T of 30° F.

Bacterial growth is controlled by the application of a sodium hypochlorite solution through the suction of each circulating pump. Chlorination is performed at 12-hour intervals for approximately 30 minutes. A heat treatment process also controls excessive marine growth, with mussels as a primary target. Heat treatment is performed every 6 weeks by partially recycling the circulating water flow, which increases the circulating water discharge temperature to about 105º F.

Table 1 Pertinent Project Data — HBGS

Location

21730 Newland Street Huntington Beach, California
Latitude: N 33° 38'
Longitude: W117° 58'
Waterbody: Pacific Ocean
Waterbody: ocean (nearshore zone)
NPDES permit expiration date: June 1, 2005
Estimated project intake flow
    Plant design: 794.5 cfs (356,600 gpm)
Intake velocities
    Horizontal current at cap: 1.3 ft/sec (Calculated by Alden)
    Intake pipe: 5.2 ft/sec (Calculated by Alden)
Mean velocities in the screenbays
    Calculated by Alden: 1.04 ft/sec
    Screen Approach velocity: 1.17 ft/sec (Calculated by Alden)

Water Level

Elevations
    Extreme low: El. -4.0 ft
    Mean low water: El. 0.0 ft
    Mean tidal range: El. 3.7 ft
Water depths: (around offshore intake)
    Maximum: approx 37 ft
    Minimum: approx 29 ft
    Normal: approx 33 ft
Other info: all elevations refer to mean sea level

Project Structures

Offshore intake structure
    Type: capped offshore intake
    Location: 1,500 ft offshore (nearshore zone)
    Top of cap: El. -17.5
    Cap height above intake: 5 ft
    Cap size: 28 ft x 33 ft (approx.)
    Intake invert: El. -23.3 ft
    Intake pipe material: concrete
    Intake pipe diameter: 14 ft (inside diameter)
    Pipe invert: El. -47.5 ft inlet
    Recirculation: gates located in intake pipe
    Mammal exclusion barrier: bars approx 18 in. on center within velocity cap
Onshore screenhouse
    Length: 112 ft
    Guide vanes: 2 vanes split flow three ways prior to entering forebay
    Forebay: 13 ft x 50 ft
    Invert: El. -17.0 ft inlet

Table 1 (Continued)

Trash racks
- Location: end of forebay
- Sections: 2 (20 ft wide 18 ft deep)
- Invert: El. -17.0 ft
- Top: El. 1.0 ft
- Material: steel
- Bar spacing: 3 in. openings

Traveling water screens
- Location: 19.5 ft downstream of trash racks
- Number: 4
- Bay width: 11 ft
- Invert: El. -17.0 ft
- Top: El 17.0 ft
- Rotation speeds: 1.2 rpm
- Width: 10 ft (approx from bay width)
- Mesh size and geometry: 3/8 in^2 openings
- Spray nozzle configuration: inside spray nozzles spray front and back (6 nozzles/screen)
- Volume: 1,000 gpm
- Operation: twice per shift for 20 minutes
- Fish return (trough/ pipes): debris trough discharges into trash basket
- Trough configuration: single trough leading to Units 1 & 2 discharge pipe

Culvert
- Culvert: 14 ft x 11 ft box culvert
- Length: 236 ft
- Invert entrance: El. -14.5 ft
- Invert exit: El -15.0 ft
- Circulating water pump structure
- Location: end of culvert downstream of traveling water screens
- Length: 112.0 ft
- Guide vanes: two vanes split flow three ways prior to entering pump structure
- Invert entrance: El. -15.0 ft
- Invert pumps: El. -12.3 ft
- Pump bays: 8
- Bay width: 9.2 ft
- Design: 2 symmetrical halves (4 bays per half)
- Bay offset: 10.6 ft back 7.2 ft over

Circulating water pumps
- Number of pumps: 8
- Type of pumps:
- Units 1 & 2: vertical, mixed-flow
- Unit 3 & 4: vertical wet-pit
- Inlet elevation: -12 ft

Table 1 (Continued)

Flow per pump:
- Units 1–3: 98.0 cfs (44,000 gpm)
- Unit 4: 103.2 cfs (46,300 gpm)

Total flow
- Condensers: 756.2 cfs (339,400 gpm)
- Auxiliary: 38.3 cfs (17,200 gpm)
- Total: 794.5 cfs (356,600 gpm)

Other water: City of Huntington Beach

Cooling water discharge
- Location: 1,200 ft offshore south of intake
- Depth: 21.3 ft
- Discharge pipe: 14 ft (inside diameter)
- Type: open pipe
- Transit time: 21.5 minutes (intake to discharge)
- Δ T: 30°F

Power Generation

Fuel Type:
- Units 1–4: gas/oil

Plant output: (net)
- Units 1 & 2: 215 MW
- Units 3 & 4: 225 MW

Total: 880 MW (Units 1-4)

Plant design total: 1,020 MW

Nominal generation: 900 MW

Operating mode: base-load

Plant capacity factor:
- Unit 1: 31.5% (2001-2006)
- Unit2: 31.0% (2001-2006)
- Unit 3: 14.4% (2003-2006)
- Unit 4: 12.7% (2003-2006)

Average annual energy: 2,058,950 MWh (approximate)

Other data: Units 3 & 4 were shut down in 1995. Both were repowered: Unit 3 came online on July 31, 2002, and Unit 4 on August 7, 2003.

Figure 1 Vicinity Map of HBGS

Figure 2 Aerial Photograph of HBGS (Google 2007)

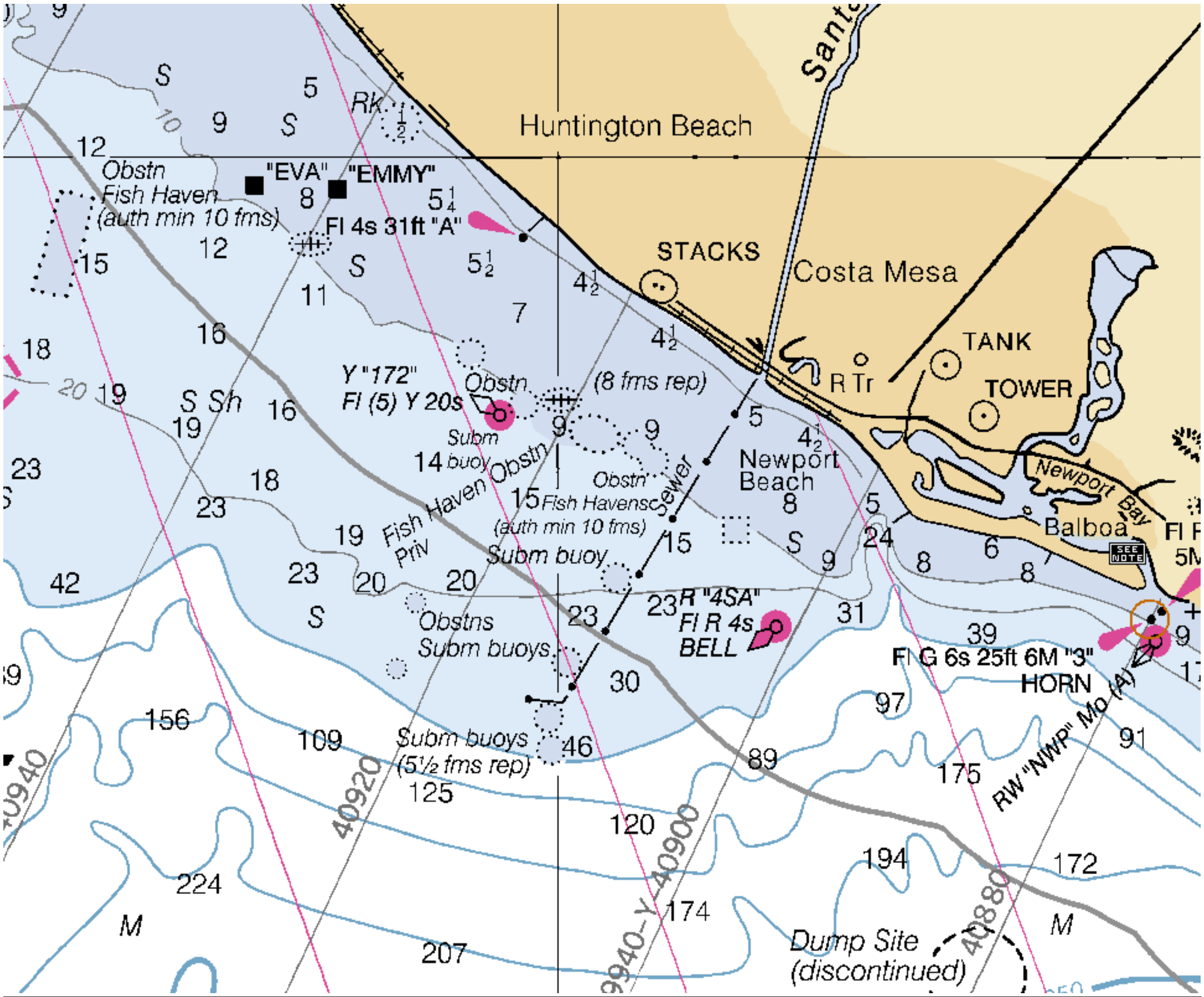


Figure 3 Navigation Chart of the Huntington Beach Area (Depth in Fathoms) (NOAA)

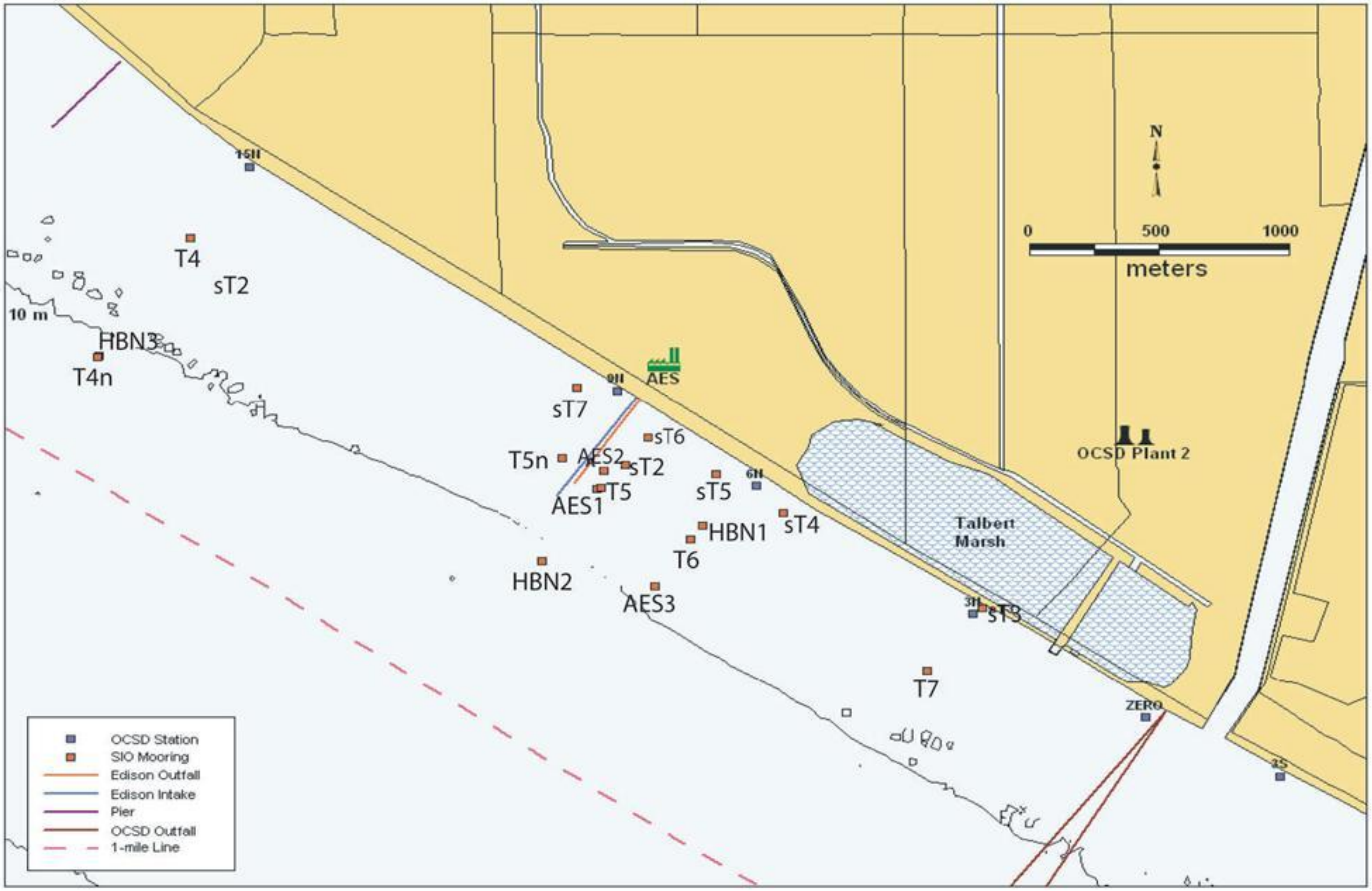


Figure 4 Location of nearshore moorings (red squares), beach sampling (blue squares), power plant intake (blue), and discharge (red), Talbert Marsh, and Santa Ana River. (Figure 2-9 USGS 2004)

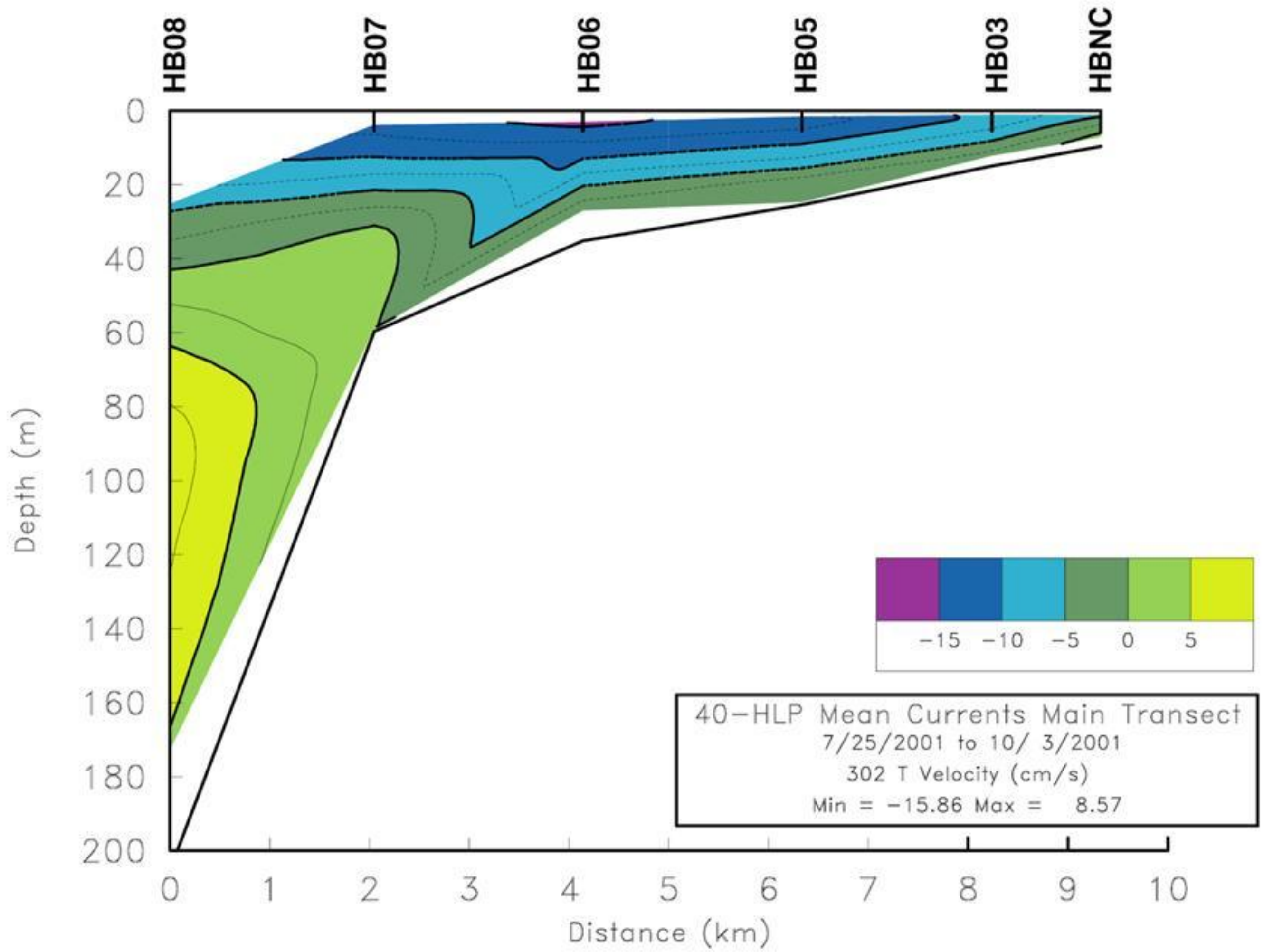


Figure 5 40-HLP mean along-shore currents, including the full depth of the slope mooring HB08. (Figure 4-5 USGS 2004)

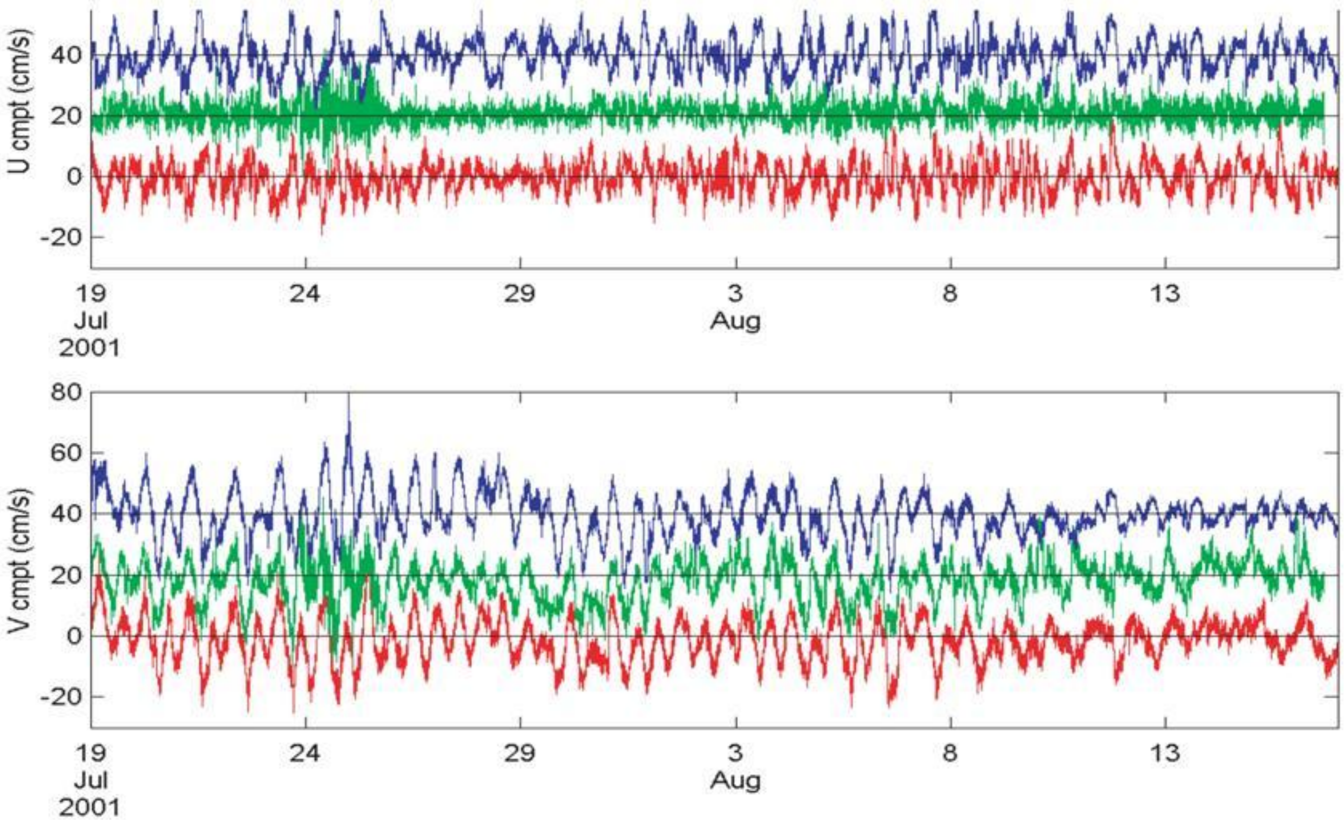


Figure 6 Near-bottom cross-shore velocities (U) (upper panel) and along-shore velocities (V) (lower panel) at HB03 (15 m, blue), HBN2 (10 m, red), and AES2 (6.5 m, green). Plots are offset 20 cm/s to separate lines–a zero line is shown for each trace. Note the decrease in both energy and coherence of cross-shore flows in the near-shore, in contrast to strong along-shore flows. (Figure 9-6 USGS 2004)

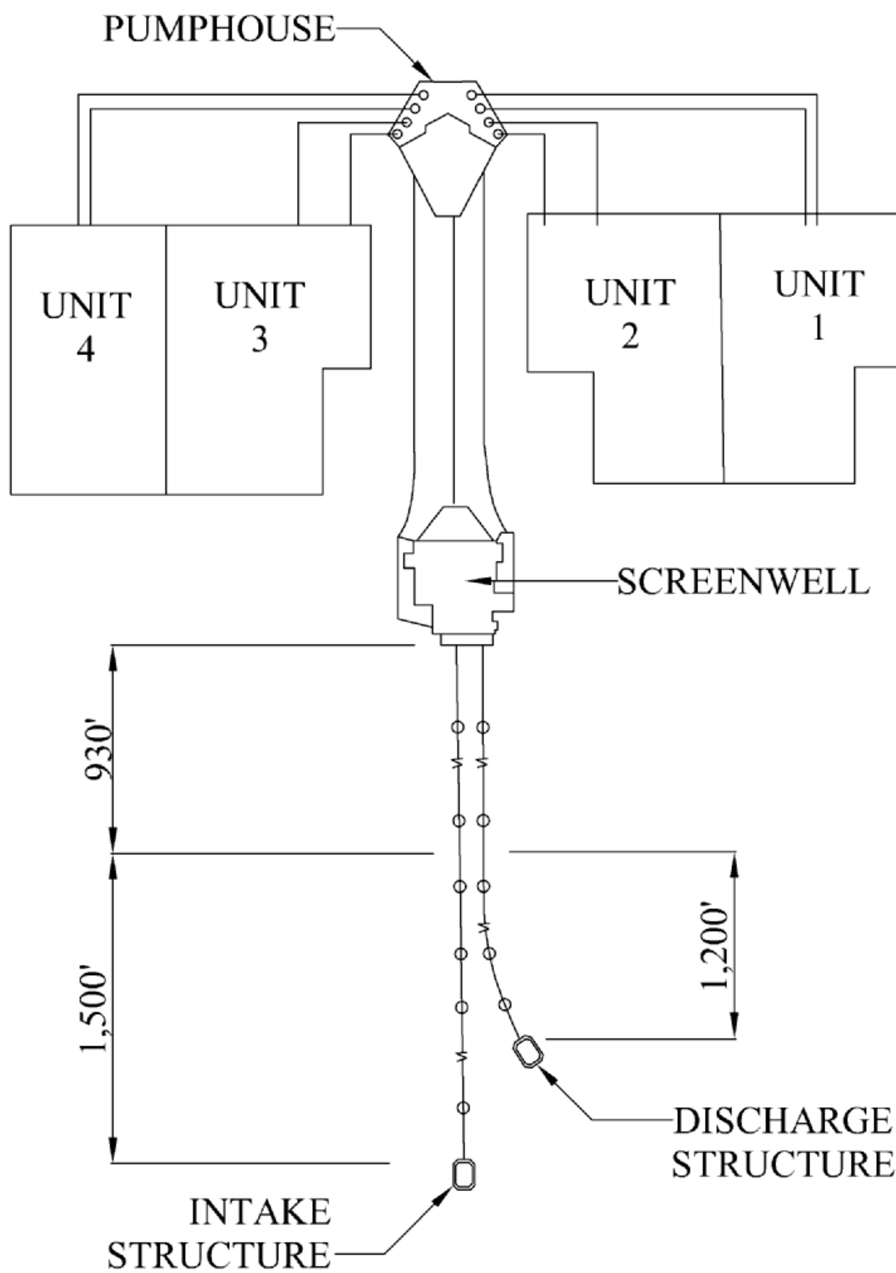


Figure 7 HBGS Circulating Water System

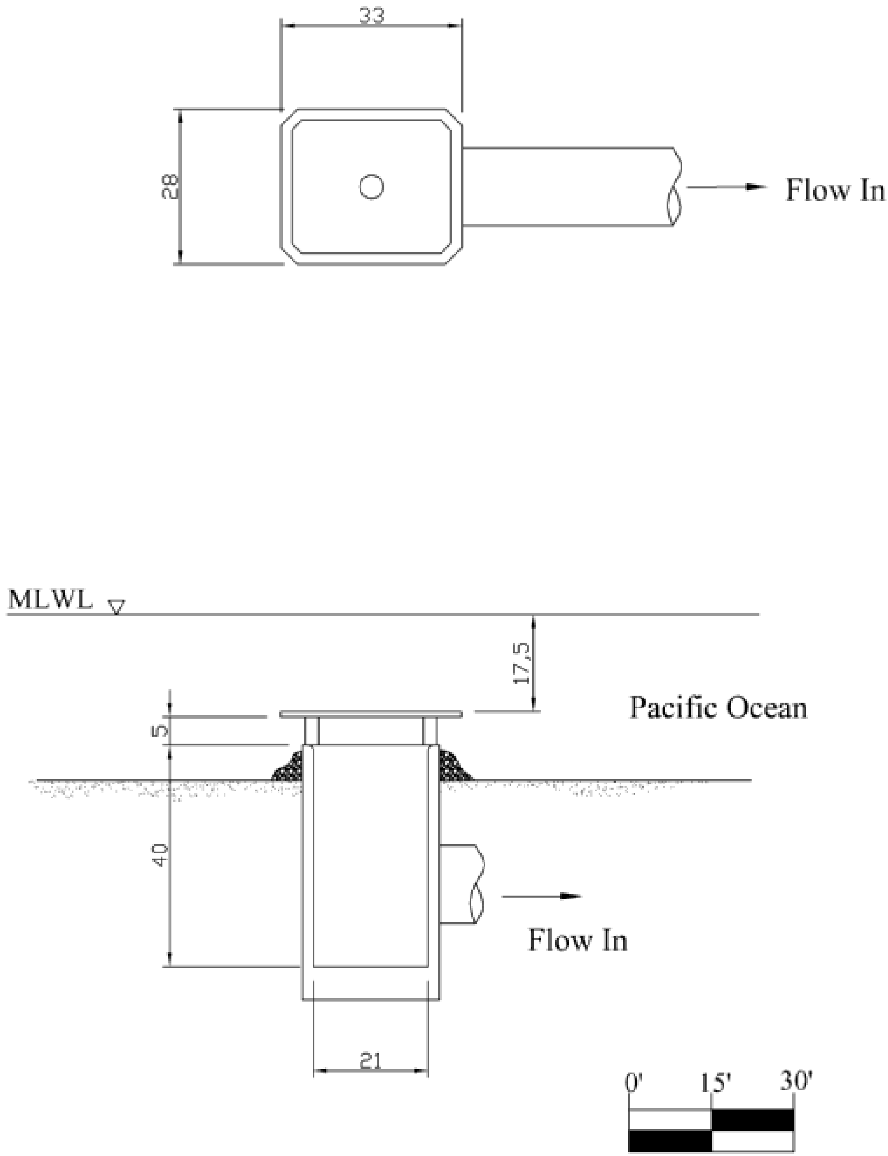


Figure 8 Velocity Cap Plan and Section

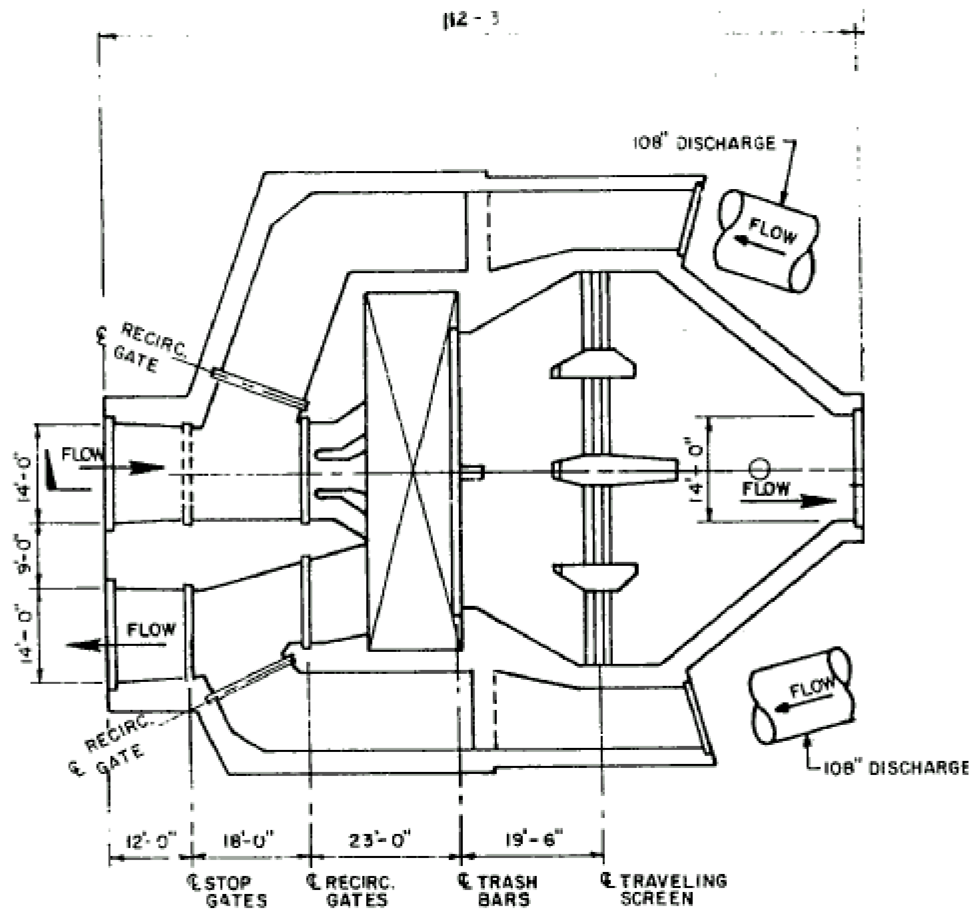


Figure 9 HBGS Screenwell Structure Plan View

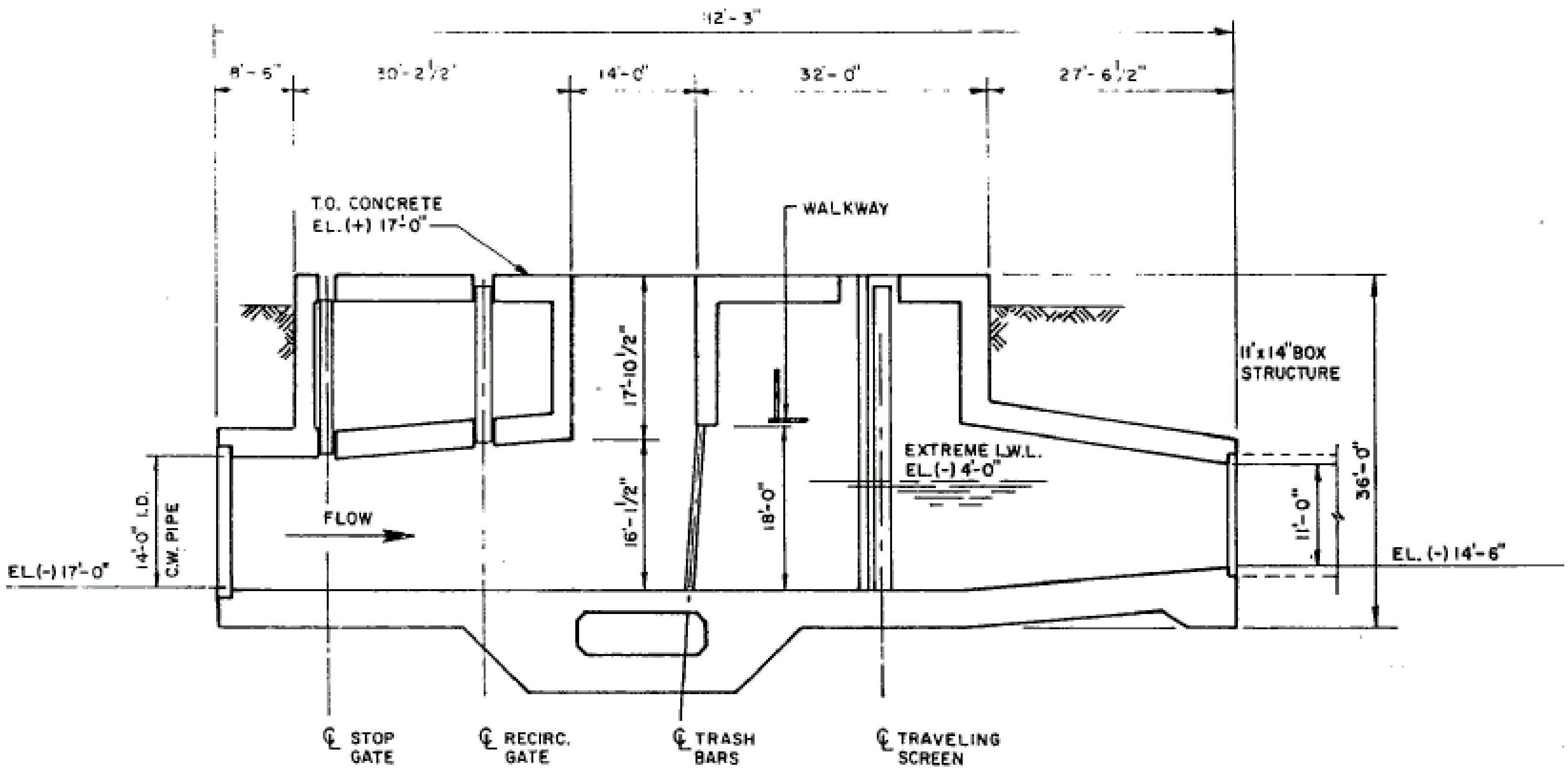


Figure 10 Screenwell Structure Section View

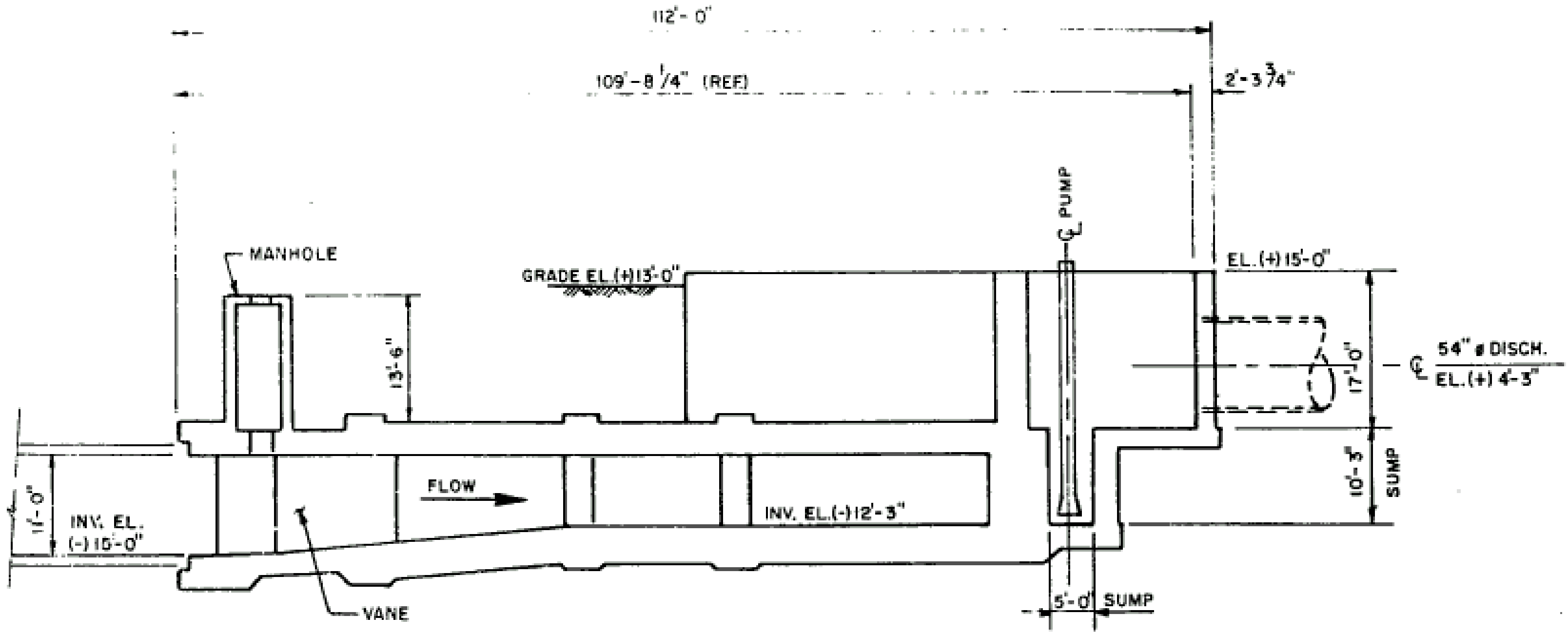


Figure 11 Pumphouse Structure Section View

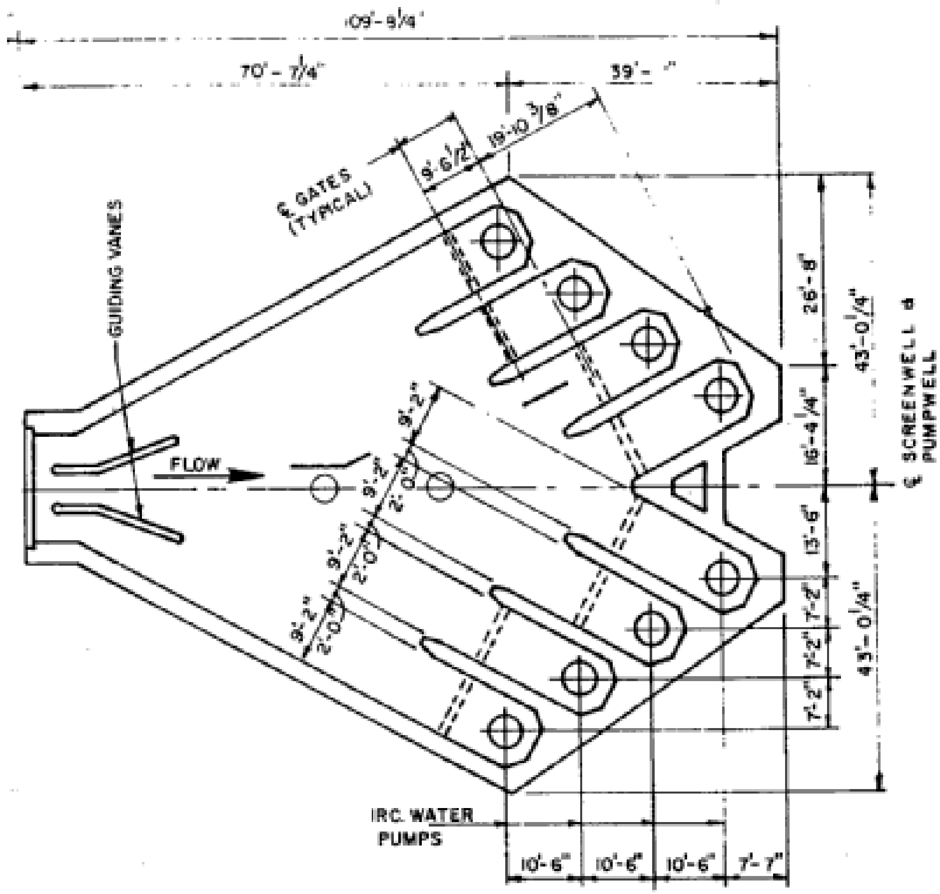
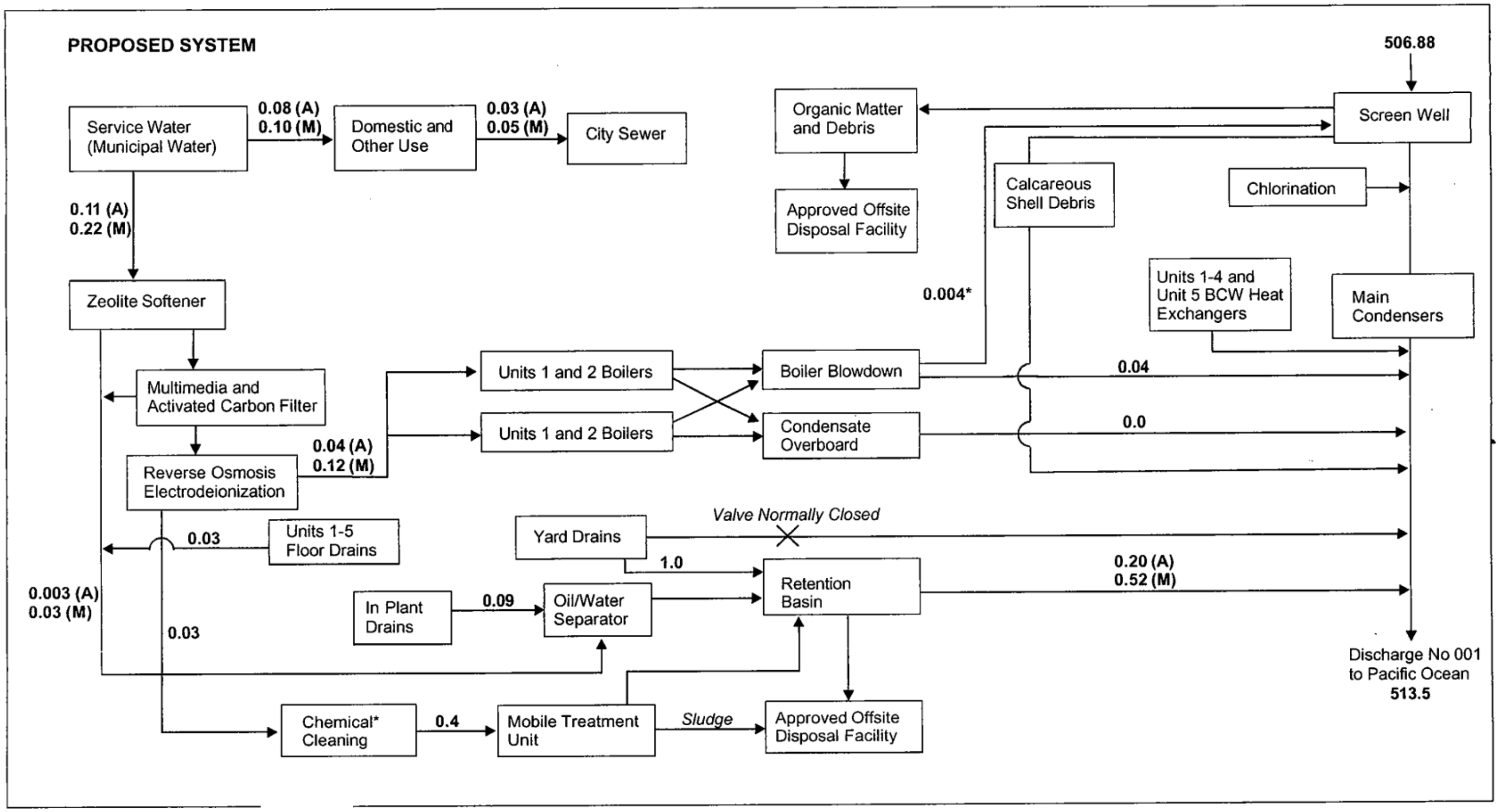


Figure 12 HBGS Pumpwell Structure Plan



Notes:
* Discharges are infrequent and do not occur simultaneously.
** All flows in mgd
(A) Average Flow
(M) Maximum Flow

Figure 13 Water Balance Diagram for HBGS (AES 2000)

5.0 References

AES. 2000. Unknown Document. Section 5.3 Water Resources

Google. 2007. Google Earth Professional.

Operational Oceanography Group: Global Temperature–Salinity Profile Program. June 2006. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Oceanographic Data Center, Silver Spring, Maryland, 20910. 10/11/07, <http://www.nodc.noaa.gov/GTSPP/>.

United States Environmental Protection Agency (USEPA). 2004. National Pollutant Discharge Elimination System - Final Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities. July 9, 2004 Federal Register: Vol. 69, No. 131 Pg 41576-41693

United States Geological Survey (USGS). 2004. Huntington Beach Shoreline Contamination Investigation Phase III. Coastal Circulation and Transport Patterns: The Likelihood of OCSD's Plume Impacting the Huntington Beach Shoreline. Prepared for Orange County Sanitation District. Open-File Report 04-1019.

National Oceanic and Atmospheric Administration (NOAA). 2007. San Diego to Santa Rosa Island. Chart Number 18740. 47th Addition, March 2007.

ATTACHMENT 2

Impingement Mortality and Entrainment Characterization Study

FINAL REPORT

HUNTINGTON BEACH GENERATING STATION

CLEAN WATER ACT SECTION 316(b) IMPINGEMENT MORTALITY AND ENTRAINMENT CHARACTERIZATION STUDY

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November 2, 2007

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LIST OF ACRONYMS

AEL	adult equivalent loss
BRRT	Biological Resources Research Team
BTA	best technology available
CalCOFI	California Cooperative Oceanic Fisheries Investigations
cm	centimeters
CDS	Comprehensive Demonstration Study
CEC	California Energy Commission
cfs	cubic feet per second
cm	centimeter
CWA	Clean Water Act
CWIS	cooling water intake structure(s)
dB	decibels
EPA	Environmental Protection Agency
ETM	Empirical Transport Model
FH	fecundity hindcasting
ft	feet
g	grams
gal	gallons
gpm	gallons per minute
GPS	Global Positioning System
HBGS	Huntington Beach Generating Station
ID	inside diameter
IM&E	impingement mortality and entrainment
in	inches
kg	kilogram
kHz	kilohertz
L	length
lbs	pounds
m	meters
mgd	million gallons per day
mi	miles
MLLW	Mean Lower Low Water
mm	millimeter
NL	notochord length
NPDES	National Pollutant Discharge Elimination System
PE	proportional entrainment
PIC	Proposal for Information Collection
P_m	probability of mortality
Ppt	parts per thousand
QA/QC	Quality Assurance/Quality Control
re:	reference
SARWQCB	Santa Ana Regional Water Quality Control Board
sec	second
SL	standard length
TL	total length

1.0 EXECUTIVE SUMMARY

This report presents data from in-plant and offshore field surveys performed for the AES Huntington Beach Generating Station (HBGS) Entrainment and Impingement Study. This study was performed to satisfy California Energy Commission Conditions of Certification BIO-4 and BIO-6 of the AES HBGS Retool Project. Impingement sampling began in late July 2003, and entrainment and source water sampling began in September 2003. Field studies were completed in late-August 2004. This report presents all entrainment, source water, and impingement data collected as part of the study.

Thirty-two entrainment surveys and twelve combined entrainment/source water surveys were performed from September 2003 through August 2004. Fish larvae from 57 different taxonomic groups were collected during the entrainment surveys. Unidentifiable CIQ gobies were the most abundant fishes in the entrainment samples, contributing 37% to the total. This group is comprised of one or more of the following nearshore gobies that cannot be distinguished during early larval stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*). Other abundant larval fish taxa included: northern anchovy (*Engraulis mordax*; 18%), spotfin croaker (*Roncador stearnsii*; 14%), white croaker (*Genyonemus lineatus*; 7%), and queenfish (*Seriphus politus*; 5%). Seventy-nine larval fish taxa were collected during the source water surveys. Six taxa comprised 80% of the total fishes collected from the source water samples: CIQ gobies (37%), northern anchovy (18%), queenfish (10%), white croaker (9%), unidentified croakers (4%), and combtooth blennies (*Hypsoblennius* spp.; 3%).

Of the five proposed target invertebrate taxa, only two were collected in entrainment samples: sand crab (*Emerita analoga*) and rock crab (*Cancer* spp.). Sand crab larvae comprised nearly 99% of the entrained target invertebrate concentration. Almost all of the sand crab larvae were in the earliest stage of their larval development (zoea stage I). No California spiny lobster (*Panulirus interruptus*), market squid (*Loligo opalescens*), or ridgeback prawn (*Sicyonia ingentis*) larvae were collected from entrainment samples.

CIQ gobies, northern anchovy, and combtooth blennies were assessed using demographic modeling (Adult Equivalent Loss [*AEL*] and/or Fecundity Hindcasting [*FH*]) and the Empirical Transport Model (*ETM*). An additional six larval fish taxa, as well as rock crabs (*Cancer* spp.), were assessed using only the *ETM*. Impact assessment modeling could not be performed for salema (*Xenistius californiensis*) due to lack of life history parameters and the lack of sufficient larvae at both entrainment and source water stations during surveys. For fishes, *AEL* estimates (assuming maximum flow) were 304,125 individuals (northern anchovy) and 147,493 individuals (CIQ gobies) (Table ES-1). *FH* estimates ranged from 3,233 adult females (combtooth blennies) to 101,269 adult females (CIQ gobies).

Table ES-1. Summary of entrainment modeling and impingement estimates for target taxa assuming maximum cooling water flow. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate.

				P_m		Impingement	
Taxon	Estimated Annual Entrainment	2·*FH*	*AEL*	Alongshore Extrapolation	Alongshore + Offshore Extrapolation	No.	Weight (kg)
CIQ gobies	113,166,834	202,538	147,493	1.0% (60.9 km)	1.0%	0	0.0
northern anchovy	54,349,017	53,490	304,125	1.2% (72.0 km)	0.7%	2,193	14.9
spotfin croaker	69,701,589	NA	NA	0.3% (16.9 km)	0.3%	49	1.8
queenfish	17,809,864	NA	NA	0.6% (84.9 km)	0.5%	35,84	648.2
white croaker	17,625,263	NA	NA	0.7% (47.8 km)	0.4%	4,903	95.4
black croaker	7,128,127	NA	NA	0.1% (19.4 km)	0.05%	65	7.0
salema	11,696,960	NA	NA	NA	NA	46	0.5
blennies	7,165,513	6,466	NA	0.8% (12.8 km)	0.3%	3	0.02
diamond turbot	5,443,118	NA	NA	0.6% (16.9 km)	0.3%	0	0.0
California halibut	5,021,168	NA	NA	0.3% (30.9 km)	0.08%	21	9.9
shiner perch	-	-	-	-	-	4,045	51.8
sand crab megalops	69,793	NA	NA	NA	NA	-	-
Calif. spiny lobster	0	NA	NA	NA	NA	32	19.6
ridgeback rock shrimp	0	NA	NA	NA	NA	0	0.0
market squid	0	NA	NA	NA	NA	7	0.4
rock crab	6,411,171	NA	NA	1.1% (26.5 km)	0.8%	5,820	42.1
D. frondosus	-	NA	NA	-	-	65,15	15.0
two-spotted octopus	-	NA	NA	-	-	61	25.4
purple-striped jelly	-	NA	NA	-	-	53	21.7

NA = Not available due to insufficient life history information or low abundance in entrainment samples.
- = Not analyzed.

Two probability of mortality (P_m) estimates (assuming maximum cooling water flow at the HBGS) were calculated for each of the target taxa: one based solely on alongshore current movement, and the other on alongshore current movement and an extrapolation of areal density of larvae offshore to a distance bounded by either the extrapolated densities or onshore current movement. Larval durations of target fish taxa ranged from 5 days (spotfin croaker) to 38 days (northern anchovy). The P_m estimates based on alongshore current displacement ranged from 0.1% to 1.2% (Table ES-1). The length of coastline (km) used in extrapolating the estimates of $P_m$ranged from 12.8 to 84.9 km (Table ES-1). An estimate of the area of larval production lost due to entrainment (area of production foregone) can be estimated by multiplying the P_m estimates by the alongshore source water length and the width of the source water area sampled (5 km). Estimates of the area of production foregone ranged from 0.11 to 4.47 km^2, and averaged 1.50 km^2 (Table ES-2).

Table ES-2. Summary of entrainment modeling estimates for target taxa and estimation of area of production foregone. The shoreline distance (km) used in the alongshore extrapolation of P_m is presented in parentheses next to the shoreline distance estimate. Estimates assume maximum cooling water flow at the HBGS.

Taxon	Estimated Annual Entrainment	P_m Alongshore Extrapolation	Shoreline Distance (km) of Production Foregone	Area of Production Foregone (km^2)
CIQ gobies	113,166,834	1.0% (60.9 km)	0.604	3.024
n. anchovy	54,349,017	1.2% (72.0 km)	0.894	4.471
spotfin croaker	69,701,589	0.3% (16.9 km)	0.050	0.248
queenfish	17,809,864	0.6% (84.9 km)	0.531	2.657
white croaker	17,625,263	0.7% (47.8 km)	0.340	1.699
black croaker	7,128,127	0.1% (19.4 km)	0.023	0.115
salema	11,696,960	NA	NA	NA
blennies	7,165,513	0.8% (12.8 km)	0.098	0.492
diamond turbot	5,443,118	0.6% (16.9 km)	0.098	0.488
California halibut	5,021,168	0.3% (30.9 km)	0.077	0.386
rock crab	6,411,171	1.1% (26.5 km)	0.284	1.418

A total of 52 normal operation impingement surveys was conducted from July 2003 to July 2004, and six heat treatment impingement surveys were conducted through July 2004. Results from the weekly normal operation surveys were extrapolated based on cooling water flow, and summed with heat treatment results to estimate total annual impingement. A total of 51,082 fishes representing 57 species and weighing 1,292 kg (2,849 lbs) was impinged, with most (75%) of the losses attributable to heat treatments. Queenfish was the most abundant species impinged, accounting for 70% of total abundance. Other abundant fish species included white croaker, shiner perch (*Cymatogaster aggregata*), and northern anchovy. A total of 70,638 macroinvertebrates representing 37 species and weighing 168 kg (370 lbs) was impinged, with most (98%) of the losses attributable to normal operations. The most abundant species were the nudibranch *Dendronotus frondosus*, yellow rock crab (*Cancer anthonyi*), slender rock crab (*Cancer gracilis*), and brown rock crab (*Cancer antennarius*).

Estimates of entrainment and impingement of fishes and macroinvertebrates at the HBGS were compared with local recreational and commercial fishery landings. Four of the larval fish and invertebrate species assessed have some commercial value: California halibut (*Paralichthys californicus*), white croaker, northern anchovy, and rock crabs. Estimated entrainment losses, based on *ETM* values, on these commercial fisheries (in 2003 and 2002 dollars) totaled $204 and $224, respectively. Estimated impingement losses on local commercial fisheries (in 2003 and 2002 dollars) totaled $1,072 and $823, respectively. If impinged queenfish were included with white croaker in landing totals, the estimated total losses for 2002 and 2003 would be $2,887 and $2,367, respectively.

Estimated entrainment losses, based on *ETM* values, on southern California recreational fisheries were calculated for queenfish, white croaker, California halibut, and spotfin croaker. Entrainment losses based on alongshore P_m values totaled 7,583 individuals, while losses based on alongshore and offshore P_m values totaled 5,757 individuals. In both cases, queenfish comprised the majority (77% or more) of these losses. Estimated impingement losses on southern California recreational fisheries were determined using two databases. Impingement losses were equivalent to 1% of southern California recreational landings using the RecFIN database, and about 10% of local landings from Huntington Beach, Newport Beach, and Long Beach, California, as reported in the NOAA Fisheries Los Angeles Times database. However, there was a large disparity between the most abundant species impinged and the most abundant species reported in landings.

Calculation Baseline estimates were made for both impingement mortality and entrainment at the HBGS assuming (1) design (maximum) cooling water flow, and (2) actual cooling water flow during 2004-5. The 2004-5 period was considered to be representative period of facility operations since Units 3&4 were refurbished. No other adjustments to entrainment data were made; however, impingement mortality estimates were adjusted to take into account the estimated performance of the velocity cap (82% reduction). The Calculation Baseline estimates for entrainment were 275 million larval fish entrained using actual flows and 355 million larval fish using design flows. Calculation Baseline estimates for impingement mortality using actual cooling water flows were 256,000 fish weighing 6,573 kg (14,493 lbs) and 7,971 shellfish weighing 136 kg (301 lbs). Using design flows, Calculation Baseline estimates increased to 373,000 fish weighing 9,546 kg (21,050 lbs) and 10,886 shellfish weighing 185 kg (408 lbs).

2.0 INTRODUCTION

2.1 BACKGROUND AND OVERVIEW

On July 9, 2004, the U.S. Environmental Protection Agency published the second phase of new regulations under §316(b) of the Clean Water Act (CWA) for cooling water intake structures (CWIS) that applied to existing facilities (Phase II facilities). The Phase II Final Rule went into effect in September 2004, and applied to generating stations with CWIS that withdraw at least 50 million gallons per day (mgd) from rivers, streams, lakes, reservoirs, oceans, estuaries, or other waters of the United States. The cooling water system for the existing AES Huntington Beach Generating Station (HBGS) in Huntington Beach, California (Figure 2-1) withdraws a maximum of 507 mgd for cooling purposes. All units withdraw cooling water from a single intake that extends approximately 457 m (1,500 ft) offshore from the HBGS.

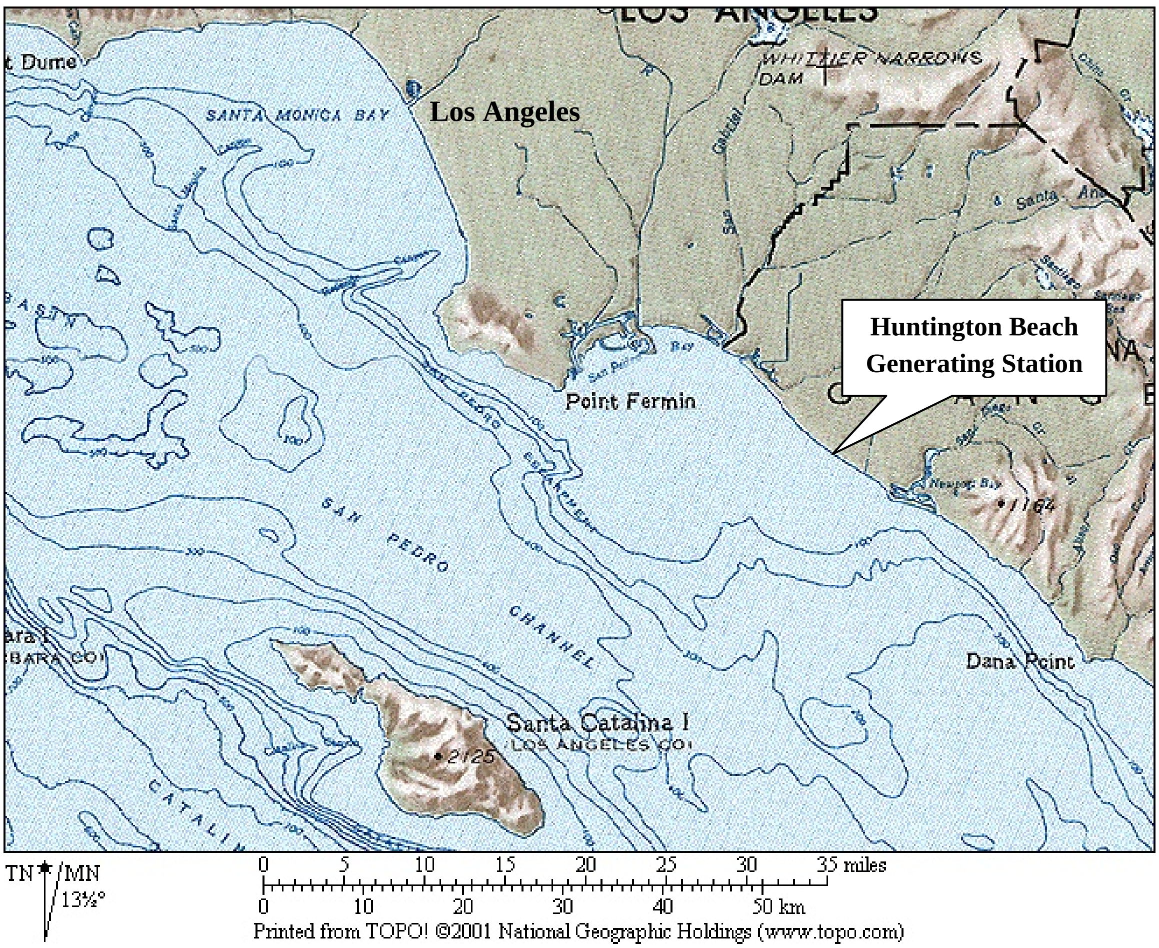


Figure 2-1. Location of the Huntington Beach Generating Station.

The HBGS was classified as a Phase II existing facility, and was subject to the 316(b) Phase II final regulations. The Phase II regulations (40 CFR 9, 122-125) established national performance standards that required reducing impingement mortality by 80 to 95% and entrainment by 60 to 90%. With the implementation of the final regulations, EPA intended to minimize the adverse environmental impact of cooling water intake structures by reducing the number of aquatic organisms lost as result of water withdrawals associated with those intake structures. The Phase II regulations became effective on September 7, 2004, and provided facilities with five compliance alternatives:

1. Demonstrate the facility has reduced flow commensurate with a closed-cycle recirculating system (only applies to the entrainment performance standard) or has reduced design intake velocity to less than 0.5 feet per second (only applies to the impingement mortality performance standard);
2. Demonstrate that existing design and construction technologies, operational measures, and/or restoration measures meet the performance standards;
3. Demonstrate that the facility has selected design and construction technologies, operational measures, and/or restoration measures that will, in combination with any existing technologies, operational measures, and/or restoration measures, meet the performance standards;
4. Demonstrate that the facility has installed and properly operates and maintains an approved technology;
5. Demonstrate that a site-specific determination of BTA is appropriate.

Pursuant to the Phase II Final Rule, AES submitted the HBGS Proposal for Information Collection (PIC) to the Santa Ana Regional Water Quality Control Board (SARWQCB) in July 2005. EPA remanded the Phase II Final Rule in April 2007; however, AES Huntington Beach is obligated to complete 316(b) Phase II compliance measures as required by the NPDES Permit (CA0001163) issued to the plant.

2.1.1 Section 316(b) of the Clean Water Act

Section 316(b) of the Clean Water Act (CWA) requires that the location, design, construction, and capacity of cooling water intake structures (CWIS) reflect the best technology available (BTA) to minimize adverse environmental impacts due to the impingement mortality (IM) of aquatic organisms (i.e., fish, shellfish, and other forms of aquatic life) on intake structures and the entrainment (E) of eggs and larvae through cooling water systems. The new 316(b) Phase II regulations established performance standards for CWISs of existing power plants that withdraw more than 50 mgd of surface waters and use more than 25% of the withdrawn water for cooling purposes. The regulations required all large existing power plants to reduce impingement mortality by 80–95% and to reduce entrainment of smaller aquatic organisms drawn through the cooling system by 60–90% when compared against a “calculation baseline”. The water body type on which the facility is located, the capacity utilization rate, and the magnitude of the design intake flow relative to the waterbody flow determined whether a facility is required to meet the performance standards for only impingement or both impingement and entrainment.

The new regulations provided power plants with five options for meeting the performance standards, but unless a facility could show that it met the standards using the existing intake design or was installing one of the approved EPA technologies for IM&E reduction, it was required to submit information documenting its existing levels of IM&E. These data could come from existing data that may have previously been collected at the facility or a similar facility nearby. The data were then required to be submitted in an Impingement Mortality and Entrainment (IM&E) Characterization Study that is one component of the §316(b) Comprehensive Demonstration Study required under the Phase II regulations. The impingement mortality component of the studies was not required if the through-screen intake velocity was less than or equal to 0.5 feet per second (15 centimeters [cm] per second). The entrainment characterization component was not required if a facility:

(a) Has a capacity utilization rate of less than 15%;

(b) Withdraws cooling water from a lake or reservoir, excluding the Great Lakes; or

(c) Withdraws less than 5% of the mean annual flow of a freshwater river or stream.

Based on previously collected intake velocity measurements and plant operating characteristics, both the IM&E components of the study were required at the HBGS. Previous §316(b) Demonstration studies were done at HBS from October 1978 through September 1980. The entrainment sampling was conducted at Ormond Beach and San Onofre on a monthly basis, while impingement samples were collected at the HBGS on approximately a weekly to biweekly basis. A more recent study consisting of weekly to biweekly entrainment sampling and weekly impingement sampling was conducted from July 2003 to September 2004. A detailed summary of the historical IM studies is provided in Section 5. As described in the PIC that AES submitted to the SARWQCB in July 2005, AES proposed to use the 2003-4 entrainment and impingement data for the IM&E Characterization Study.

2.1.2 HBGS NPDES Permit

The current NPDES permit for the HBGS was adopted in August 2006 and required compliance with 316(b) requirements that would be implemented by the Regional Board staff using ‘best professional judgment’. The requirements in the NPDES permit differed slightly from the Phase II regulations; they required a 95% reduction in impingement mortality and a 90% reduction in entrainment. Although the 316(b) Phase II regulations were remanded by EPA in 2007, the HBGS NPDES permit still required submittal of Phase II documents, including a Comprehensive Demonstration Study (CDS). This IM&E Characterization Study is a requisite section of the HBGS CDS.

2.1.3 Development of the Study Plan

The new §316(b) regulations required that the plan for the IM&E Characterization Study include sufficient data to develop a scientifically valid estimate of IM&E including all methods and quality assurance/quality control procedures for sampling and data analysis. The sampling and data analysis methods must be appropriate for a quantitative survey and include consideration of the methods used in other studies performed in the source waterbody. The sampling plan must also include a description of the study area (including the area of influence of the CWIS), and provide for taxonomic identifications of the sampled or evaluated biological assemblages (including all life stages of fish and shellfish) that are known to be relevant to the development of the plan.

The regulations required that the PIC include summaries of any historical studies characterizing impingement mortality and entrainment (IM&E), and/or the physical and biological conditions in the vicinity of the cooling water intake structures and their relevance to the proposed studies. These were required to assist the SARWQCB in reviewing and commenting on the IM&E study plan. If the data from previous studies were to be used in characterizing the existing levels of IM&E then the PIC must demonstrate that the data were representative of current conditions and were collected using appropriate quality assurance/quality control procedures.

As part of a repowering certification process, AES Huntington Beach was required to perform a yearlong IM&E study. In accordance with California Energy Commission (CEC) Conditions of Certification BIO-4 and BIO-6, MBC Applied Environmental Sciences (MBC) and Tenera Environmental (Tenera) submitted a draft entrainment and impingement study plan to the CEC in October 2001. After reviewing the study plan, CEC staff and consultants met on 5 October 2001 to discuss specifics of the study plan. In July 2002, MBC submitted a revised draft study plan to the CEC and the Biological Resources Research Team (BRRT), which consists of interested parties representing regulatory agencies, consultants, and the applicant (AES Huntington Beach L.L.C.). Comments and recommendations to the study plan were submitted by the BRRT and discussed at a meeting on 9 October 2002. The final study plan, which incorporated further comments and recommendations, was published in July 2003.

2.1.4 Overview of the Study Plan

The entrainment and impingement study was designed to estimate losses of fishes and shellfish due to operation of the cooling water system of the HBGS. The sampling methodologies and analysis techniques were derived from recent entrainment and impingement studies conducted for the Diablo Canyon Power Plant, Morro Bay Power Plant, and Moss Landing Power Plant (Tenera 2000a, 2000b, 2001). Similar projects were performed nation-wide in the last 25 years to comply with Section 316(b) of the Federal Clean Water Act, including the 1996–1999 study at the Diablo Canyon Power Plant. The 1999–2000 studies at Morro Bay and Moss Landing were performed as part of the California Energy Commission CEQA process for permitting power plant modernization projects.

For the Huntington Beach entrainment study, the numbers of fishes and target invertebrates entrained by the generating station were estimated from plankton samples collected just offshore of the intake structure. Samples collected at the entrainment station and at six other stations extending 4 km upcoast, downcoast, and offshore the intake structure, were used to estimate the source water populations at risk of entrainment. For the impingement study, impingement samples were collected from the screening facility within the generating station.

2.1.5 Study Plan Objectives

Under the remanded Phase II §316(b) regulations, the IM&E Characterization Study must include the following (for all applicable components):

1. Taxonomic identifications of all life stages of fish, shellfish, and any species protected under federal, state, or tribal law (including threatened or endangered species) that are in the vicinity of the CWIS and are susceptible to impingement and entrainment;
2. A characterization of all life stages of fish, shellfish, and any species protected under federal, state, or tribal law (including threatened or endangered species) identified in the taxonomic identification noted previously, including a description of the abundance and temporal and spatial characteristics in the vicinity of the CWIS, based on sufficient data to characterize the annual, seasonal, and diel variations in the IM&E; and
3. Documentation of current IM&E of all life stages of fish, shellfish, and any protected species identified previously and an estimate of IM&E to be used as the calculation baseline.

The remanded Phase II §316(b) regulations provided the SARWQCB with considerable latitude in determining the level of detail necessary in meeting these objectives and states that "while the taxonomic identification in item 1 will need to be fairly comprehensive, the quantitative data required in items 2 and 3 may be more focused on species of concern, and/or species for which data are available." If the CDS was based on a given technology, restoration or site-specific standards, the level of detail in terms of the quantification of the baseline can be tailored to the compliance alternative selected and did not have to address all species and life stages. Logically it could be based on dominant species and/or commercially or recreationally important species. Therefore, there was agreement with the working group (including the SARWQCB) that the impingement sampling would identify, count, weigh, and measure all collected fishes, crabs, lobsters, shrimp, squid and octopus. This approach was taken to include all of the impingeable 'shellfish' that are recreationally or commercially important and a large number of species that are not fishery species. It was also agreed that the entrainment sampling would identify and count all fish larvae, megalops stage larvae for cancrid crabs, megalopae for mole crabs (sand crabs), ridgeback rock shrimp phyllosoma larvae, California spiny lobster phyllosoma larvae, and market squid hatchlings.

These data were to be used in developing a characterization of baseline levels of IM&E for the HBGS. An important feature of the Phase II regulations was use of the calculation baseline. The calculation baseline is defined in the regulations as follows:

> *"Calculation baseline means an estimate of impingement mortality and entrainment that would occur at your site assuming that: the cooling water system has been designed as a once-through system; the opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment. You may also choose to use the current level of impingement mortality and entrainment as the calculation baseline. The*

calculation baseline may be estimated using: historical impingement mortality and entrainment data from your facility or another facility with comparable design, operational, and environmental conditions; current biological data collected in the waterbody in the vicinity of your cooling water intake structure; or current impingement mortality and entrainment data collected at your facility. You may request that the calculation baseline be modified to be based on a location of the opening of the cooling water intake structure at a depth other than at or near the surface if you can demonstrate to the Director that the other depth would correspond to a higher baseline level of impingement mortality and/or entrainment."

As presented in the PIC, the HBGS CWIS does not conform to the calculation baseline. Significant deviations from the calculation baseline are:

- The intake is submerged rather than at, or near, the surface;
- The traveling screens are located more than 1,000 ft from the shoreline rather than at the shoreline; and
- The intake design includes a velocity cap.

The Phase II regulations allowed facilities to take credit for deviations from the calculation baseline if it could demonstrate that these deviations provided reduced levels of IM&E. The approach taken for calculating baseline levels of IM&E is present in Section 7.0.

Another objective of the study is to provide data that can be used in meeting different alternatives for compliance that might be used by AES. One approach previously allowed under the Phase II regulations that was the subject of the court challenge was the use of restoration that could be used, in whole or in part, to meet the performance standards for IM&E reduction. To this end, source water data were collected to estimate the sizes of the populations potentially subject to entrainment. The analysis of IM&E data could be used in determining the amount of restoration necessary to provide a minimum benefit equivalent to reductions of 95% in impingement mortality and 90% in entrainment. Another compliance approach allowed the use of cost-cost and cost-benefit tests that ensure that Phase II facilities not incur costs that would be considered significantly greater than either the costs estimated by USEPA for these facilities or the economic value of the site-specific environmental benefits that will be achieved. The study provides data that could be used to estimate the economic value of the environmental benefit of meeting the performance standards will be evaluated. This analysis would include evaluation of the costs of meeting the entrainment performance standard after taking any credits as a result of baseline deviations that can be demonstrated to provide the benefit of fish protection.

2.1.6 Study Plan Approach

The IM&E studies at HBGS were designed to examine losses resulting from both impingement of juvenile and adult fish and shellfishes on traveling screens at the intake during normal operations and from entrainment of larval fishes and shellfishes into the cooling water intake system. The sampling methodologies and analysis techniques were designed to collect the data necessary for compliance with the Phase II §316(b) regulations. The study plan was subject to review by state and federal resource agency staff and independent scientists.

Impingement sampling has been conducted at the HBGS since the 1970s. The recent NPDES permits for the HBGS required impingement sampling monthly during normal operations and during all heat treatments. The impingement sampling methods used in the IM&E study were similar to the NPDES monitoring program, but the sampling frequency was increased to weekly.

3.0 DESCRIPTION OF THE GENERATING STATION AND CHARACTERISTICS OF THE SOURCE WATER BODY

The following section describes the HBGS and the surrounding aquatic environment. A description of the generating station and its cooling water intake system (CWIS) is presented in Sections 3.1 and 3.2. A description of the physical and biological environments in the vicinity of the HBGS is presented in Section 3.3.

3.1 DESCRIPTION OF THE GENERATING STATION

The HBGS is located on the Orange County coast in the city of Huntington Beach (Figure 2-1). The generating station consists of four steam-powered electric generating units. Steam is supplied to each turbine generator from oil- and gas-fired boilers. Units 1 and 2 are each rated at 215 megawatts (MW) and Units 3 and 4 are each rated at 225 MW. Units 3 and 4 were operated very sparingly after 1989 and were retired from service from 1995 until completion of the retool project in 2003. Unit 5, a multiple-jet-turbine peaker unit (133 MW), was retired from service in 2002. The current total station rating is 880 MW. From October 2005 through December 2006 the HBGS operated at 15% capacity.

3.2 DESCRIPTION OF THE COOLING WATER INTAKE SYSTEM

Ocean water for cooling purposes is supplied to the generating station via a single cooling water system. Seawater for Units 1–4 is withdrawn from an intake structure located 457 m (1,500 ft) offshore (**Figure 3-1**). The intake structure is located in approximately 10 m (33 ft) of water, and rises approximately 4 m (13 ft) off the bottom. The vertical riser section is 6.4-m inside-diameter (ID), and the horizontal conduit to the generating station is 4.3-m (21 ft) ID. The vertical riser is fitted with a velocity cap, and the vertical opening between the riser and the velocity cap is about 1.5 m (5 ft) (Figure 3-2). Entrance velocities at the point of withdrawal have been measured at 0.6 and 1.2 m/sec (2 and 4 fps) (FES et al. 1980; McGroddy et al. 1981).

Seawater is drawn into the plant by up to eight circulating water pumps, each capable of delivering 44,000 gallons per minute, or about 63.4 million gallons per day (mgd), for a station maximum of about 507 mgd (1,919,000 m^3). The flow is directed to a 4-m x 15.2-m open rectangular forebay and screening facility within the plant. The screen system is composed of vertical bar racks spaced 76.2 mm (3”) on center and vertical traveling screens with 9.5-mm (3/8”) mesh designed to remove trash, algae, marine life, and other incidental debris incoming with the cooling water. After flowing through the screen system, the cooling water is pumped to two steam condensers, one per turbine generator. At full load, the temperature increase through the condensers (ΔT) is approximately 10°C (18°F). After passing through the condensers the water is directed to a single 4.3-m (14 ft) concrete discharge conduit, which extends approximately 366 m (1,200 ft) offshore. The discharge structure resembles the intake structure, except there is no velocity cap. Discharged waters are directed vertically to the surface to allow for dilution and atmospheric cooling.

Units 1–4 have closed cooling water systems to cool auxiliary equipment. Demineralized water is cooled by part of the main cooling stream, which is diverted to a heat exchanger and returned to the main stream. Each unit diverts about 9,750 gpm (14 mgd), and this water is subsequently elevated 4.6°C (8.3°F) (AES and URS 2000). No modifications to the cooling water system were made as part of the Repowering Project.

To control the growth of bacteria and other micro-fouling organisms within the cooling water system, the cooling water is treated with sodium hypochlorite in accordance with the station's National Pollutant Discharge Elimination System (NPDES) permit. Biofouling within the cooling water conduits and forebay is controlled by heat treatment. During heat treatments, a portion of the heated discharge water is diverted into the forebay and intake conduits until the water temperature rises to approximately 40.5°C (105°F) (Figure 3-3). Temperature of discharge waters during this procedure is about 44° to 50°C (112° to 122°F). This temperature is maintained for about one hour, during which time all mussels, barnacles, fishes, and other invertebrates within the cooling water system succumb to the high water temperature. This procedure has been used for decades at most of southern California's coastal generating stations (Graham et al. 1977), and is done in compliance with NPDES permit limitations. Divers also periodically remove accumulated debris, such as mussel and barnacle shells and sand, from the forebay and in-plant conduits.

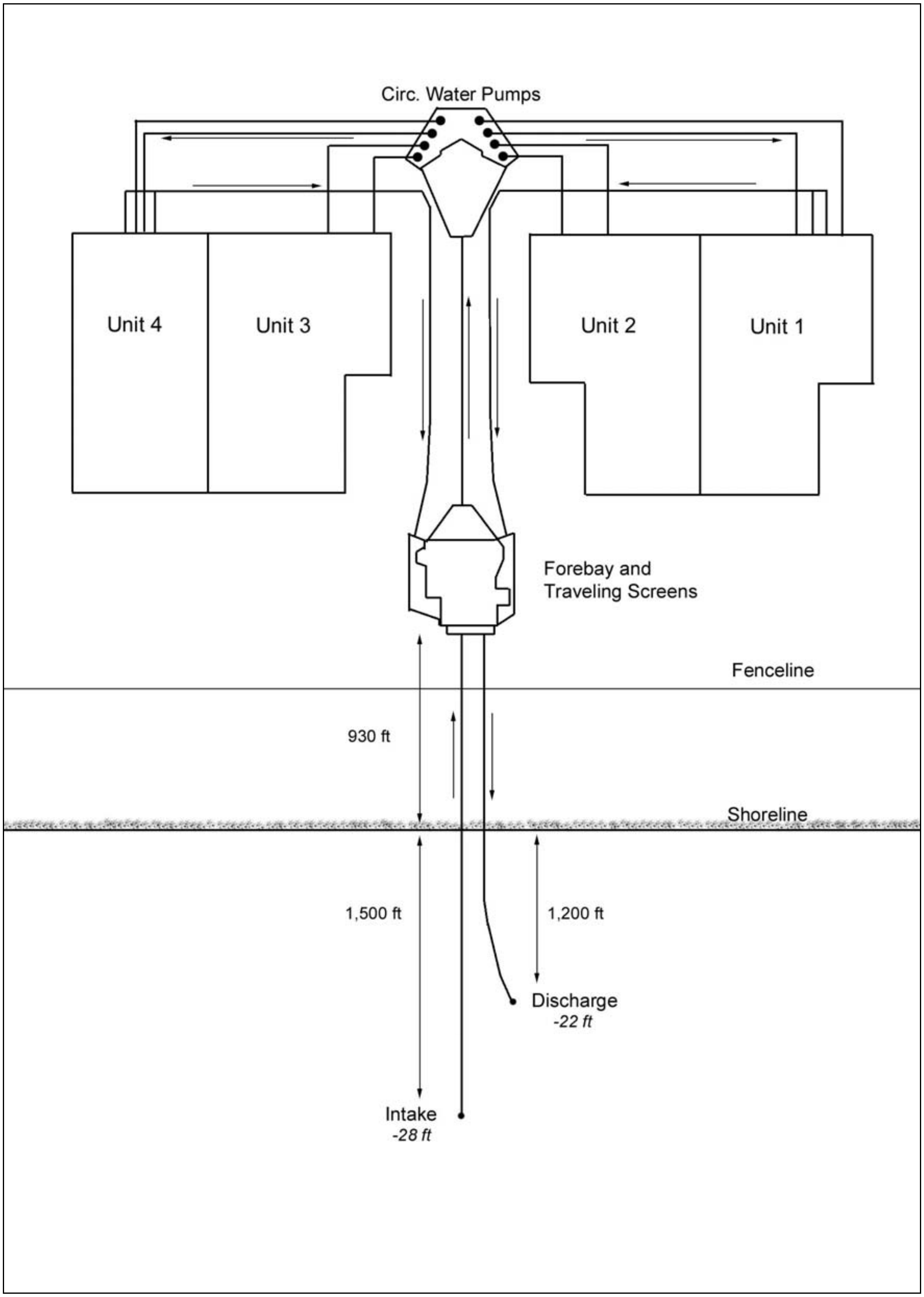


Figure 3-1. Schematic of the HBGS cooling water intake system.

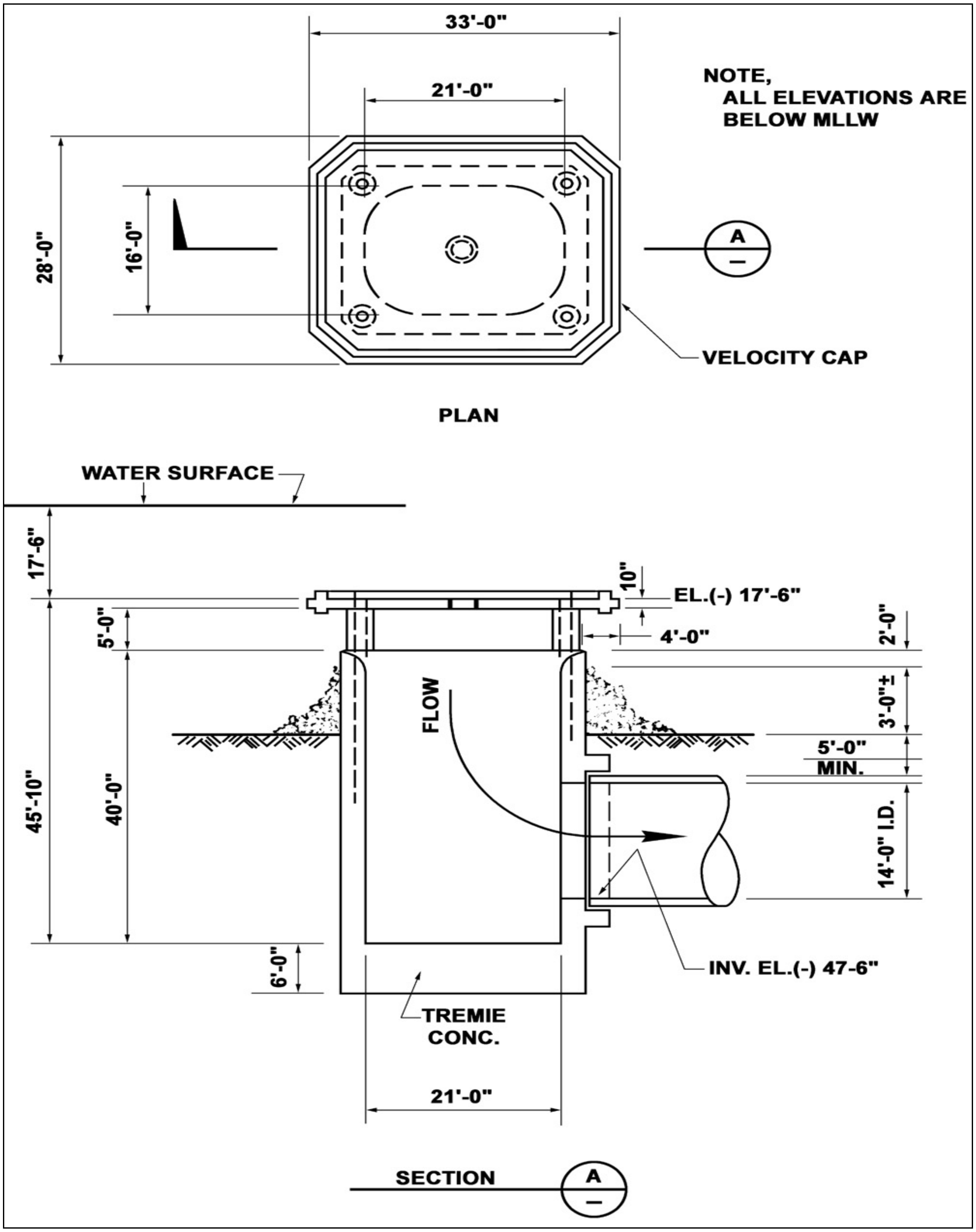


Figure 3-2. Schematic of the HBGS cooling water intake structure: velocity cap (top) and intake profile (bottom).

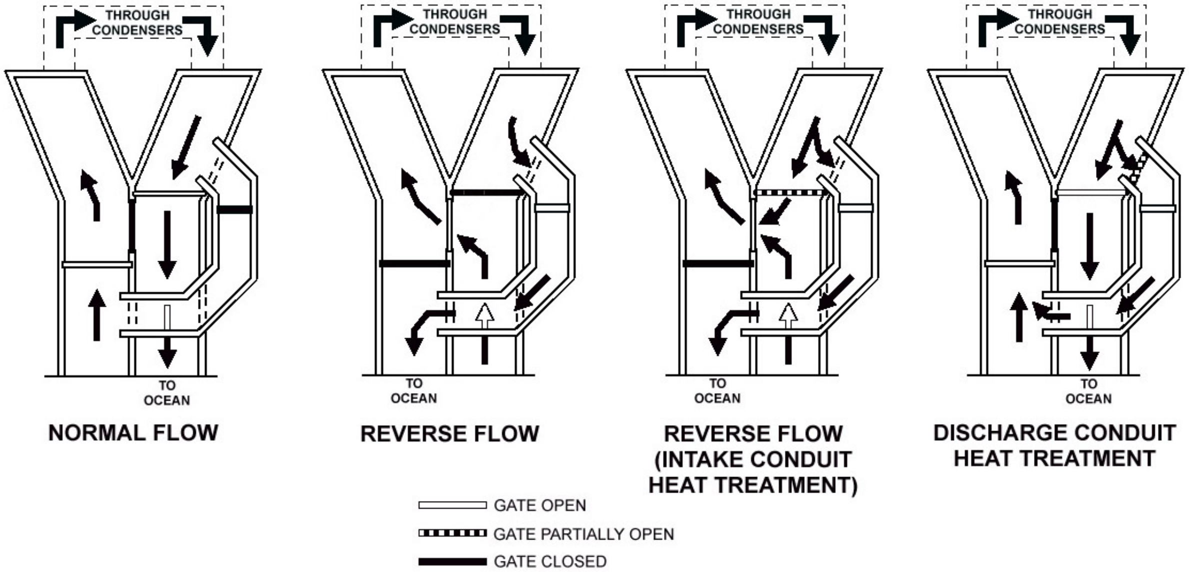


Figure 3-3. Cooling water flow regimes at the HBGS.

3.2.1 Circulating Water Pump Flows

Daily cooling water flow volumes at the HBGS from July 2003 through December 2005 are depicted in Figure 3-4. There is almost always at least one cooling water pump in operation at the HBGS. Highest flows generally occur in summer and fall, with decreased flows in winter and spring. Cooling flow averaged 366.0 mgd from July through December 2003, 362.8 mgd in 2004 and 322.9 mgd in 2005.

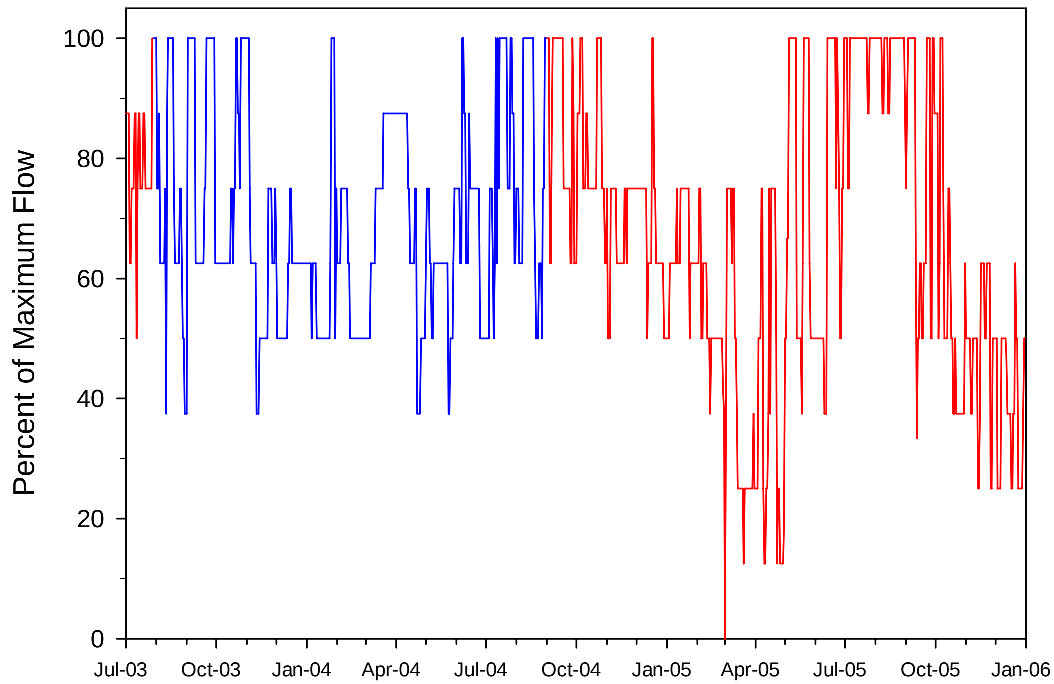


Figure 3-4. Daily cooling water flow volumes at the HBGS, 2004-5. (Blue line indicates 2003-4 study period (Maximum flow = 507 mgd).

3.3 ENVIRONMENTAL SETTING

The following section describes the physical and biological environments in the vicinity of the HBGS.

3.3.1 Physical Description

The physical and biological characteristics of the subtidal environment off Huntington Beach have been studied extensively by the Huntington Beach Generating Station operators (SCE and AES Huntington Beach L.L.C.) and by the Orange County Sanitation District (OCSD), which discharges primary- and secondary-treated wastewater from a diffuser outfall about four nautical miles offshore the generating station in about 60 m (197 ft) of water. Studies performed for the generating station have examined the physical and biological characteristics of the nearshore zone (depths to about 10 m [33 ft]), while studies performed by OCSD have been focused in deeper waters around the wastewater outfall.

The coastline of Huntington Beach runs, in general, from west-northwest to east-southeast. The continental shelf offshore the generating station is gently sloping; the 30-m (98 ft) isobath is nearly 6.4 km (4 mile) from shore. Subtidal sediments are predominantly sand, with lesser amounts of silt and clay (OCSD 2000, 2003a). Off Huntington Beach, grain size generally decreases with depth, grain size generally increases upcoast from the OCSD wastewater outfall, and the Newport and San Gabriel Submarine Canyons (downcoast and upcoast of the generating station, respectively) are depositional areas. The nearest stand of giant kelp (*Macrocystis pyrifera*) is located inside the Newport Harbor entrance jetty 11.0 km (6.8 mile) downcoast.

3.3.1.1 Huntington State Beach

The Huntington Beach Generating Station is located just across Pacific Coast Highway (inland) from the Huntington State Beach, and the intake and discharge structures for the generating station are just offshore the state beach. The state beach is a little over two miles in length, extending north from the Santa Ana River mouth past the generating station to Beach Boulevard. At Beach Boulevard, the state beach borders the Huntington City Beach. Over 11 million people visit the beaches of Huntington Beach annually.

3.3.1.2 Santa Ana River and Talbert Marsh

The mouth of the Santa Ana River is approximately 2.4 km (1.5 mile) downcoast from the generating station. The Santa Ana River is the largest river system in southern California, with a watershed of about 634,550 hectare (2,450 mi^2). Flow volume in the river is intermittent, and is partially dependent on the amount of precipitation in the watershed. Diversion and storage of water behind dams during winter and subsequent slow release during summer result in continual flow in some stretches of the river that would be dry otherwise (MBC 2000). In addition, there is year-round input from dischargers, including wastewater treatment facilities. Talbert Marsh is a recently restored salt marsh located just west of the Santa Ana River mouth. The marsh, which was previously isolated from tidal exchange, was restored in the late 1980s, and is connected to the ocean through a 30-m (98 ft) wide entrance channel adjacent to the river mouth. Both the Santa Ana River and Talbert Marsh are sources of fecal indicator bacteria (fecal coliform and enterococcus) during ebb tides, and these bacteria are transported parallel to shoreline resulting in frequent beach postings in the vicinity of the generating station (Kim et al. 2004).

3.3.2 Biological Resources

The following section describes the aquatic biological communities in the vicinity of the HBGS, including both invertebrate and fish communities.

3.3.2.1 Invertebrate Communities

Infaunal organisms off Huntington Beach were studied annually from 1975 through 1993 (MBC 1993). In the 19 years of sampling, an average of 43 individuals representing 17 species was collected per liter of sediment. Dominant species included the polychaetes *Apoprionospio pygmaea* and *Goniada littorea*, the amphipod *Rhepoxynius menziesi*, the cumacean *Diastylopsis tenuis*, and the gastropod *Olivella baetica*. These species are common in the sandy nearshore environments of southern California (Morris et al. 1980).

Diver surveys at four to six locations offshore the generating station were conducted annually from 1975 through 2001 (MBC 2001). On average, divers observed 34 benthic macrofaunal species per year during the surveys, though interannual variation was high, ranging from 22 species in 1975 to 55 species in 1984. Average density of organisms recorded by divers was 61 individuals per m^2, with values ranging from 12 individuals per m^2 (1976 and 1977) to 161 individuals per m^2 (1989). In 2001, biologist-divers recorded 25 species at an average density of 51 individuals per m^2. Polychaete worms were numerically dominant in 2001, comprising 79% of the total abundance, followed by arthropods with 13%. A single species, the onuphid polychaete *Diopatra splendidissim*a, accounted for 75% of the abundance. This species provides stability to the sediments and enhances the diversity of the bottom community by providing habitat for macrofaunal inhabitants of the shallow sandy subtidal. The density of many other macrofaunal species is intimately tied to that of *Diopatra* as it effectively acts as a biological artificial reef on an otherwise featureless sandy bottom. *Diopatra* tubes are colonized by larval organisms that require stable substrate for attachment, such as slippersnails, kelp scallops, barnacles, hydroids, bryozoans, and tube-building amphipods. Small, unidentified spider crabs (Majidae) comprised 9% of the abundance in 2001, followed by the slippersnail *Crepidula adunca* (4%), Maldanid worms (3%), barnacles in the genus *Balanus* (3%), and brittlestars (Ophiuroidea; 2%).

A total of 10 epibenthic macroinvertebrate species was collected during the 2001 trawl surveys offshore the generating station (MBC 2001). The most abundant species was the spiny sand star *Astropecten armatus*, comprising 34% of trawl-caught abundance. Other abundant trawl-caught invertebrates included the penicillate jellyfish (*Polyorchis penicillatus*; 24%), tuberculate pear crab (*Pyromaia tuberculata*; 18%), blackspotted bay shrimp (*Crangon nigromaculata*; 14%), and Pacific sand dollar (*Dendraster excentricus*; 5%).

A total of 30 macroinvertebrate species was collected in the 2002 fish impingement surveys at the generating station (MBC 2003a). The dominant species were the opalescent nudibranch (*Hermissenda crassicornis*), yellow rock crab (*Cancer anthonyi*), frond-aeolis (*Dendronotus frondosus*), tuberculate pear crab, and Pacific rock crab (*Cancer antennarius*). From 1994 through 2002, other abundant species impinged at the generating station were giant frond-aeolis (*Dendronotus iris*), penicillate jellyfish, red rock shrimp (*Lysmata californica*), common salp (*Thetys vagina*), California aglaja (*Navanax inermis*), and graceful rock crab (*Cancer gracilis*).

The intertidal community adjacent to the generating station was studied quarterly in 1971 and 1972 (EQA/MBC 1973). The major components of the intertidal community were the polychaetes *Hemipodus borealis*, *Nephtys californiensis*, and *Nerinides acuta*, the sand crab *Emerita analoga*, the Pismo clam *Tivela stultorum*, and the bean clam *Donax gouldii*. Species richness and densities of these species were lower than those recorded at similar sites in southern California. It was concluded that several factors, potentially including wave action and disturbance from beach-goers, limited the population.

3.3.2.2 Fish Communities

Demersal fish surveys were conducted off the HBGS annually since 1976 (MBC 2001). Six to twelve trawls were performed at stations directly offshore the generating station, and 1.6 km (1 mile) upcoast and downcoast from the generating station. At least 64 species of fishes have been collected in the trawl surveys. The catch was numerically dominated by northern anchovy (*Engraulis mordax*; 50%), white croaker (*Genyonemus lineatus*; 27%), and queenfish (*Seriphus politus*; 18%). Combined, these three species accounted for more than 95% of the trawl-caught fish abundance.

Other historically abundant species include surfperches, such as white seaperch (*Phanerodon furcatus*), walleye surfperch (*Hyperprosopon argenteum*), barred surfperch (*Amphistichus argenteus*), and shiner perch (*Cymatogaster aggregata*), and flatfishes such as California halibut (*Paralichthys californicus*) and speckled sanddab (*Citharichthys stigmaeus*). Numbers of several surfperches collected by trawl and in fish impingement surveys declined by more than 90% between 1979 and 1984, and abundances have remained relatively low since then. This coincided with a warming of ocean waters in southern California (Beck and Herbinson 2003), as well as a decrease in upwelling (Allen et al. 2003). Numbers of California halibut collected by trawl declined in 1994 when sampling effort was halved.

In-plant fish impingement sampling has been conducted since the 1970s. From 1979 through 2002, queenfish was the dominant species in impingement samples, comprising 82 percent of the total abundance (MBC 2003a). Similar to trawl catches off the generating station, white croaker and northern anchovy were also abundant in impingement samples, accounting for 6% and 3% of the total abundance, respectively. Other abundant species were walleye surfperch, white seaperch, Pacific pompano (*Peprilus simillimus*), California grunion (*Leuresthes tenuis*), jacksmelt (*Atherinopsis californiensis*), shiner perch, and deepbody anchovy (*Anchoa compressa*). Similar to long-term trends observed in the trawl data, numbers of walleye surfperch, white seaperch, and Pacific pompano declined dramatically from 1979 through 1984. In 2002, the most abundant fish species impinged were queenfish (83%), white croaker (4%), shiner perch (2%), jacksmelt (2%), and deepbody anchovy (1%).

Two of California Department of Fish and Game's Catch Blocks are located directly offshore the HBGS: Blocks 738 and 739. Though ports of origin for most landings are reported from San Pedro, Terminal Island, and Newport Beach, some are reported from as far away as San Diego and San Francisco. From 1999 through 2001, three-year top commercial landings in Block 738 included Pacific sardine (*Sardinops sagax*; 10,841 metric tons), market squid (*Loligo opalescens*; 953 metric tons), Pacific mackerel (*Scomber japonicus*; 544 metric tons), northern anchovy (408 metric tons), California spiny lobster (*Panulirus interruptus*; 36 metric tons), and jack mackerel (*Trachurus symmetricus*; 27 metric tons) (CDFG 2002). The pelagic species (Pacific sardine, market squid, Pacific mackerel, northern anchovy, and jack mackerel) were generally caught by purse seine, drum seine, and long-line, while California spiny lobster were collected by crab/lobster trap. Landings of Pacific sardine ranked first economically ($13.3 million from 1999-2001), followed by Pacific mackerel ($1.0 million), market squid ($0.5 million), and northern anchovy ($0.39 million). From 1975 to 1981, the annual commercial catch in Catch Block 738 was fairly stable, ranging from 590 to 1,179 metric tons, and then increased to over 3,175 metric tons in 1982 due to a large increase in northern anchovy landings. From 1983 to 1986, landings in Block 738 declined to 32 to 82 metric tons. From 1999 through 2001, landings in Block 738 ranged from 372 to 6,895 metric tons per year.

From 1999 through 2001, top commercial landings in Block 739 included Pacific sardine (19,187 metric tons), Pacific mackerel (2,585 metric tons), market squid (1,315 metric tons), northern anchovy (544 metric tons), jack mackerel (136 metric tons), and California halibut (68 metric tons). Jack mackerel were caught primarily by purse seine; Pacific sardine, market squid, and northern anchovy by purse seine and drum seine; Pacific mackerel by purse seine, set gillnet and set longline; and California halibut by gillnet and trawl. Economically important landings included Pacific sardine ($1.8 million), California halibut ($0.49 million), Pacific mackerel ($0.33 million), and market squid ($0.26 million).

A setline dory fishery off Newport Beach has existed since 1891, and is one of the few traditional dory fisheries remaining on the west coast. Fisherman use dories launched from the shores of Newport Beach to fish on the continental shelf and slope with setlines at depths of about 100 to 600 m (328 to 1,969 ft). In a yearlong study of the fishery in 1983 and 1984, most of the fishing was concentrated at slope depths of 380 to 580 m (1,247 to 1,903 ft) (Cross 1984). Some of the fishing areas frequented in that study were located about 10 km (6.2 mile) directly offshore the HBGS. Principal species landed in this localized fishery include sablefish (*Anoplopoma fimbria*), thornyhead (*Sebastolobus* spp.), and rockfishes (*Sebastes* spp.). While dory landings of these species pale in comparison to overall commercial landings, they represent a fishery that has changed little in over 110 years.

In 1987, seven species of fishes were collected by a variety of methods from the tidally influenced lower Santa Ana River, which is concrete-lined (Marsh 1992). Only two species were native: California killifish (*Fundulus parvipinnis*) and striped mullet (*Mugil cephalus*). The other five species were introduced, and included common carp (*Cyprinus carpio*), fathead minnow (*Pimephales promelas*), mosquitofish (*Gambusia affinis*), green sunfish (*Lepomis cyamellus*), and Mozambique tilapia (*Tilapia mossambica*). Of these seven species, only three were impinged at the HBGS from 1979 through 2002. Mozambique tilapia occurred in 11 of the last 24 years, but not after 1998 (MBC 2003a). The highest annual impingement for this species was 105 individuals in 1983. Eleven California killifish were impinged in 1995, and three striped mullet were impinged in 1979.

From 1989 through 1990 eleven species of fishes were collected by beach seine from Talbert Marsh (Gorman et al. 1990). California killifish, topsmelt (*Atherinops affinis*), Pacific staghorn sculpin (*Leptocottus armatus*), and arrow goby (*Clevelandia ios*) were the most abundant species. Fishes collected in small numbers (10 individuals or less) included shiner perch, white croaker, longjaw mudsucker (*Gillichthys mirabilis*), walleye surfperch, bay goby (*Lepidogobius lepidus*), California halibut, and bay pipefish (*Syngnathus leptorhynchus*).

4.0 COOLING WATER INTAKE STRUCTURE ENTRAINMENT AND SOURCE WATER STUDY

4.1 INTRODUCTION

The purpose of the entrainment study is to determine the extent of potential impacts from the operation of the cooling water system of the HBGS on larval fishes and selected invertebrate larvae (target species). Entrainment refers to the incorporation of aquatic organisms into the cooling water intake structure of the generating station. The entrainment study focuses on larval life stages, while the impingement study focuses on juvenile and adult forms. The entrainment sampling plan was designed to characterize the composition and abundance of those organisms both 1) entrained by the generating station, and 2) present in the source waters and potentially at risk of entrainment.

4.1.1 Species to be Analyzed

Several types of organisms are susceptible to entrainment by the generating station. The intent of this study is to estimate entrainment effects on two types of organisms: fish larvae and larvae of the following invertebrate species: rock crabs (*Cancer* spp.), market squid (*Loligo opalescens*), California spiny lobster (*Panulirus interruptus*), ridgeback rock shrimp (*Sicyonia ingentis*), and sand crab (*Emerita analoga*). Assessment of entrainment effects were limited to the most abundant fish taxa that together comprised 90% of all larvae entrained and/or juveniles and adults impinged by the generating station.

4.2 METHODS

The sampling plan and analysis techniques of the Entrainment and Impingement Study were developed by the Biological Resources Research Team (BRRT), which was formed by the California Energy Commission (CEC). The BRRT consisted of representatives of AES Huntington Beach L.L.C., MBC Applied Environmental Sciences, Tenera Environmental, California Energy Commission staff and consultants, Santa Ana Regional Water Quality Control Board, U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Game, and the California Coastal Commission. Members of the BRRT reviewed and commented on two drafts of the study plan, the first quarterly data report, and the Six-Month and Nine-Month Reports.

4.2.1 Field Sampling

4.2.1.1 Entrainment

To determine composition and abundance of ichthyoplankton entrained by the generating station, sampling in the immediate proximity of the cooling water intake was conducted twice monthly in September and October 2003, weekly from November 2003 through July 2004, and twice during August 2004. During each sampling event, two replicate tows at the entrainment station were collected four times per 24-hr period—once every six hours. Sampling cycles were initiated at approximately

1200 hr, 1800 hr, 2400 hr, and 0600 hr. The second and fourth cycles were initiated to correspond with sunset and sunrise, respectively.

Sampling was conducted offshore (within 100 m [328 ft]) of the submerged intake structure (Figure 4-1) using an oblique tow that sampled the water column from approximately 13 cm (5.12 in) off the bottom and then back to the surface. Two replicate tows were taken with a minimum target sample volume of 30 to 40 m^3 (1,059 to 1,413 ft^3) for each net on the bongo frame. The net was redeployed if the target volume was not collected during the initial tow.

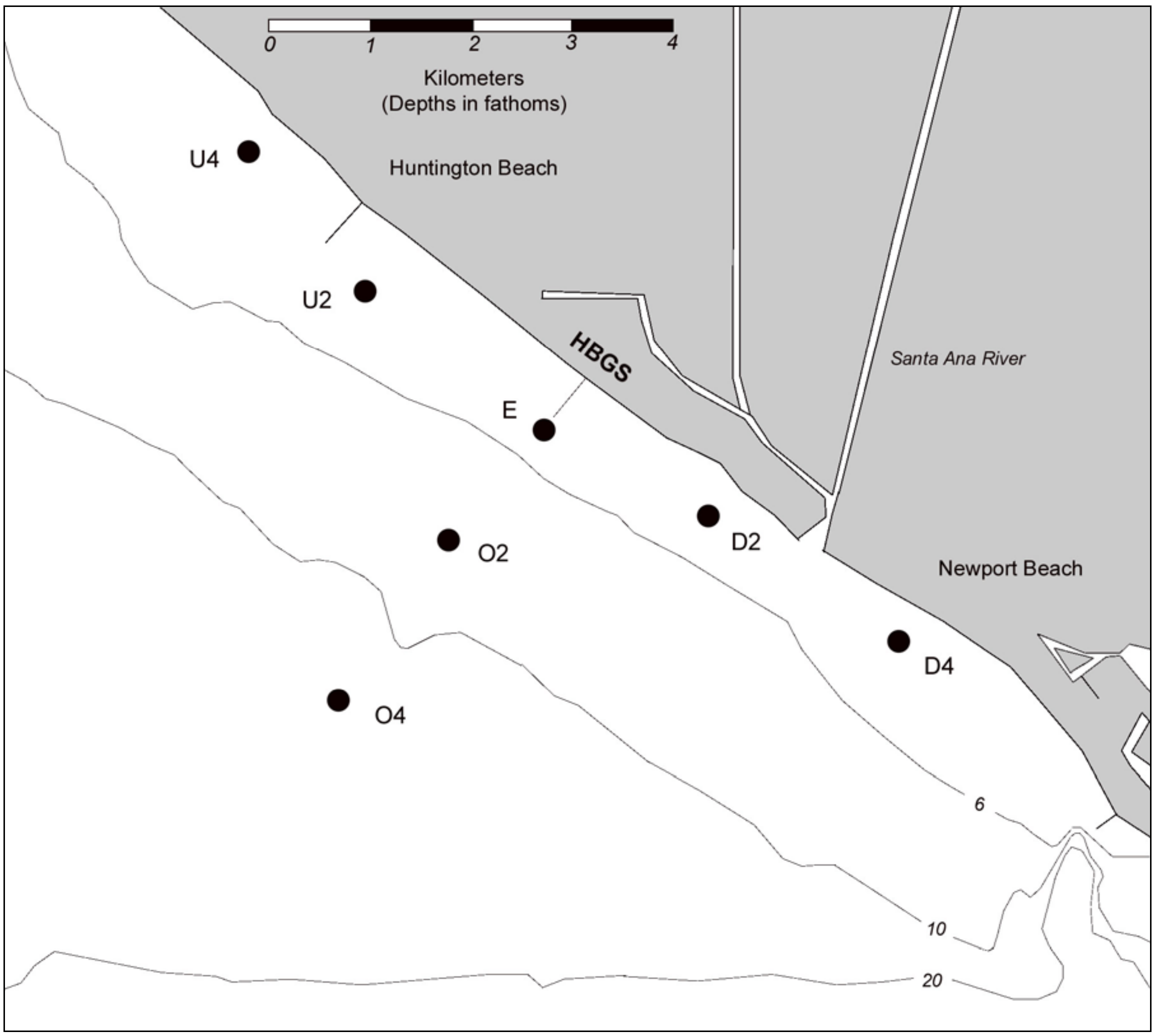


Figure 4-1. Location of entrainment (E) and source water sampling stations (U4, U2, D2, D4, O2, and O4), where U, D, and O designate stations upcoast, downcoast, and offshore of the intake, respectively. Also shown are the 6-fathom (11-m), 10-fathom (18-m), and 20-fathom (36-m) isobaths.

The wheeled bongo frame was fitted with 60-cm (23.6 in) diameter net rings with plankton nets constructed of 333-µm Nitex® nylon mesh, similar to the nets used by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). Each net was fitted with a Dacron sleeve and a cod-end container to retain the organisms. Each net was equipped with a calibrated General Oceanics® flowmeter, allowing the calculation of the amount of water filtered. At the end of each tow, nets were retrieved and the contents of the net gently rinsed into the cod-end with seawater. Contents were washed down from the outside of the net to avoid the introduction of plankton from the wash-down water. Samples were then carefully transferred to prelabeled jars with preprinted internal labels. Samples from one of the two nets were preserved in 4% buffered formalin-seawater, while contents of the other net were preserved in 70 to 80% ethanol. The larvae preserved in the ethanol would be available for genetic and/or otolith analysis, if required. Genetic analyses have been performed in recent studies in attempts to validate the identity of certain species.

4.2.1.2 Source Water Sampling

To determine composition and abundance of ichthyoplankton in the HBGS source water, sampling was conducted monthly in September and October 2003, twice per month from November 2003 through July 2004 (during the peak spawning period for fishes in late winter and spring), and once in August 2004.

Besides the entrainment station, source water sampling occurred at six additional source water stations located upcoast, downcoast, and offshore from the intake structure (Figure 4-1). Two source water stations were located 2 km (1.2 mile) and 4 km (2.5 mile) upcoast (U2 and U4) and downcoast (D2 and D4) from the intake on the intake isobath, and two stations were located approximately 1.5 km (0.9 mile) and 3 km (1.9 mile) offshore (O2 and O4) from the intake structure. Water depth at the upcoast and downcoast stations is similar to the depth at the intake (9.5 m [31.2 ft]) while the depth at the two offshore stations is approximately 14 m (45.9 ft) and 22 m (72.2 ft). Tows were performed in the same manner as the entrainment tows (obliquely). The sampling grid is similar in design to that used during the study of cooling water system effects at the San Onofre Nuclear Generating Station (Barnett et al. 1983).

All stations were sampled with a wheeled bongo using the same oblique tow technique described for the entrainment sampling. During each source water survey, the additional six source water stations (plus the entrainment station) were sampled four times per 24-hr period—once every six hours. Two replicates were collected at each station during each of the four sampling periods. During sampling at the seven stations (six source water plus one entrainment), the entrainment station was always bracketed by the source water station sampling.

Conductivity, temperature, and depth (CTD) profiles were collected at both entrainment and source water stations during most surveys, beginning with the second survey in September 2003 and ending August 2004. The purpose of these profiles was to determine if any oceanographic features, such as influxes of brackish or fresh water from nearby marshes, were related to the distribution of larval fishes in the study area.

4.2.2 Laboratory Analysis

Ichthyoplankton samples were returned to the laboratory, and after approximately 72 hours the samples preserved in 4% buffered formalin-seawater were transferred to 70–80% ethanol before processing. One net from each replicate was processed from the entrainment surveys. Only the samples initially preserved in formalin from the first of the two bimonthly source water surveys (November through July) were processed. Samples were examined under dissecting microscopes and fish larvae and targeted invertebrate larvae were separated from debris and other zooplankton. Larvae were identified to the lowest practical taxonomic level (species for most larvae) and enumerated. Fish eggs were not sorted or identified, as their taxonomy remains difficult and time-consuming.

Myomere counts and pigmentation patterns were used to identify the larval fishes; however this was problematic for some species. Some larval fishes could not be identified to the species level using microscopic techniques and were recorded at the lowest taxonomic classification possible (e.g., genus or family level). For example, many species of the family Gobiidae share morphologic and meristic characters during early life stages (Moser 1996) making identifications to the species level difficult. Larvae of the arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) are difficult to identify to species when they are newly hatched. Therefore, these three species were combined into an “unidentified goby” category referred to as the “CIQ goby complex”.

Larval combtooth blennies (*Hypsoblennius* spp.) can be easily distinguished from other larval fishes (Moser et al. 1996). However, the three sympatric species that could occur in the area cannot be distinguished from each other on the basis of morphometrics or meristics at the smaller sizes common in the samples. Therefore, the combtooth blennies were grouped into an “unidentified combtooth blennies” category (e.g., *Hypsoblennius* spp.).

A number of larvae from the Family Sciaenidae (croakers) were collected during the study. The larvae in this family are recognized by their relatively large, somewhat bulbous head, compact coiled gut and relatively slender, tapering tail. Pigmentation ranges from light (e.g., white croaker) to heavy (e.g., white seabass *Atractoscion nobilis*) (Moser 1996). A great majority of yolk-sac stage larvae collected during the summer surveys belonged to the family Sciaenidae. Identification to the species level for these early developmental stages is very difficult because some of the species (e.g., queenfish and spotfin croaker *Roncador stearnsii*) have similar initial pigmentation patterns along the dorsal margin, migrating down as the larvae develop. White seabass, black croaker *Cheilotrema saturnum*, California corbina *Menticirrhus undulatus*, and yellowfin croaker *Umbrina roncador* have moderate to heavy pigmentation for this developmental stage allowing them to be separated from other species of sciaenids. The white croaker has a distinct pigmentation pattern that allows it to be separated from other sciaenids. Despite these difficulties in identifying the yolk-sac stages of this family, unidentified yolk-sac sciaenid larvae accounted for only 12% of the total sciaenid larvae collected from the entrainment station. Therefore, the individual species were not combined into a single group for analysis because of the difficulty in interpreting the results for a taxonomic grouping that includes both commercial and non-commercial species with varying life histories. In addition, the primary method of assessment, the

Empirical Transport Model, uses an estimate of plant-induced mortality that would not be affected by small changes in the estimates from the entrainment and source water sampling as long as the proportion between the two estimates didn't change.

The lengths (notochord/standard lengths) of larvae collected from the entrainment station were measured to estimate the age of the entrained larvae. A representative number of individual larvae of each of the most abundant taxa, or species with recreational or commercial fishery importance, collected during each survey, were measured using a video capture system and Optimus™ image analysis software. The average length calculated from these measurements was used to estimate the average age of the larvae by dividing the difference between the average and minimum lengths by a larval growth rate (mm/d) obtained from the scientific literature for the species or a closely related species. The 1st percentile value was used as the minimum length to account for outliers in the measurements. The difference between the 1st and 95th percentile values was used to estimate the maximum period of time that the larvae would be exposed to entrainment.

4.2.3 Data Analysis

The following sections describe how the collected data were processed and analyzed.

4.2.3.1 Entrainment Estimates

Entrainment estimates were derived using larval concentrations from field samples and maximum cooling water flow volume at the HBGS. The precursor to the *AEL* and *FH* calculations is an estimate of total annual larval entrainment. Estimates of larval entrainment at HBGS were based on weekly sampling where E_T is the estimate of total entrainment for the study period and E_i is the weekly entrainment estimate. Estimates of entrainment for the study period are based on two-stage sampling designs, with days within periods and cycles (four six-hour collection periods per day) within days. The within-day sampling is based on a stratified random sampling scheme with four temporal cycles and two replicates per cycle.

4.2.3.2 Entrainment Impact Assessment

Estimates of daily larval entrainment for the sampling period from September 2003 through August 2004 at HBGS were calculated from data collected at the entrainment station. Assessment of entrainment effects were limited to the most abundant fish taxa (target taxa) that together comprised 90% of all larvae entrained and/or juveniles and adults impinged by the generating station. Estimates of entrainment loss, in conjunction with demographic data collected from the fisheries literature, were used in modeling entrainment effects on target taxa using adult equivalent loss (*AEL*) and fecundity hindcasting (*FH*). Data for the same target taxa from sampling of the entrained larvae and potential source populations of larvae was used to calculate estimates of proportional entrainment (*PE*) and used to estimate the probability of mortality (P_m) due to entrainment using the Empirical Transport Model (*ETM*). In the HBGS entrainment and impingement studies each approach (e.g., *AEL*, *FH*, and *ETM*), as appropriate for each target taxon, was used to assess effects of power plant losses.

4.2.3.2.1 Demographic Models

Adult equivalent loss models evolved from impact assessments that compared power plant losses to commercial fisheries harvests and/or estimates of the abundance of adults. In the case of adult fishes impinged by intake screens, the comparison was relatively straightforward. To compare the numbers of impinged sub-adults and juveniles and entrained larval fishes to adults, it was necessary to convert all these losses to adult equivalents. Horst (1975) provided an early example of the equivalent adult model (*EAM*) to convert numbers of entrained early life stages of fishes to their hypothetical adult equivalency. Goodyear (1978) extended the method to include the extrapolation of impinged juvenile losses to equivalent adults.

Demographic approaches, exemplified by the *EAM*, produce an absolute measure of loss beginning with simple numerical inventories of entrained or impinged individuals and increasing in complexity when the inventory results are extrapolated to estimate numbers of adult fishes or biomass. We used two different but related demographic approaches in assessing entrainment effects at the HBGS: *AEL*, which expresses effects as absolute losses of numbers of adults, and *FH*, which estimates the number of adult females whose reproductive output has been eliminated by entrainment of larvae. Both approaches require an estimate of the age at entrainment. These estimates were obtained by measuring a representative number of larvae of each of the target taxa from the entrainment samples and using published larval growth rates to estimate the age at entrainment. The age at entrainment was calculated by dividing the difference between the size at hatching and the average size of the larvae from entrainment by the growth rate obtained from the literature.

Age-specific survival and fecundity rates are required for *AEL* and *FH*. Adult-equivalent loss estimates require survivorship estimates from the age at entrainment to adult recruitment; *FH* requires egg and larval survivorship up to the age of entrainment plus estimates of fecundity. Furthermore, to make estimation practical, the affected population is assumed to be stable and stationary, and age-specific survival and fecundity rates are assumed to be constant over time. Each of these approaches provides estimates of adult fish losses, which ideally need to be compared to standing stock estimates of adult fishes.

Species-specific survivorship information (e.g., age-specific mortality) from egg or larvae to adulthood is limited for many of the taxa considered in this assessment. These rates when available are inferred from the literature along with estimates of uncertainty. Uncertainty surrounding published demographic parameters is seldom known and rarely reported, but the likelihood that it is very large needs to be considered when interpreting results from the demographic approaches for estimating entrainment effects. For some well-studied species (e.g., northern anchovy), portions of early mortality schedules and fecundity have been reported. Because the accuracy of the estimated entrainment effects from *AEL* and *FH* will depend on the accuracy of age-specific mortality and fecundity estimates, lack of demographic information may limit the utility of these approaches.

There were usually no estimates of variation available for the life history information used in the models. The ratio of the mean to standard deviation (coefficient of variation) was assumed to be 50% for all life history parameters used in the models.

4.2.3.2.1.1 Adult Equivalent Loss (AEL)

The *AEL* approach uses estimates of the abundance of the entrained or impinged organisms to project the loss of equivalent numbers of adults based on mortality schedules and age-at-recruitment. The primary advantage of this approach is that it translates power plant-induced early life-stage mortality into numbers of adult fishes that are familiar units to resource managers. Adult equivalent loss does not require source water estimates of larval abundance in assessing effects. This latter advantage may be offset by the need to gather age-specific mortality rates to predict adult losses and the need for information on the adult population of interest for estimating population-level effects (i.e., fractional losses).

Starting with the number of age class *j* larvae entrained E_j, it is conceptually easy to convert these numbers to an equivalent number of adults lost (*AEL*) at some specified age class from the formula:

$$\widehat{AEL} = \sum_{j=1}^{n} \widehat{E}_j S_j \qquad (1)$$

where

n = number of age classes from the average age at entrainment to adult recruitment;

E_j = estimated number of larvae lost in age class j; and

S_j = survival probability for the j th class to adulthood (Goodyear 1978).

Age-specific survival rates from the average age at entrainment to recruitment into the fishery must be included in this assessment method. The average age at entrainment was estimated from lengths of a representative sample of larvae measured from the entrainment samples (Section 4.2.2). For some commercial species, natural survival rates are known after the fish recruit into the commercial fishery. For the earlier years of development, this information is not well known for commercial species and may not exist for some non-commercial species.

An alternative expression of adult-equivalent loss would be to standardize *AEL* by the size of the adult population of interest to estimate the relative magnitude of the equivalent adult loss such that,

$$\widehat{RAEL} = \frac{\widehat{AEL}}{\widehat{P}}, \qquad (2)$$

where *P* = estimated size of the adult population of interest. Information on adult source populations will be limited for many species and thereby limit the utility of Equation (2), although the same approach will be used to place the estimated losses into context for taxa with published commercial or recreational fishery catch data.

4.2.3.2.1.2 Fecundity Hindcasting (FH)

The *FH* approach compares larval entrainment losses with adult fecundity to estimate the amount of adult female reproductive output eliminated by entrainment, hindcasting the numbers of adult females effectively removed from the reproductively active population. The accuracy of these estimates of effects, as with those of the *AEL* above, is dependent upon accurate estimates of age-specific mortality from the egg and early larval stages to entrainment and accurate estimates of the total lifetime female fecundity. If it can be assumed that the adult population has been stable at some current level of exploitation and that the male:female ratio is constant and 50:50, then fecundity and mortality are integrated into an estimate of adult loss by converting entrained larvae back into females (e.g., hindcasting) and multiplying by two.

A potential advantage of *FH* is that survivorship need only be estimated for a relatively short period of the larval stage (e.g., egg to larval entrainment). The method requires age-specific mortality rates and fecundities to estimate entrainment effects and some knowledge of the abundance of adults to assess the fractional losses these effects represent. This method assumes that the loss of a single female's reproductive potential is equivalent to the loss of two adult fish, assuming a 50:50 male:female ratio.

In the *FH* approach, the total larval entrainment for a species, E_T, was projected backward from the average age at entrainment to estimate the number of breeding females required to provide the numbers of larvae seen in the entrainment samples. The estimated number of breeding females *FH* whose fecundity is equal to the total loss of entrained larvae was calculated as follows:

$$\widehat{FH} = \frac{\widehat{E_T}}{\widehat{TLF} \bullet \prod_{j=1}^{n} S_j} \qquad (3)$$

where

E_T = total entrainment estimate;

S_j = survival rate from eggs to entrained larvae of the j th stage ;

TLF = average total lifetime fecundity for females, equivalent to the average number of eggs spawned per female over their reproductive years.

The two key input parameters in Equation (3) are total lifetime fecundity *TLF* and survival rates S_j from spawning to the average age at entrainment. The average age at entrainment was estimated from lengths of a representative sample of larvae measured from the entrainment samples (Section 4.2.2). Descriptions of these parameters may be limited for many species and are a possible limitation of the method. *TLF* is approximated using the "average" age for the females using the following formula:

$$\begin{aligned}\widehat{TLF} &= \text{Average eggs/year} \times \text{Average number of years of reproductive life} \\ &= \text{Average eggs/year} \cdot \left(\frac{\text{Longevity - Age at maturation}}{2} \right).\end{aligned}$$

An alternative interpretation of *FH* is possible by expressing the estimate in terms of the relative size of the adult fish stock in the source populations where

$$\widehat{RFH} = \frac{\widehat{FH}}{\widehat{P}}, \qquad (4)$$

where *P* = estimated size of the adult population of interest. Information on adult source populations will be limited for many species and thereby limit the utility of Equation (4), although the same approach can be used to place the estimated losses into context for taxa with published commercial or recreational fishery catch data where *RFH* is the proportion of the breeding females whose fecundity was lost due to entrainment by the HBGS.

4.2.3.2.2 Empirical Transport Model (*ETM*)

The *ETM* calculations provide an estimate of the probability of mortality due to power plant entrainment. The calculations require not only the abundance of larvae entrained but also the abundance of the larval populations at risk of entrainment. Sampling at the cooling water intake is used to estimate the total number of larvae entrained for a given time period, while sampling in the coastal waters around the HBGS intake is used to estimate the source population for the same period.

On any one sampling day, the conditional entrainment mortality can be expressed as

$$PE_i = \frac{\widehat{E_i}}{\widehat{N_i}} \qquad (5)$$

where

E_i = total numbers of larvae entrained during the i th survey; and

N_i = numbers of larvae at risk of entrainment, i.e., abundance of larvae in source water.

The values used in calculating *PE* are population estimates based on the respective larval concentrations and volumes of the cooling water system flow and source water areas. The abundance of larvae at risk in the source water during the i^{th} survey can be directly expressed as

$$\widehat{N_i} = \sum_{k=1}^{9} V_{S_k} \cdot \widehat{\overline{\rho}_{ik}} \tag{6}$$

where V_{S_k} denotes the static volume of the source water at station *k*, and $\widehat{\overline{\rho}}_{ik}$ denotes an estimate of the average larval concentration in the source water for station *k* during survey *i*. The number of source water stations include seven sampled stations (E, D1, D2, U1, U2, O1, and O2) and two areas (I1 and I2) where the concentrations were interpolated using an inverse distance weighted average of the concentrations at the other stations (Figure 3-2). This was done to allow for a rectangular shaped source water area that could be extrapolated using alongshore current displacement, otherwise the layout of the sampling locations would have required separate source water estimates for the offshore (O1 and O2) and alongshore station areas (E, D1, D2, U1, and U2).

Regardless of whether the species has a single spawning period per year or multiple overlapping spawnings the estimate of total larval entrainment mortality can be expressed by

$$\widehat{P_M} = 1 - \sum_{i=1}^{N} \widehat{f}_i \left(1 - \widehat{PE_i} \bullet P_S\right)^q \tag{7}$$

where

q = number of days the larvae are exposed to entrainment,

P_S = the proportion of the sampled source water population to the total source water population vulnerable to entrainment, and

f_i = estimated fraction of total larval population present during the i th survey.

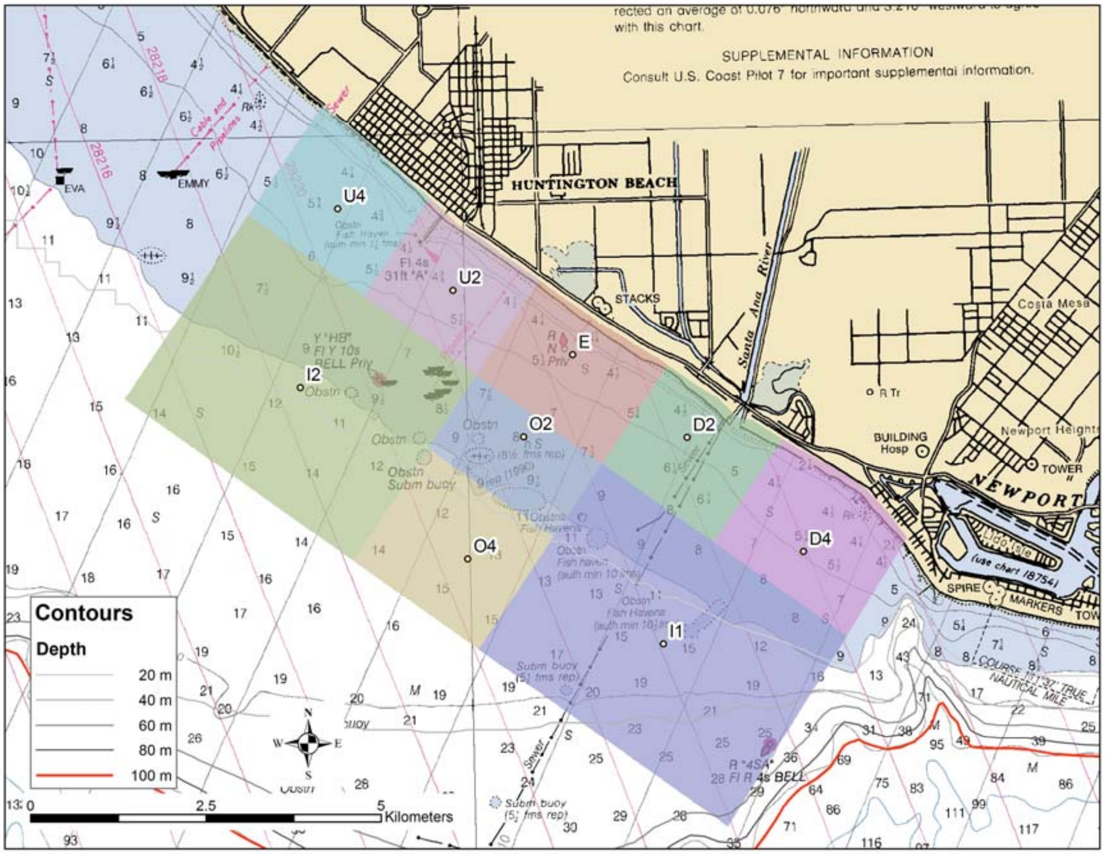


Figure 4-2. Bathymetry and areas used in calculating sampling volumes for each station used in calculating source water for ETM calculations. Station E is located near the intake where the entrainment samples were collected. Source water stations U4, U2, D2, D4, O2, and O4 designate stations upcoast (U), downcoast (D), and offshore (O) of the intake, respectively. Concentrations in areas I1 and I2 were interpolated using an inverse distance-weighted average from the concentrations collected at the other stations.

To establish independent survey estimates, it is assumed that during each survey a new and distinct cohort of larvae is subject to entrainment. The number of days a taxon was exposed to entrainment was estimated by dividing a larval growth rate into the difference between the 1st and 95th percentile values of length measurements from the entrainment samples (Section 4.2.2). Each of the monthly surveys is weighted by f_i and estimated as the proportion of the total population at risk during the i^{th} survey period. In the original study plan we proposed to use the proportion of the larvae entrained during each i^{th} survey period as the weights for the *ETM* model. The weights were proposed to be calculated as follows:

$$f_i = \frac{E_i}{E_{Total}}, \tag{8}$$

where E_i is the estimated entrainment during the i^{th} survey period, and E_{Total} is the estimated entrainment for the entire study period. Equation 8 conflicts with Equation 5 for *PE* that uses the population in the source water during the i^{th} survey period to define the population at risk. The weights calculated using Equation 8 redefine the population at risk as the population entrained and represent a logical inconsistency in the model as presented in the study plan. If the weights are meant to represent the proportion of the population at risk during each survey then the weights should be calculated as follows:

$$f_i = \frac{N_i}{N_{Total}}, \tag{9}$$

where N_i is the estimated fraction of the source population spawned during the i^{th} survey period, and N_{Total} is the total source population for the entire study period.

As shown in Equations 5 and 6 the estimates of *PE* are based on larval population estimates within specific volumes of water. While a reasonably accurate estimate of the volume of the cooling water intake flow can be obtained, estimating the volume of the source water is more difficult and will vary depending upon oceanographic conditions and taxa group. Estimates of P_M were calculated using two estimates for P_S, the proportion of the sampled source water population to the total source population. One estimate was based on alongshore and onshore current displacement while the other used only alongshore current displacement. The current displacement was calculated over the period of time that the larvae were estimated to be exposed to entrainment. This period of time was estimated using length data from a representative number of larvae (100-200) from the entrainment samples for each target taxon. The maximum age was calculated as the upper 95th percentile value of the lengths measured from the samples. The maximum age at entrainment was calculated by dividing the difference between the upper 95th percentile values of the lengths and the lower 1st percentile value of the lengths by an estimated larval growth rate.

The incorporation of P_S into the *ETM* model is typically defined as the ratio of the area or volume of the study grid to a larger area or volume containing the population of inference (Parker and DeMartini 1989). If an estimate of the larval (or adult) population in the larger area is available, it can also be computed using the estimate of the larval or adult population in the study grid, defined by Ricker (1975) as the proportion of the parental stock. If the distribution in the larger area is assumed to be uniform, then the value of P_S for the proportion of the population will be the same as the proportion computed using area or volume. For target taxa whose larval distribution extends to the offshore edge of the study grid, P_S will be calculated as the ratio:

$$P_S = N_G / N_P \ , \qquad (10)$$

where N_G is the number of larvae in the study grid, and N_P is the number of larvae in the population of inference. The numerator N_G is the same as estimate, S_i (Equation 5), used in the calculation of *PE*, i.e.

$$\widehat{N_{G_i}} = \sum_{k=1}^{9} A_{G_k} \cdot \bar{D}_k \cdot \rho_{\mathrm{i,k}} \ , \qquad (11)$$

where

A_{G_k} = area of source water sampling area station k,

$\bar{D}_k$ = average depth of the *k* th station, and

$\rho_{\mathrm{i,k}}$ = concentration (per m^3) of larvae in *k*th station during survey *i*.

N_P was estimated by offshore and alongshore extrapolation of the study grid concentrations, using water current measurements. First, a conceptual model was formulated to extrapolate larval concentrations (per m^3) offshore of the grid:

$$\widehat{P_S} = \frac{\widehat{N_G}}{\widehat{N_P}} = \frac{\sum_{k=1}^{9} L_{G_k} \cdot W_k \cdot \bar{D}_k \cdot \widehat{\rho_k}}{\sum_{k=1}^{K\max} L_{Pk} \cdot W_k \cdot \bar{D}_k \cdot \widehat{\rho_k}} \ , \qquad (12)$$

where

L_{G_k} = alongshore length of source water sampling area station *k*,

W_k = average width of the *k* th station,

$\bar{D}_k$ = average depth of the *k* th station,

$\widehat{\rho_k}$ = estimated average concentration (per m^3) of larvae in *k* th station,

Kmax = index of offshore extent, based on current data

and

L_{P_k} = alongshore length of the population based on current data,

The denominator in Equation 12 includes an extrapolation offshore that is a discrete version of a conceptually continuous function. Therefore, to ease implementation, an essentially equivalent formulation that incorporates the use of the sampling station concentrations for stations E, O2, and O4 during the i^{th} survey and integrates a linear extrapolation of density (per m^2) calculated by multiplying the density by the station depth as a function of offshore distance:

$$\widehat{P_{S_i}} = \frac{\widehat{N_{G_i}}}{\widehat{N_{P_i}}} = \frac{\widehat{N_{G_i}}}{\sum_{k=1}^{7} \frac{L_{P_i} \cdot \widehat{N_{G_{ik}}}}{L_{G_{ik}}} + L_{P_i} \cdot \int_{W_O}^{W_{max}} \rho(w)\,dw}, \qquad (13)$$

where

L_{P_i} = alongshore length of the population (P) in the i th study period based on current data,

$\rho(w)$ = density of larvae (per m^2) as a linear function of w, distance offshore, and

W_{max}, W_O = limits of integration for extrapolation outside study grid.

The limits of the integration are from the offshore margin of Station O4 to a point estimated by the onshore movement of currents, where the extrapolated density is zero, or to the edge of the shelf at a depth of 75 m (246 ft) (distance of 8,500 m [27,887 ft]). Note that the population number, N_P, is composed of two components that represent the alongshore extrapolation of the sampled source population and the offshore extrapolation of the sampled source population.

Parameter values needed in performing the extrapolation were obtained through a regression analysis using the data from all of the surveys. This resulted in the calculation of a common slope and intercept for all of the surveys for each of the target taxa. The differences in onshore currents changed the limit of the extrapolation used for each survey.

For a P_S using only alongshore current, displacement was calculated without using the offshore extrapolation based on onshore or offshore current movement to predict a coastwise fraction of the population of inference. The total alongshore displacement in the i^{th} survey, includes both upcoast and downcoast movement calculated during a period equal to the larval duration before each survey. The P_S using only alongshore current was calculated as:

$$\widehat{P_{S_i}} = \frac{\widehat{N_{G_i}}}{\widehat{N_{P_i}}} = \frac{\widehat{N_{G_i}}}{\sum_{k=1}^{9} \frac{L_{P_i} \cdot \widehat{N_{G_{ik}}}}{L_{G_{ik}}}}. \qquad (14)$$

The current data for both estimates were from data collected for the Orange County Sanitation District from June 1999 to June 2000 at station Q (33° 37.874’N, 117° 59.804’W with 14.8 m [48.5 ft] depth) directly offshore from the HBGS. The historical data was collected near the HBGS intake from June 17, 1999 to June 24, 2000. Measurements were taken at 30-min intervals, 3-hr low pass filtered, and then resampled at 1-hr intervals. North and east currents were rotated to 307ºT, the orientation of the shoreline. The instrument was positioned 5 m (16.4 ft) below the surface over a bottom depth of 14.8 m (48.5 ft) MLLW at 33.63129º N latitude and 117.99673º W longitude (re: NAD83). This location lies

1.47 km (0.9 mile) at 236º from the HBGS intake. The magnetic vectors were corrected to true north using a 13.35º east variation. These true vectors were then rotated to align with the coastline. Hourly excursion distances were calculated in the alongshore (positive upcoast) and cross shelf (positive onshore) directions using sums of the excursions based on the 1-hr resampled currents.

Data from the current meter deployed for this study were not used because of a failure of the internal compass during the last deployment. The failure of the system also raised concerns about the data from other deployments that were generally not characteristic of currents described from the area by Noble et al. (2003) that described, for summer 2001, a downcoast average current over the shelf with a maximum near the surface on the outer shelf, decreasing in magnitude and depth and toward shore.

The source water volumes for the sampling areas were calculated from bathymetric data for the coastal areas around Huntington Beach (Figure 4-2, Table 4-1). These volumes were used in calculating the total number of larvae for target taxa in the sampled source water, and used with the total volume of the HBGS cooling water system (1,919,204 m^3 per day, 507 mgd) in calculating *PE* estimates used in the *ETM* calculations. The areas of the extrapolated stations are approximately four times the area of the sampled stations, while the volume for station I2 is also approximately four times the volume of the sampled stations, the volume of station I1 is substantially larger because the area includes deeper depths associated with the drop-off into Newport Canyon (Figure 4-2).

Table 4-1. Area, volume, and average depth of HBGS source water sampling locations, including the values for the two extrapolated source water area, I1 and I2.

Station	Area (m^2)	Volume (m^3)	Average Depth (m)
D2	3,349,340	28,487,976	8.5
D4	4,164,939	34,138,031	8.1
E	3,613,797	28,360,943	7.7
O2	2,765,512	43,697,047	15.8
O4	4,234,490	99,644,641	23.7
U2	3,211,727	21,159,762	6.2
U4	3,651,953	21,696,873	5.6
I1	13,804,831	398,613,394	28.3
I2	12,692,946	232,359,192	18.2

4.3 DATA SUMMARY

The U.S. EPA defines entrainment as "the incorporation of all life stages of fish and shellfish with intake water flow entering and passing through a cooling water intake structure and into a cooling water system" (USEPA 2002a). At the HBGS, organisms are entrained when they are drawn into the offshore intake structure and conveyed with the cooling water flow to the generating station. Larval fishes and invertebrates are comparatively weak swimmers, and enter the cooling water flow passively. Section 4.5 presents entrainment and source water results for larval fishes collected in 45 surveys from September 2003 through August 2004. Survey HBS026 (26-27 March 2004) was aborted due to high winds.

4.4 HISTORICAL DATA

The previous operator of the HBGS performed an entrainment study as part of the 316(b) demonstration study (SCE 1983). Entrainment samples were collected monthly from the Ormond Beach Generating Station and San Onofre Nuclear Generating Station Unit 1. Samples were collected by pump from the intake structures during six cycles each 24-hr survey period, and filtered through 333-µm mesh plankton nets. AES Huntington Beach is not proposing to utilize this data as part of the 316(b) Phase II compliance process.

4.5 RESULTS

The following section presents results of the AES Huntington Beach Entrainment and Impingement Study, including data on entrainment and source water larval concentrations collected from September 2003 through August 2004. Estimates of entrainment were derived from samples collected just offshore of the intake structure. Source water estimates were derived from samples collected up to four kilometers upcoast, downcoast, and offshore of the intake structure.

4.5.1 Physical Oceanographic Results

Sea surface temperatures recorded at the entrainment station displayed seasonal variation (Figure 4-3). Maximum temperatures were recorded in fall and summer, and lowest temperatures were recorded in winter. Analysis of profiles indicates that during the onset of sampling in September 2003, summer conditions prevailed and the water column was fairly stratified with a discernable thermocline (MBC and Tenera 2005). Beginning in the second week of October 2003, the transition to winter conditions began, and the thermocline dissipated. Winter conditions (cool water and no thermocline) were recorded from late November 2003 through early March 2004, with coolest temperatures recorded in February 2004. Warming of the water column began in March 2004 and the transition to summer conditions (warm water and establishment of a thermocline) continued through May 2004. In many cases, warmest waters were recorded during daytime cycles initiated at 1200 hr and 1800 hr.

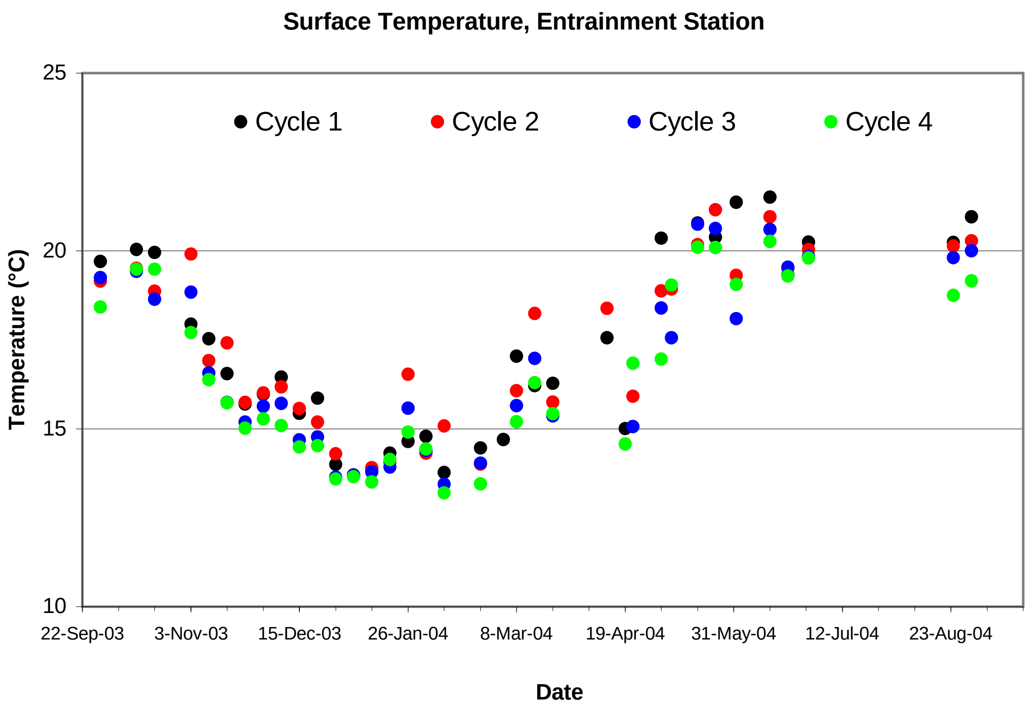


Figure 4-3. Surface temperatures at Station E during each cycle of each entrainment and source water survey.

Brackish or fresh water was detected in the study area during a few surveys. During Entrainment Survey HBS005 (first week of November 2003), light rain fell during the first cycle of sampling, and a lens of brackish water (19 to 30 practical salinity units [psu]) was present in the upper two meters of the water column. Surface salinity was also low throughout the study area during Source Water Survey HBS023 (8-9 March 2004). During that survey, lowest near-surface salinities were recorded at the offshore stations (10 psu), followed by upcoast stations (16 psu) and entrainment and downcoast stations (22 psu). Approximately two inches of rain fell in the week prior to the 8-9 March survey. Even though rain occurred during some other surveys salinity in the nearshore waters was generally >33 psu, which is considered normal for southern California nearshore waters.

Currents generally moved onshore and downcoast from June 1999 to June 2000 (Figure 4-4). Overall, during the period, there was 499 km (310 mile) of onshore movement and 659 km (409.5 mile) of downcoast excursion. From June through September currents moved nearly 226 km (140.4 mile) downcoast and 128 km (79.5 mile) onshore. During October through December there was onshore movement of 180 km (111.8 mile) and 145 km (90.1 mile) downcoast movement. From January through March there was similar onshore and downcoast movement of 192 km (119.3 mile) and 131 km (81.4 mile). From April through June 24, there was no onshore movement and a 155 km (96.3 mile) downcoast excursion. Other researchers have reported similar current patterns in the area near HBGS. Noble and Xu (2003) described the currents near the HBGS and found that larger-scale coastal processes influenced local current patterns more than tides and localized wind conditions. They found that, in summer 2001, currents moved predominantly in a downcoast direction over the continental shelf with maximum velocities occurring near the surface on the outer portion of the shelf. Currents tended to decrease as a function of proximity to the shore.

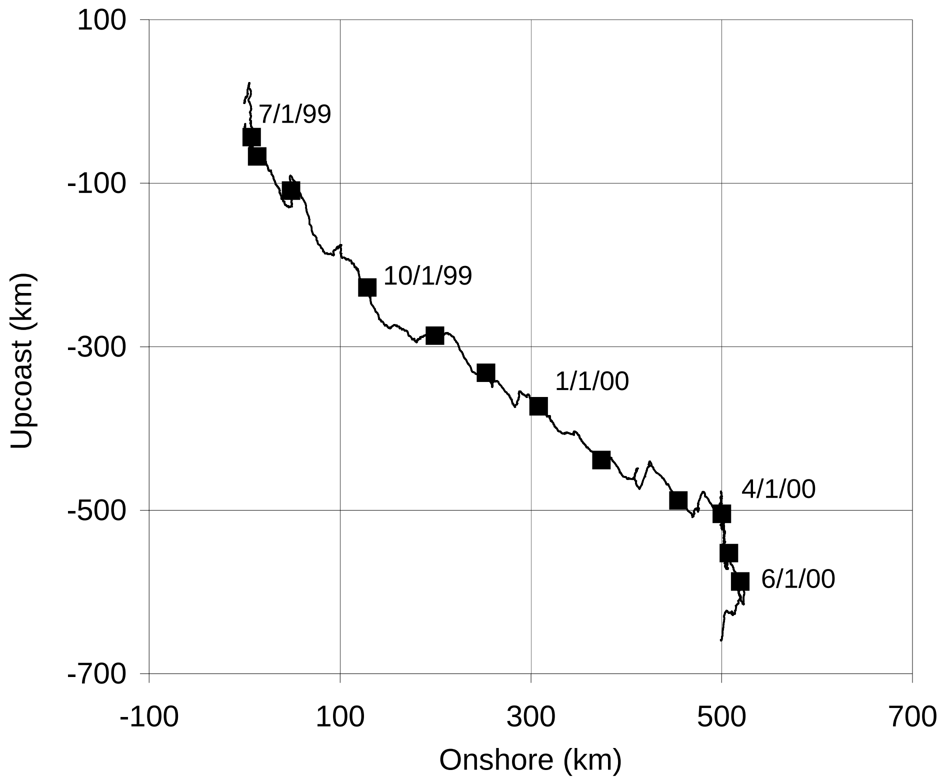


Figure 4-4. Cumulative onshore and upcoast (alongshore) current vectors from 17 June 1999 through 24 June 2000. Squares show cumulative monthly positions.

4.5.2 Cooling Water Intake Structure Entrainment Summary

A total of 6,950 fish larvae in 57 different taxonomic groups was collected during the 45 entrainment surveys completed during the September 2003 through August 2004 period (Table 4-2), including 227 unidentified or damaged specimens. Ten taxa comprised 90% of the total larvae collected: unidentified gobies (mainly of the genera *Clevlandia*, *Ilypnus*, and *Quietula* [CIQ complex]), spotfin croaker, unidentified anchovies (>95% northern anchovy), queenfish, white croaker, salema, unidentified croakers (newly hatched larvae of several species), combtooth blennies, black croaker, and diamond turbot. The life histories and potential impacts from entrainment on the local populations of these taxa and California halibut, which is an important recreational and commercial species and ranked 11th in abundance overall, are analyzed in greater detail in this report (See Section 6.5.3–*Results by Species*). The target taxa are not presented in the order of abundance so that the results for the four species of Sciaenidae could be presented together. Of the five target invertebrate taxa included in the study (*Cancer* crab megalops, market squid hatchlings, mole crab (sand crab), California spiny lobster, and ridgeback rock shrimp) only mole crab and *Cancer* crabs were found in the entrainment samples (Table 4-3). Mole crab zoeae comprised almost 99% of the entrained target invertebrates. Almost all of the mole crab larvae collected were in the earliest stages of their larval development (Zoea Stage I); only two megalopal stage larvae were collected from entrainment samples and none were collected from source water samples. Sampling results are presented for *Cancer* and mole crabs, but no assessments of potential entrainment impacts were conducted for mole crab because of the low numbers collected and absence of megalops in the source water samples.

The measured larval concentrations during each survey were multiplied by a total daily maximum intake flow of 1,919,204 m^3 (507 mgd) that equates to an estimated annual cooling water volume of 702,428,664 m^3 (185 billion gallons). Approximately 350 million fish larvae were calculated to have been entrained during the study (Table 4-2). The number of individual taxa increased during the study with greatest numbers of taxa occurring in summer 2004, from an average of approximately 8 taxa per survey from September through February to 18 taxa per survey in summer 2004, including a survey in late July when over 30 taxa were collected (Figure 4-5). The greatest overall abundances occurred in late summer 2004 when concentrations were approximately five times greater than earlier months (Figure 4-6). Although gobies and anchovies were abundant throughout the sampling period, high concentrations of spotfin croaker, salema, and queenfish contributed to peak abundances in August 2004. Low concentrations of larvae were measured during some surveys in early February and early March, although abundances generally increased through spring when many fishes start reproducing.

Entrainment samples were characterized by large numbers of gobies, blennies, and several other fishes common in bay environments whose larvae were probably exported into the open ocean by tidal currents from estuarine spawning areas upcoast and downcoast of the HBGS. Some commercially and recreationally important taxa such as California halibut, white seabass, and rockfishes comprised a smaller percentage of the total number of taxa entrained, but others, including northern anchovy and several croaker species, comprised nearly 50% of the total fish larvae collected (Table 4-2).

Table 4-2. Larval fishes collected during 45 entrainment surveys from September 2003 through August 2004. A flow volume of 702,428,664 m^3 was used to estimate total entrainment for the sampling period.

	Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (#/1000m3)	Total Estimated Entrainment	Entrainment Std. Error
1	Gobiidae (CIQ complex)	gobies	2,484	36.95	36.95	151.56	113,166,834	6,568,091
2	*Roncador stearnsi*	spotfin croaker	912	13.57	50.51	53.07	69,701,589	8,636,383
3	Engraulidae	anchovies	1,209	17.98	68.50	74.46	54,349,017	4,355,775
4	*Seriphus politus*	queenfish	306	4.55	73.05	18.17	17,809,864	2,415,487
5	*Genyonemus lineatus*	white croaker	446	6.63	79.68	28.14	17,625,263	1,491,336
6	*Xenistius californiensis*	salema	153	2.28	81.96	7.70	11,696,960	5,186,479
7	Sciaenidae	croaker	244	3.63	85.59	14.73	10,534,802	1,004,033
8	*Hypsoblennius* spp.	blennies	166	2.47	88.06	10.28	7,165,513	580,175
9	*Cheilotrema saturnum*	black croaker	96	1.43	89.48	5.41	7,128,127	1,481,158
10	*Hypsopsetta guttulata*	diamond turbot	87	1.29	90.78	5.28	5,443,118	476,544
11	*Paralichthys californicus*	California halibut	98	1.46	92.24	6.40	5,021,168	447,516
12	Atherinopsidae	silverside	97	1.44	93.68	5.98	3,654,229	577,117
13	*Menticirrhus undulatus*	California corbina	43	0.64	94.32	2.33	2,809,417	807,329
14	*Paralabrax* spp.	sand bass	48	0.71	95.03	2.93	2,793,730	518,724
15	*Citharichthys* spp.	sanddabs	31	0.46	95.49	2.15	1,913,607	314,973
16	*Hypsypops rubicundus*	garibaldi	43	0.64	96.13	2.44	1,622,966	776,711
17	*Oxyjulis californica*	senorita	27	0.40	96.53	1.66	1,190,449	311,376
18	*Sphyraena argentea*	California barracuda	14	0.21	96.74	0.79	1,133,103	258,040
19	Pleuronectidae	flounders	17	0.25	97.00	1.02	982,419	131,877
20	*Umbrina roncador*	yellowfin croaker	24	0.36	97.35	1.63	962,905	266,187
21	*Gillichthys mirabilis*	longjaw mudsucker	20	0.30	97.65	1.29	834,682	155,798
22	*Lepidogobius lepidus*	bay goby	18	0.27	97.92	1.16	683,887	161,835
23	Syngnathidae	pipefishes	17	0.25	98.17	0.91	591,496	353,236
24	*Leptocottus armatus*	Pacific staghorn sculpin	16	0.24	98.41	0.97	584,664	115,109
25	*Pleuronichthys ritteri*	spotted turbot	12	0.18	98.59	0.75	561,958	87,434
26	*Triphoturus mexicanus*	Mexican lampfish	8	0.12	98.71	0.51	536,324	95,606
27	*Acanthogobius flavimanus*	yellowfin goby	15	0.22	98.93	0.88	522,589	176,940
28	*Diaphus theta*	California headlight fish	11	0.16	99.09	0.63	486,274	110,942
29	Myctophidae	lanternfishes	6	0.09	99.18	0.39	423,578	94,314
30	Haemulidae	grunts	5	0.07	99.26	0.28	368,219	121,028
31	*Atractoscion nobilis*	white seabass	5	0.07	99.33	0.29	347,306	114,685
32	*Gibbonsia* spp.	clinid kelpfishes	10	0.15	99.48	0.55	341,921	87,691
33	*Pleuronichthys verticalis*	hornyhead turbot	3	0.04	99.52	0.17	198,470	52,984
34	*Sardinops sagax*	Pacific sardine	4	0.06	99.58	0.25	166,724	117,891
35	*Peprilus simillimus*	Pacific butterfish	2	0.03	99.61	0.14	138,138	56,479
36	*Semicossyphus pulcher*	California sheephead	2	0.03	99.64	0.13	129,222	52,033
37	*Stenobrachius leucopsarus*	northern lampfish	3	0.04	99.69	0.21	111,109	46,395
38	Labrisomidae	labrisomid kelpfishes	3	0.04	99.73	0.18	108,964	58,784
39	*Halichoeres semicinctus*	rock wrasse	1	0.01	99.75	0.06	97,344	45,888
40	Paralichthyidae	lefteye flounders & sanddabs	2	0.03	99.78	0.12	95,195	45,031
41	*Medialuna californiensis*	halfmoon	2	0.03	99.81	0.13	77,804	58,815
42	*Scomber japonicus*	Pacific mackerel	2	0.03	99.84	0.10	61,004	32,608
43	Scorpaenidae	scorpionfishes	1	0.01	99.85	0.09	50,467	38,150
44	*Symphurus atricauda*	California tonguefish	1	0.01	99.87	0.07	42,344	32,009
45	*Strongylura exilis*	California needlefish	1	0.01	99.88	0.07	40,637	30,719
46	*Oxylebius pictus*	painted greenling	1	0.01	99.90	0.07	40,289	30,456
47	*Typhlogobius californiensis*	blind goby	1	0.01	99.91	0.06	36,976	27,951
48	*Merluccius productus*	Pacific hake	1	0.01	99.93	0.06	33,954	25,667
49	*Coryphopterus nicholsi*	blackeye goby	1	0.01	99.94	0.06	33,202	25,099
50	Agonidae	poachers	1	0.01	99.96	0.05	30,817	23,295
51	*Ruscarius creaseri*	rouchcheek sculpin	1	0.01	99.97	0.05	30,813	23,293
52	Pleuronectiformes	flatfishes	1	0.01	99.99	0.05	30,192	22,823
53	Cottidae	sculpins	1	0.01	100.00	0.05	28,990	21,914
			6,723			**406.91**	**344,570,635**	
	larvae, unidentified yolksac	unidentified yolksac larvae	136			9.23	6,100,663	1,148,559
	larval fish fragment	unidentified larval fishes	51			3.08	2,508,742	386,659
	larval/post-larval fish unid.	larval fishes	39			2.37	1,655,508	246,622
	larval fish - damaged	unidentified larval fishes	1			0.06	41,681	29,473
			227			**14.74**	**10,306,594**	

Table 4-2. Invertebrate larvae (select taxa) collected during 45 entrainment surveys from September 2003 through August 2004. A flow volume of 702,428,664 m^3 was used to estimate total entrainment for the sampling period.

Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (#/1000m3)	Total Estimated Entrainment	Entrainment Std. Error
Emerita analoga (zoea)	mole crabs - larva	10,399	98.73	98.73	658.95	465,806,877	91,912,298
Cancer anthonyi (megalops)	yellow crab	77	0.73	99.46	4.68	5,207,996	1,320,180
Cancer gracilis (megalops)	slender crab	31	0.29	99.75	1.97	1,304,771	311,450
Cancer antennarius (megalops)	brown rock crab	18	0.17	99.92	1.15	973,538	202,088
Cancer productus (megalops)	red rock crab	3	0.03	99.95	0.18	164,478	53,672
Emerita analoga (megalops)	mole crabs - larva	2	0.02	99.97	0.17	69,793	54,061
Cancer spp. (megalops)	cancer crabs	2	0.02	99.99	0.11	65,159	34,834
Cancer spp.	cancer crabs	1	0.01	100.00	0.06	35,885	27,126
		10,533			**667**	**473,628,497**	

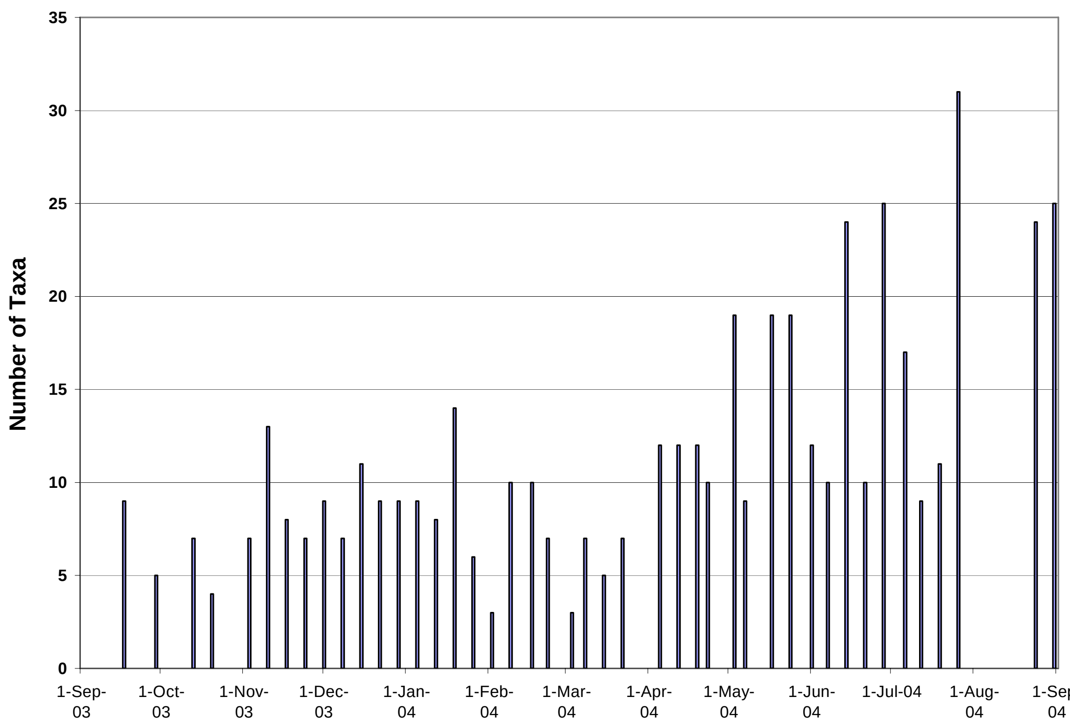


Figure 4-5. Total number of taxa collected per survey at HBGS entrainment Station E from September 2003 through August 2004.

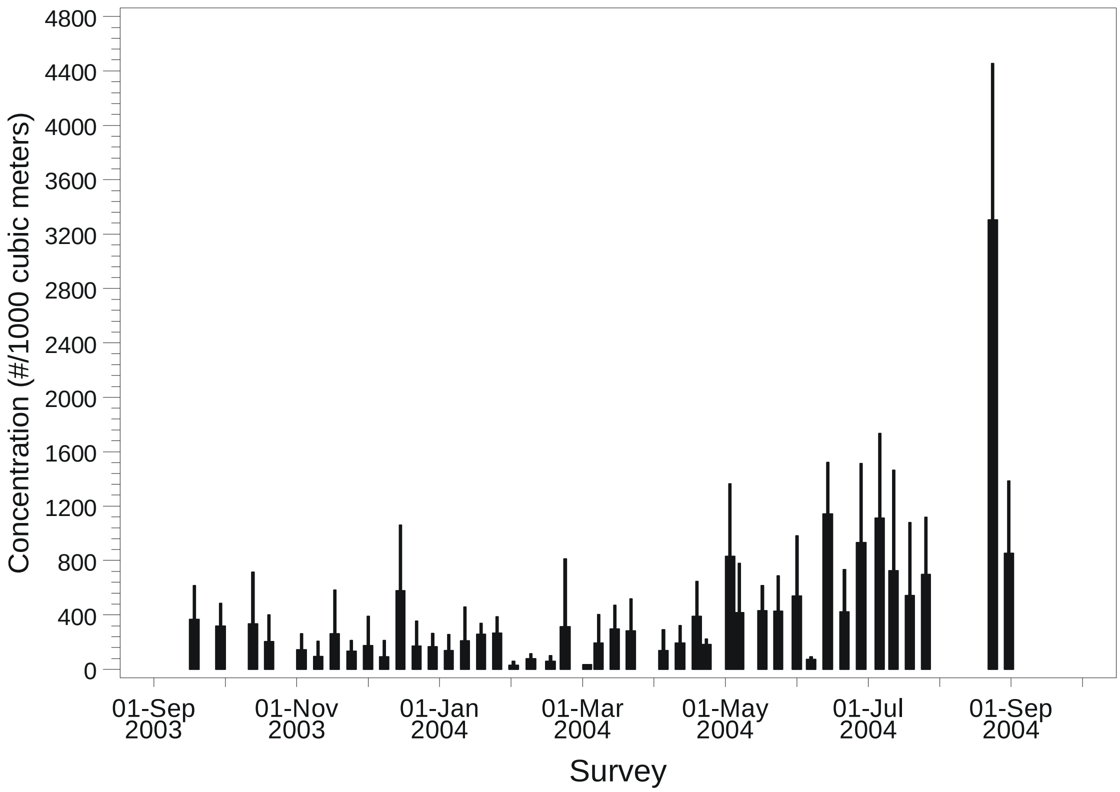


Figure 4-6. Mean concentration (No. per 1,000 m^3) and standard error for all larval fishes collected at HBGS entrainment Station E from September 2003 through August 2004.

Larval fish concentrations at the entrainment station were relatively similar from the onset of the study in September 2003 through April 2004 (Figure 4-6). Concentrations increased in spring and summer (May through July 2004), corresponding to higher concentrations of CIQ gobies, white croaker, combtooth blennies, and several other taxa. Highest concentrations at the entrainment station were measured in late August 2004, and corresponded to high concentrations (greater than 1,800 larvae per 1,000 m^3) of spotfin croaker. Larval fish concentrations measured at the entrainment station were almost always higher at nighttime than during daytime (Figure 4-7).

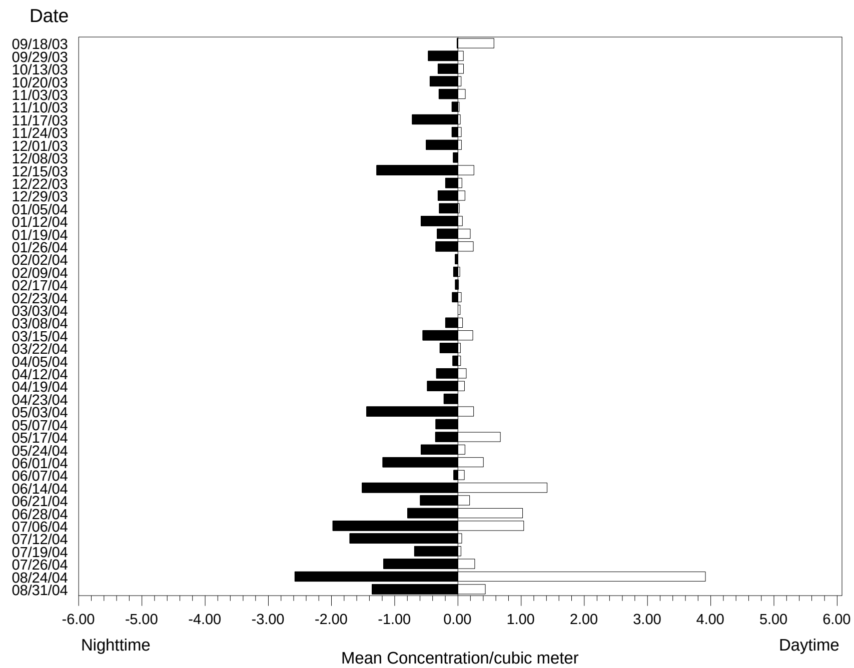


Figure 4-7. Mean concentration (No. per m^3) of all larval fishes collected at HBGS entrainment Station E at nighttime (black) and daytime (white).

4.5.3 Source Water Summary

A total of 14,627 fish larvae in 79 different taxonomic groups was collected during the 12 source water surveys completed during the September 2003 – September 2004 period (Table 4-3), including 299 unidentified or damaged specimens. Eleven taxa comprised nearly 90% of the total larvae collected: unidentified gobies (36.8%; mainly of the genera *Clevelandia*, *Ilypnus*, and *Quietula* [CIQ complex]), unidentified anchovies, queenfish, white croaker, unidentified croakers (newly hatched larvae of several species), combtooth blennies, unidentified sea bass, California halibut, spotfin croaker, silversides, and Pacific sardine (Table 4-3). During the 12 source water surveys there were 23 additional taxa collected at stations other than the single entrainment Station E during 45 entrainment surveys (Table 4-4). Similar to the entrainment station concentrations, the lowest larval concentrations in the source water were measured in winter and the highest concentrations in summer (Figure 4-8).

The composition of the target invertebrates collected at the source water stations was similar to the entrainment samples with mole crab larvae comprising nearly 95% of the target invertebrates (Table 4-5). Almost all of the mole crab larvae collected were in the earliest stage of larval development (Zoea Stage I); only two megalopal stage larvae were collected at the entrainment station during one of the paired entrainment-source water surveys. In addition to *Cancer* crab larvae, one California spiny lobster puerulus stage larva was collected (Table 4-5).

Concentrations of the CIQ goby complex, northern anchovy, and white croaker, three of the most abundant fish taxa, varied spatially among the seven sampling stations and temporally among months (Figures 4-9 through 4-14). The CIQ goby complex was generally more abundant at the inshore stations in all months and also tended to be more abundant at the intake (entrainment) and downcoast stations. Northern anchovy did not show a strong distributional trend among stations whereas white croaker was more abundant offshore in summer (Figure 4-11).

Table 4-3. Larval fishes collected during 12 source water surveys from September 2003 through August 2004. Sample totals and mean concentrations were calculated from all seven stations, which includes entrainment Station E.

	Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (#/1000m3)	Density Std. Error
1	Gobiidae (CIQ complex)	gobies	5,275	36.82	36.82	169.83	46.30
2	Engraulidae	anchovies	2,525	17.62	54.44	81.41	17.20
3	*Seriphus politus*	queenfish	1,418	9.90	64.34	45.85	21.80
4	*Genyonemus lineatus*	white croaker	1,239	8.65	72.98	39.46	9.32
5	Sciaenidae	croakers	541	3.78	76.76	17.92	5.90
6	*Hypsoblennius* spp.	blennies	439	3.06	79.82	13.82	3.93
7	*Paralabrax* spp.	sand bass	408	2.85	82.67	13.61	24.05
8	*Paralichthys californicus*	California halibut	399	2.78	85.46	12.70	3.60
9	Atherinopsidae	silversides	333	2.32	87.78	10.55	4.41
10	*Sardinops sagax*	Pacific sardine	147	1.03	88.81	4.91	20.01
11	*Sphyraena argentea*	California barracuda	145	1.01	89.82	4.73	6.35
12	*Chromis punctipinnis*	blacksmith	166	1.16	90.98	4.59	20.83
13	*Citharichthys* spp.	sanddabs	141	0.98	91.96	4.53	2.21
14	*Hypsopsetta guttulata*	diamond turbot	122	0.85	92.81	3.96	1.40
15	Ophidiidae	cusk-eels	99	0.69	93.50	3.26	12.49
16	*Lepidogobius lepidus*	bay goby	86	0.60	94.10	2.73	1.65
17	*Pleuronichthys ritteri*	spotted turbot	68	0.47	94.58	2.10	0.89
18	*Pleuronichthys verticalis*	hornyhead turbot	65	0.45	95.03	2.07	1.34
19	*Cheilotrema saturnum*	black croaker	61	0.43	95.46	1.90	1.67
20	*Xenistius califoriensis*	salema	50	0.35	95.81	1.75	7.07
21	*Typhlogobius californiensis*	blind goby	56	0.39	96.20	1.73	6.28
22	*Oxyjulis californica*	senorita	51	0.36	96.55	1.64	1.48
23	*Roncador stearnsi*	spotfin croaker	53	0.37	96.92	1.62	2.62
24	*Gillichthys mirabilis*	longjaw mudsucker	40	0.28	97.20	1.28	0.71
25	Pleuronectidae	flounders	41	0.29	97.49	1.25	0.77
26	*Leptocottus armatus*	Pacific staghorn sculpin	28	0.20	97.68	0.91	1.04
27	*Acanthogobius flavimanus*	yellowfin goby	23	0.16	97.84	0.78	1.36
28	*Icelinus* spp.	sculpins	25	0.17	98.02	0.75	1.70
29	*Gibbonsia* spp.	clinid kelpfishes	21	0.15	98.16	0.64	0.67
30	*Xystreurys liolepis*	fantail sole	20	0.14	98.30	0.62	1.53
31	*Triphoturus mexicanus*	Mexican lampfish	19	0.13	98.44	0.62	0.54
32	*Hypsypops rubicundus*	garibaldi	20	0.14	98.58	0.60	1.09
33	*Syngnathus* spp.	pipefishes	20	0.14	98.72	0.58	1.95
34	*Menticirrhus undulatus*	California corbina	14	0.10	98.81	0.46	1.09
35	*Atractoscion nobilis*	white seabass	14	0.10	98.91	0.43	0.92
36	*Gobiesocidae*	clingfishes	12	0.08	98.99	0.39	0.51
37	*Semicossyphus pulcher*	California sheephead	13	0.09	99.09	0.37	1.23
38	*Sebastes* spp.	rockfishes	11	0.08	99.16	0.36	1.64
39	Labrisomidae	labrisomid kelpfishes	9	0.06	99.23	0.29	0.54
40	*Stenobrachius leucopsarus*	northern lampfish	9	0.06	99.29	0.27	0.49
41	*Peprilus simillimus*	Pacific butterfish	7	0.05	99.34	0.26	2.28
42	Paralichthyidae	lefteye flounders & sanddabs	8	0.06	99.39	0.26	0.43
43	*Hippoglossina stomata*	bigmouth sole	7	0.05	99.44	0.24	0.64
44	*Umbrina roncador*	yellowfin croaker	7	0.05	99.49	0.22	0.56
45	*Ruscarius creaseri*	rouchcheek sculpin	6	0.04	99.53	0.19	0.50
46	*Symphurus atricauda*	California tonguefish	6	0.04	99.57	0.18	1.29
47	*Coryphopterus nicholsi*	blackeye goby	5	0.03	99.61	0.16	0.40
48	*Diaphus theta*	California headlight fish	5	0.03	99.64	0.16	0.45
49	Haemulidae	grunts	5	0.03	99.68	0.16	0.67
50	*Merluccius productus*	Pacific hake	5	0.03	99.71	0.15	1.04
51	Myctophidae	lanternfishes	4	0.03	99.74	0.14	0.46
52	*Halichoeres semicinctus*	rock wrasse	3	0.02	99.76	0.11	1.00
53	*Etrumeus teres*	round herring	3	0.02	99.78	0.10	0.65
54	*Medialuna californiensis*	halfmoon	3	0.02	99.80	0.09	0.63
55	Labridae	wrasses	2	0.01	99.82	0.07	0.83
56	*Lythrypnus* spp.	gobies	3	0.02	99.84	0.07	0.83
57	Cottidae	sculpins	2	0.01	99.85	0.06	0.39
58	Kyphosidae	sea chubs	2	0.01	99.87	0.06	0.77
59	*Oxylebius pictus*	painted greenling	2	0.01	99.88	0.06	0.38
60	Hexagrammidae	greenlings	2	0.01	99.90	0.06	0.37

(table continued)

Table 4-3 (continued). Larval fishes collected during 12 source water surveys from September 2003 through August 2004. Sample totals and mean concentrations were calculated from all seven stations, which includes entrainment Station E.

	Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (#/1000m3)	Density Std. Error
61	*Artedius lateralis*	smoothhead sculpin	1	0.01	99.90	0.04	0.48
62	*Girella nigricans*	opaleye	1	0.01	99.91	0.04	0.47
63	*Anisotremus davidsonil*	sargo	1	0.01	99.92	0.04	0.44
64	*Scorpaenichthys marmoratus*	cabezon	1	0.01	99.92	0.04	0.42
65	*Parophrys vetulus*	English sole	1	0.01	99.93	0.03	0.40
66	*Aulorhynchus flavidus*	tubesnout	1	0.01	99.94	0.03	0.39
67	*Zaniolepis* spp.	combfishes	1	0.01	99.94	0.03	0.36
68	*Artedius* spp.	sculpins	1	0.01	99.95	0.03	0.34
69	Pleuronectiformes	flatfishes	1	0.01	99.96	0.03	0.33
70	Agonidae	poachers	1	0.01	99.97	0.03	0.33
71	Scorpaenidae	scorpionfishes	1	0.01	99.97	0.03	0.32
72	Chaenopsidae	tube blennies	1	0.01	99.98	0.03	0.31
73	Scombridae	mackerels & tunas	1	0.01	99.99	0.02	0.27
74	Clupeiformes	herrings and anchovies	1	0.01	99.99	0.02	0.26
75	Pomacentridae	damselfishes	1	0.01	100.00	0.02	0.22
			14,328			**460.52**	
	larvae, unidentified yolksac	unidentified yolksac larvae	168			5.08	3.44
	larval fish fragment	unidentified larval fishes	87			2.60	1.07
	larval/post-larval fish unid.	larval fishes	43			1.46	0.95
	larval fish - damaged	unidentified larval fishes	1			0.03	0.39
			299			**9.17**	

Table 4-4. Larval fishes collected at source water stations other than entrainment Station E from September 2003 through August 2004.

Taxon name	Common Name
Anisotremus davidsoni	sargo
Artedius lateralis	smoothhead sculpin
Artedius spp.	sculpins
Aulorhynchus flavidus	tubesnout
Chaenopsidae	tube blennies
Chromis punctipinnis	blacksmith
Clupeiformes	herrings and anchovies
Etrumeus teres	round herring
Girella nigricans	opaleye
Gobiesocidae	clingfishes
Hexagrammidae	greenlings
Hippoglossina stomata	bigmouth sole
Icelinus spp.	sculpins
Kyphosidae	sea chubs
Labridae	wrasses
Lythrypnus spp.	gobies
Ophidiidae	cusk-eels
Parophrys vetulus	English sole
Pomacentridae	damselfishes
Scorpaenichthys marmoratus	cabezon
Sebastes spp.	rockfishes
Xystreurys liolepis	fantail sole
Zaniolepis spp.	combfishes

Table 4-5. Larval invertebrates (target taxa) collected during 12 source water surveys from September 2003 through August 2004. Sample totals and mean concentrations were calculated from all seven stations, which includes entrainment Station E.

Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (#/1000m3)	Density Std. Error
Emerita analoga (zoea)	mole crabs - larva	5,476	94.54	94.54	173.26	109.94
Cancer gracilis (megalops)	slender crab	107	1.85	96.39	3.48	2.50
Cancer anthonyi (megalops)	yellow crab	106	1.83	98.22	3.41	3.72
Cancer antennarius (megalops)	brown rock crab	92	1.59	99.81	2.96	2.75
Cancer spp. (megalops)	cancer crabs	4	0.07	99.88	0.11	0.32
Cancer productus (megalops)	red rock crab	3	0.05	99.93	0.10	0.43
Cancer spp.	cancer crabs	3	0.05	99.98	0.09	0.64
Panulirus interruptus (puerulus)	California spiny lobster	1	0.02	100.00	0.03	0.34
		5,792			**183.44**	

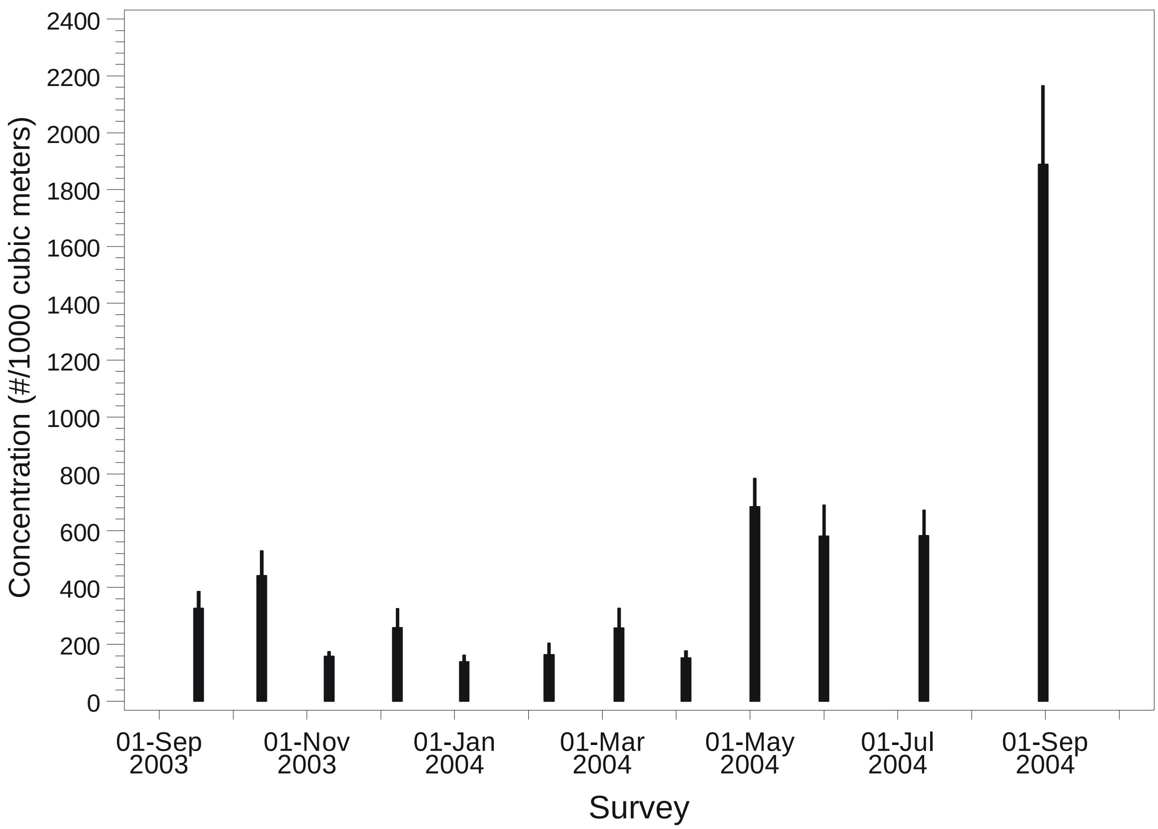
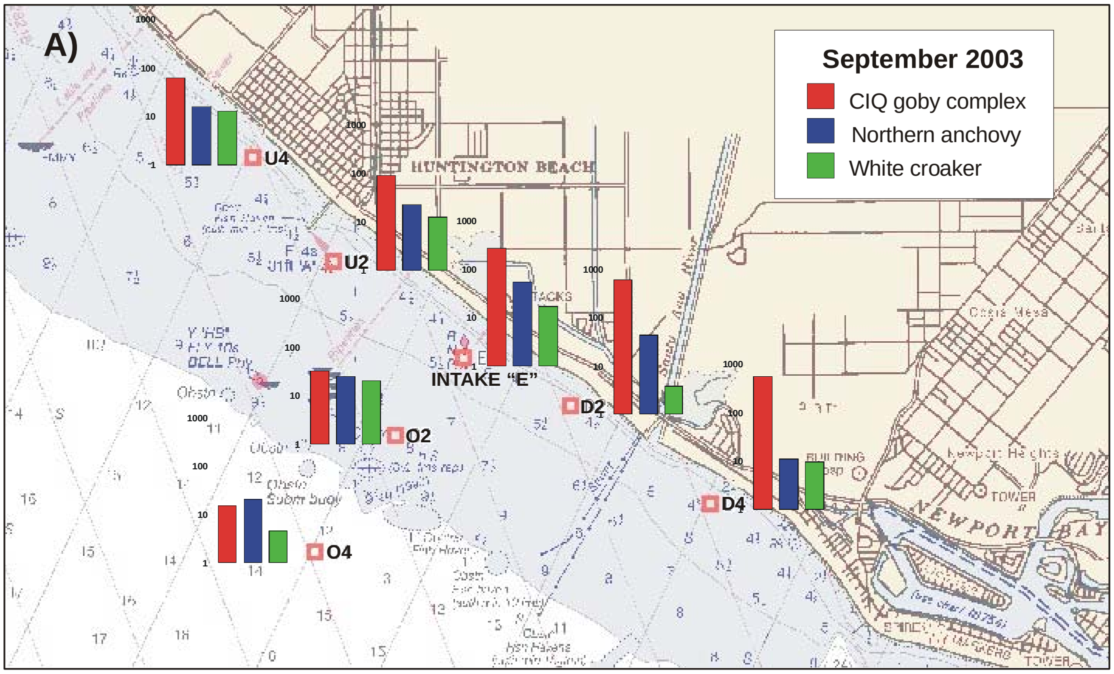


Figure 4-8. Mean concentration (No. per 1,000 m^3) and standard error for all larval fishes collected at HBGS source water stations (D2, D4, E, U2, U4, O2, O4) from September 2003 through August 2004.



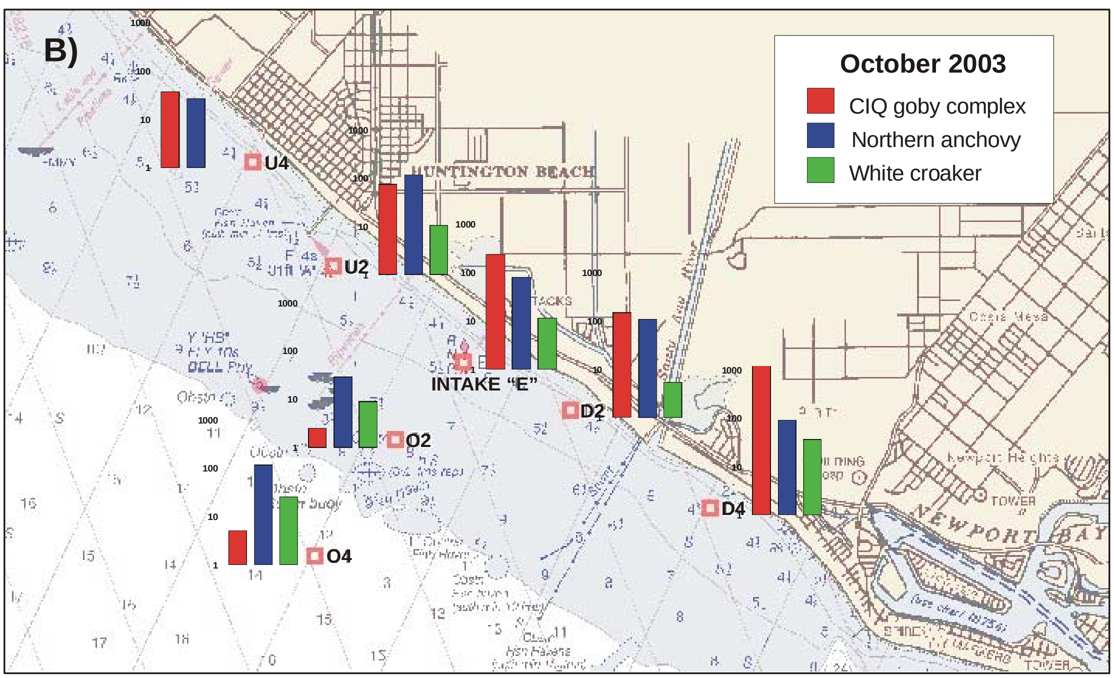
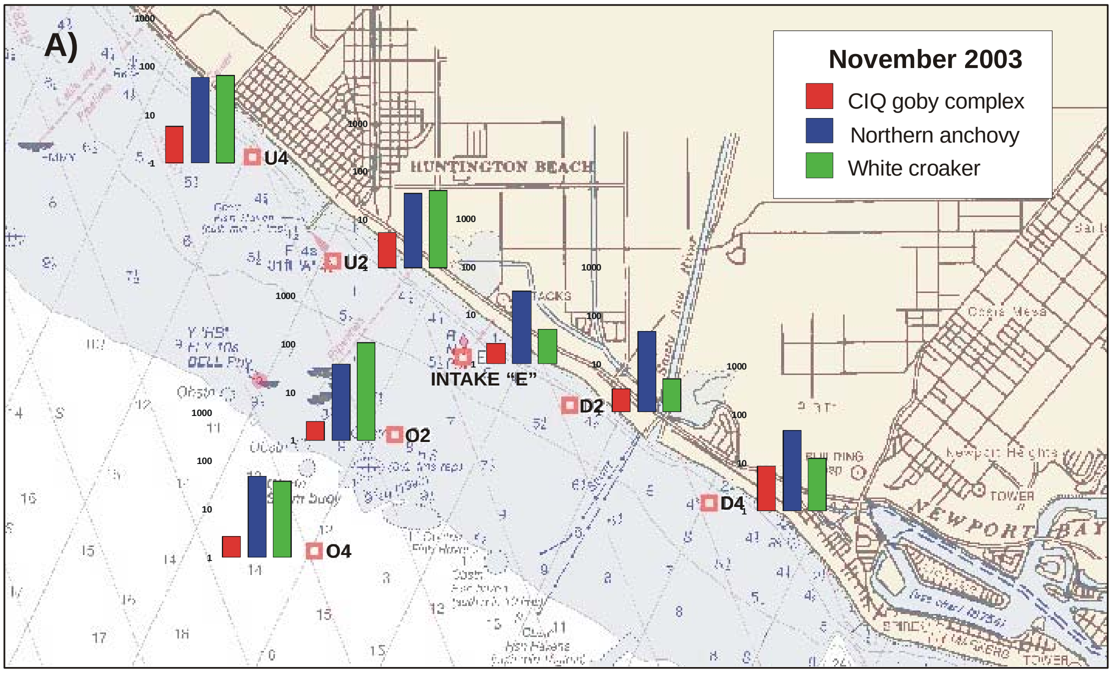


Figure 4-9. Concentrations (No. per 1,000 m^3) of larval CIQ gobies, northern anchovy, and white croaker at entrainment and source water stations in (A) September 2003 and (B) October 2003. Abundances are plotted on a logarithmic scale.



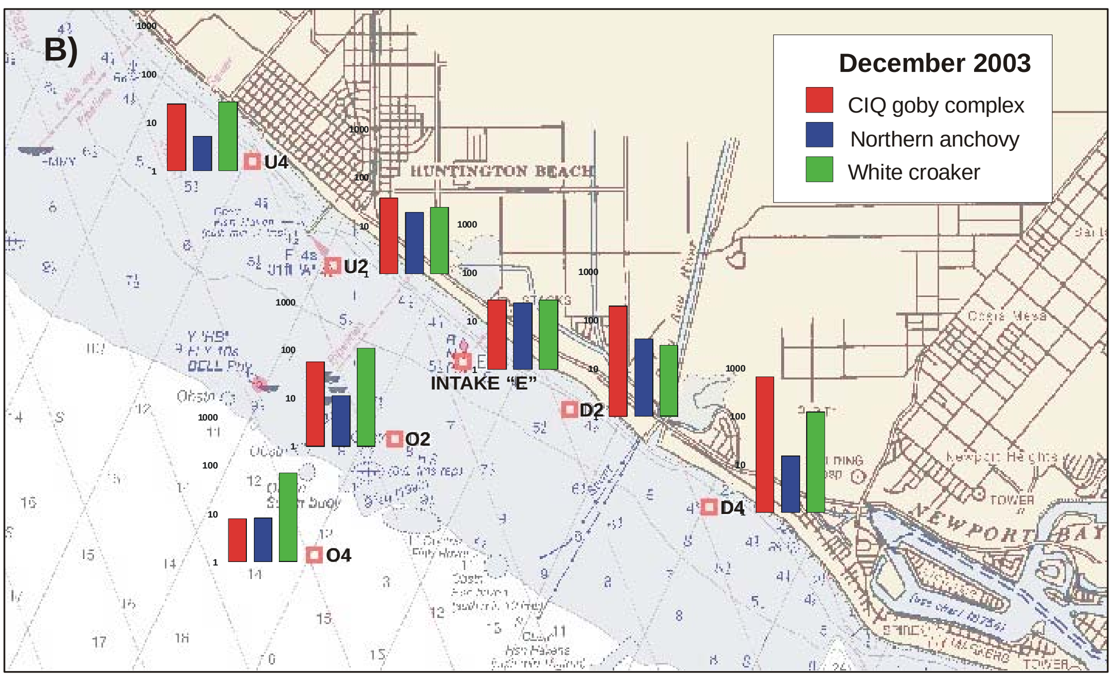
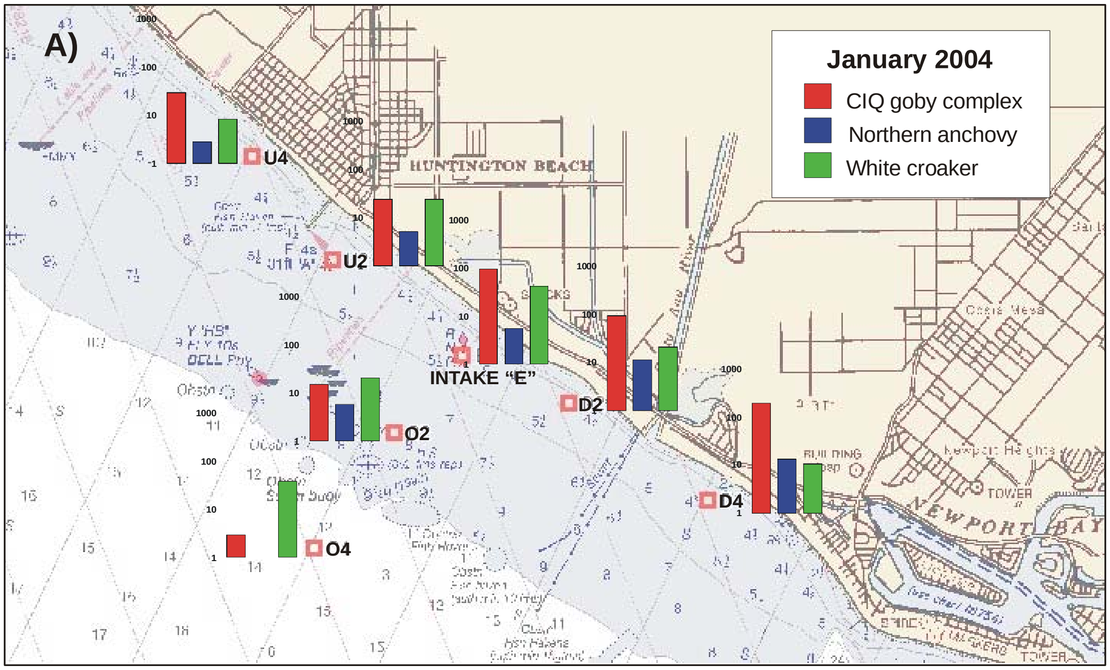


Figure 4-10. Concentrations (No. per 1,000 m^3) of larval CIQ gobies, northern anchovy, and white croaker at entrainment and source water stations in (A) November 2003 and (B) December 2003. Abundances are plotted on a logarithmic scale.



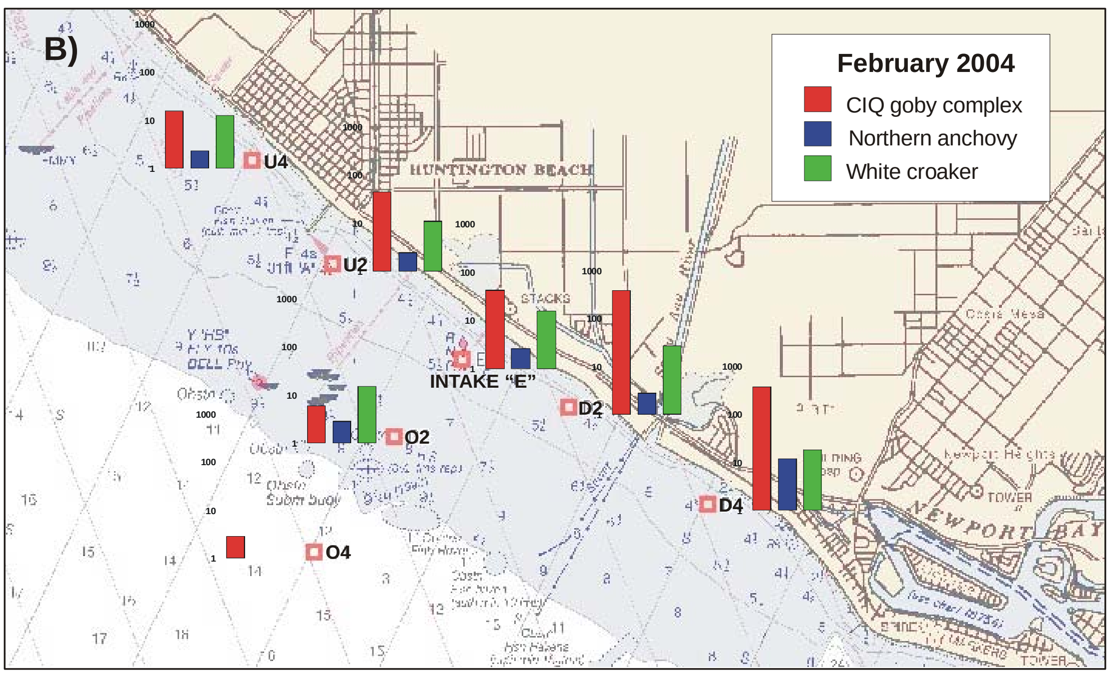


Figure 4-11. Concentrations (No. per 1,000 m^3) of larval CIQ gobies, northern anchovy, and white croaker at entrainment and source water stations in (A) January 2004 and (B) February 2004. Abundances are plotted on a logarithmic scale.

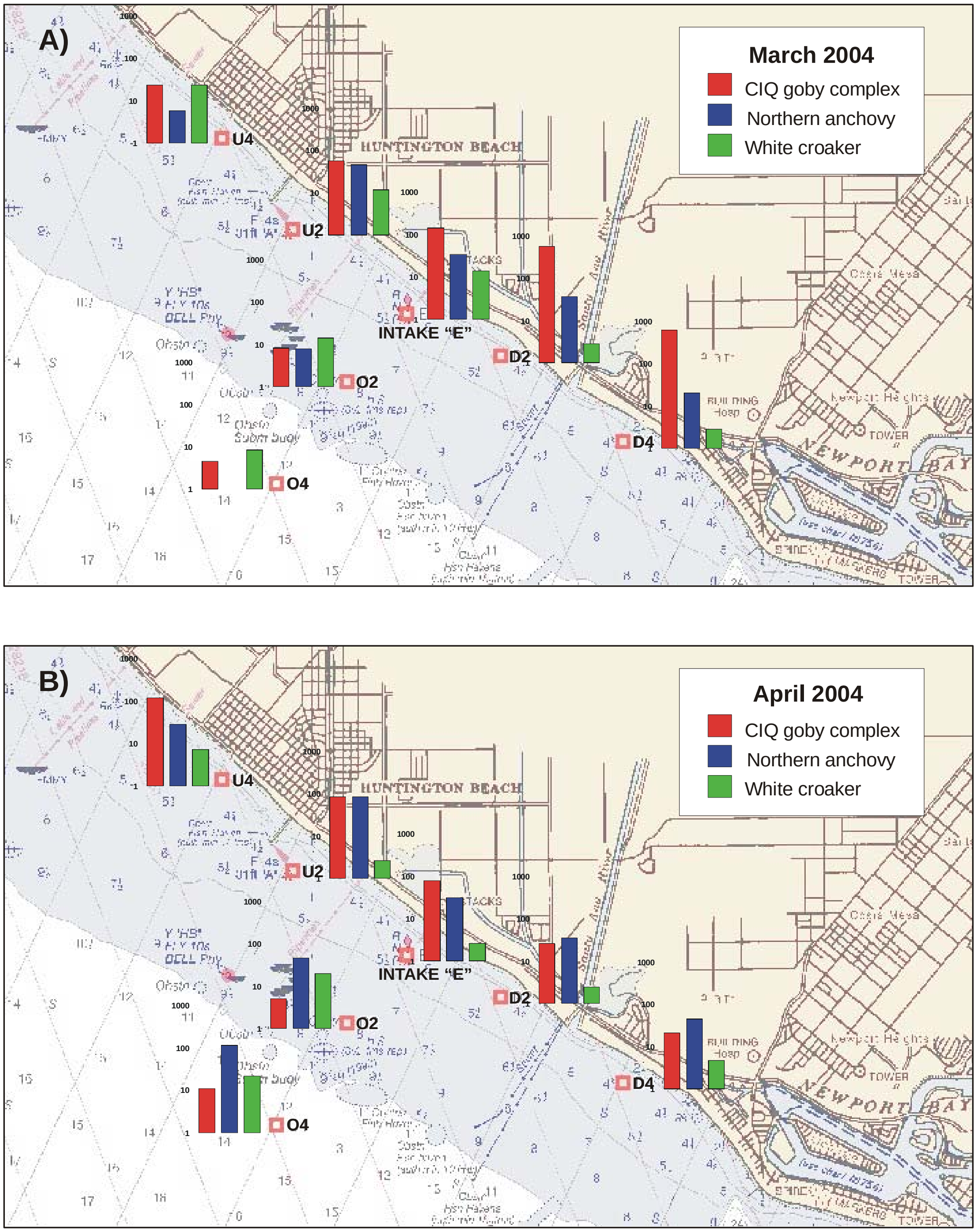
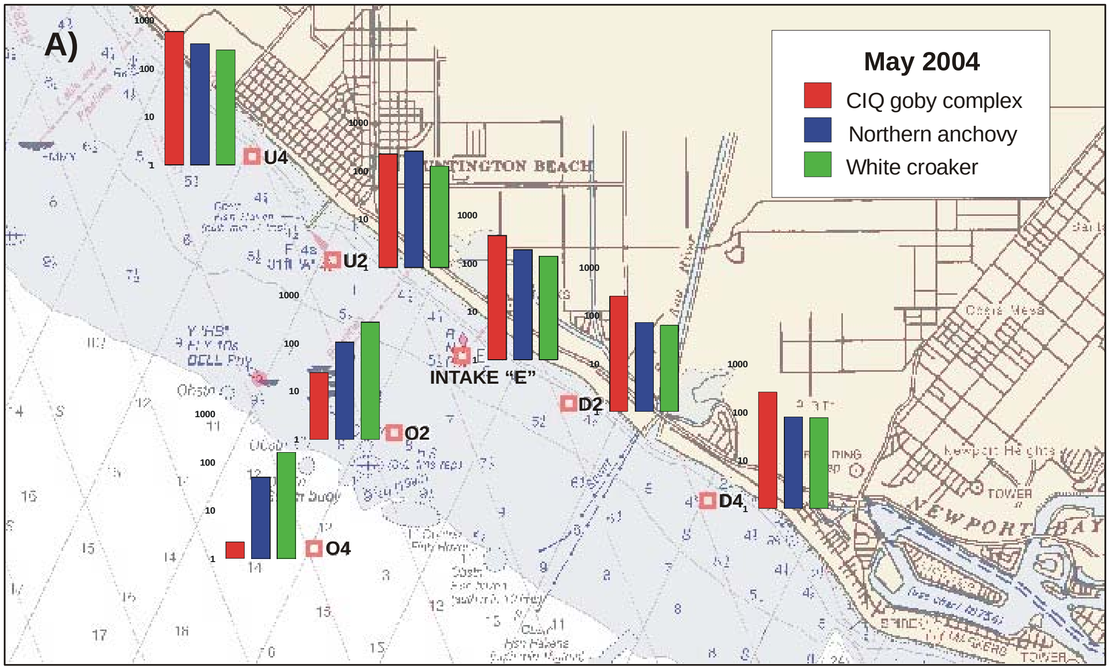


Figure 4-12. Concentrations (No. per 1,000 m^3) of larval CIQ gobies, northern anchovy, and white croaker at entrainment and source water stations in (A) March 2004 and (B) April 2004. Abundances are plotted on a logarithmic scale.



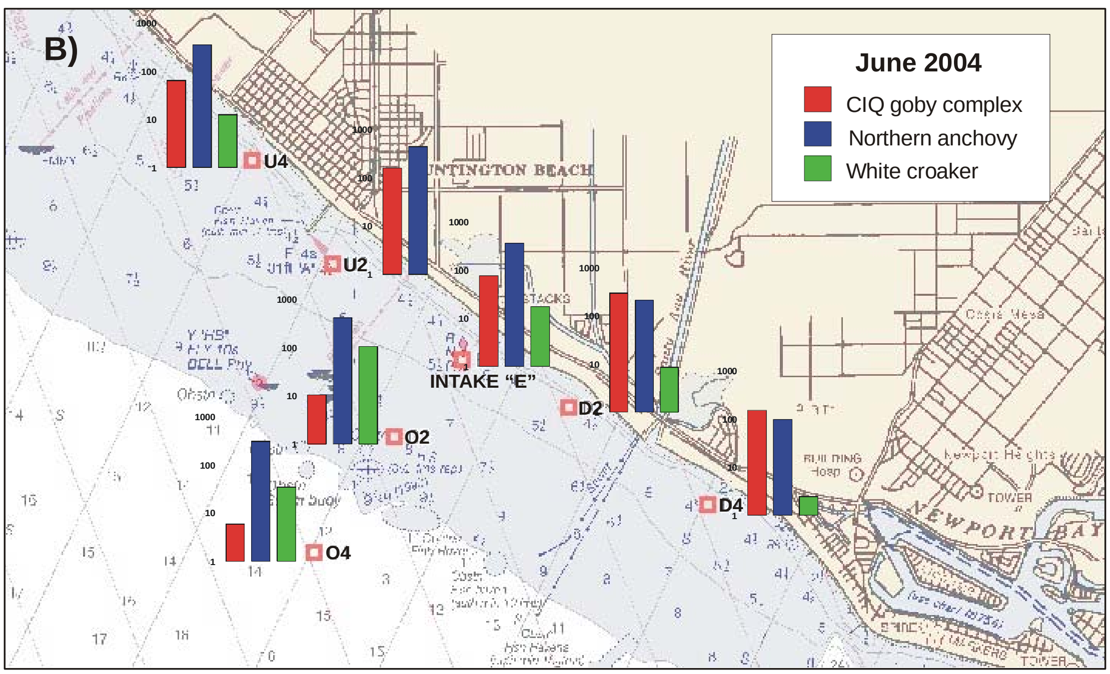


Figure 4-13. Concentrations (No. per 1,000 m^3) of larval CIQ gobies, northern anchovy, and white croaker at entrainment and source water stations in (A) May 2004 and (B) June 2004. Abundances are plotted on a logarithmic scale.

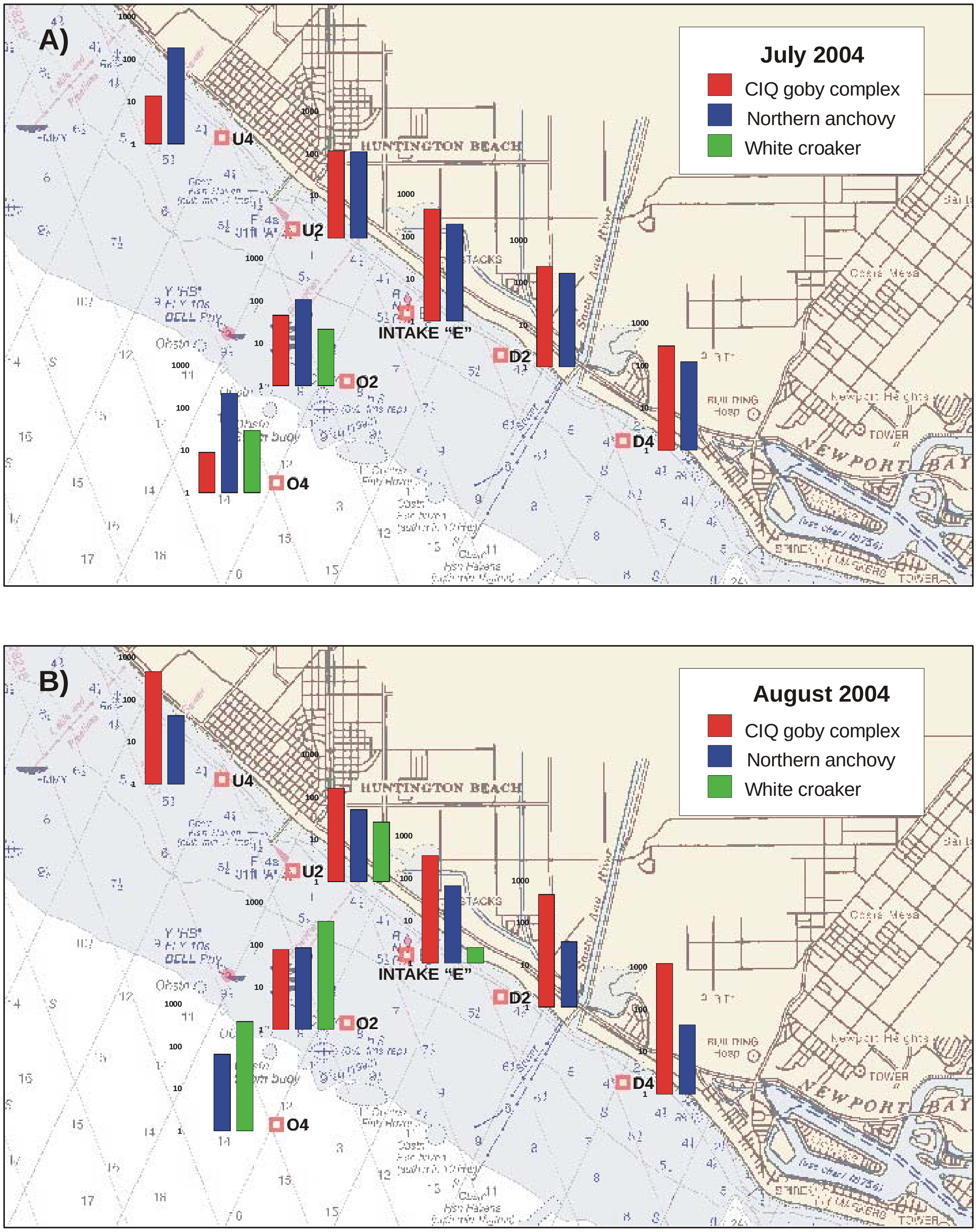


Figure 4-14. Concentrations (No. per 1,000 m^3) of larval CIQ gobies, northern anchovy, and white croaker at entrainment and source water stations in (A) July 2004 and (B) August 2004. Abundances are plotted on a logarithmic scale.

4.5.4 Results by Species for Cooling Water Intake Structure Entrainment

Based on their abundance in entrainment samples, the larval fish taxa that comprised the top 92% of total abundance were selected for detailed analysis. This included 10 taxa, including CIQ gobies, spotfin croaker, anchovies, queenfish, white croaker, salema, combtooth blennies, black croaker, diamond turbot, and California halibut. Additionally, the target invertebrate taxa were also analyzed, including sand crab, California spiny lobster, ridgeback rock shrimp, market squid, and rock crabs.

4.5.4.1 Unidentified Gobies: CIQ Goby Complex

The family Gobiidae is the largest family of marine fishes, comprised of about 1,875 species in 212 genera (Nelson 1994; Moser 1996). In the CalCOFI study area (from northern California to southern Baja California), 21 species in 16 genera have been collected (Moser 1996). In southern California, 14 species of gobies occur in nearshore waters, and 11 are considered common (Miller and Lea 1972). Tidewater goby (*Eucyclogobius newberryi*) is listed as federally endangered, but is not known to occur in the Huntington Beach area. The nearest known populations of tidewater gobies to HBGS are in Malibu Creek (Los Angeles County) and in San Mateo Lagoon (San Diego County) (Swift, pers. comm. 2002; Gutierrez 2003). Longtail goby (*Ctenogobius sagittula*) is considered rare in southern California (Miller and Lea 1972), and prior to 1998 was not collected in California since the early 1900s. However, during the warm-water years of 1997-98, several longtail gobies were collected in southern California, including in Newport Bay and Long Beach Harbor (Lea and Rosenblatt 2000).

Larval gobiids are distinctive and unlikely to be confused with other larval fishes, but positive identification of larval gobies to the species level remains difficult. Three species cannot be differentiated with certainty during early larval stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*) (Moser 1996). All three of these species are considered common in southern California (Miller and Lea 1972), and arrow goby is known to occur in Talbert Marsh (Gorman et al. 1990). These three species were combined into the CIQ goby complex for analysis. The larvae of arrow goby, cheekspot goby, shadow goby, longjaw mudsucker (*Gillichthys mirabilis*), and yellowfin goby (*Acanthogobius flavimanus*) were collected in nearby Upper Newport Bay from 1997 to 1999 (MBC 1999). Juvenile or adult arrow goby, bay goby (*Lepidogobius lepidus*), longjaw mudsucker, yellowfin goby, and cheekspot goby were also collected from Upper Newport Bay (MBC 1999). Descriptions of the life histories of arrow, cheekspot, and shadow goby were compiled by Brothers (1975) and were used to parameterize the models used in the following analysis.

4.5.4.1.1 Habitat Requirements

Most adult gobies are small (<10 cm [3.9 in]) and inhabit bays, estuaries, lagoons, and nearshore open coastal waters (Allen 1985, Moser 1996). Marine gobies occupy a variety of habitats, including mudflats and reefs. Many of the soft-bottom species live in burrows. In southern California, arrow gobies use the burrows constructed by bay ghost shrimp (*Neotrypaea californiensis*) to flee predators or to escape aerial exposure at low tides (Brothers 1975). Shadow gobies construct burrows that are usually near eelgrass (*Zostera marina*) or below mats of *Ulva* or *Enteromorpha*. The cheekspot goby also constructs burrows as a refuge from predators, to escape aeration, and as a brood site for eggs guarded by the male. Bay gobies are typically found on the middle and outer shelf (Allen et al. 2002) and are also common in the Los Angeles-Long Beach Harbor complex (MBC 2002a, b).

4.5.4.1.2 Reproduction

Arrow gobies mature at one year, but cheekspot and shadow gobies mature at about three years (Brothers 1975). Gobies are oviparous, and the demersal eggs are elliptical, typically adhesive, and about 2–4 mm (0.08-0.16 in) long (Moser 1996). Parental care of the nests is common, though the arrow goby does not guard its nest. Primary spawning activity of arrow goby occurs from March through June (Prasad 1958). Protracted spawning is likely in arrow, shadow, and cheekspot gobies (Brothers 1975). High abundances of arrow goby larvae in southern California were seen from March to September corresponding to the timing of settlement (Brothers 1975). Settlement of shadow and cheekspot goby occurs in late summer and early fall (Brothers 1975).

4.5.4.1.3 Age and Growth

The arrow goby grows faster than the cheekspot and shadow goby (Brothers 1975). After maturity, however, the growth rate in the arrow goby levels off. Shadow and cheekspot gobies settle at smaller sizes and grow more slowly, but the growth rate is relatively constant for their entire life. Shadow and cheekspot gobies live up to four years, while arrow goby rarely live longer than three years. In southern California, arrow gobies reach maximum lengths of 32 mm (1.25 in), shadow gobies reach 40 mm (1.57 in), and cheekspot 46 mm (1.8 in) (Brothers 1975). Brothers (1975) estimated that the population mortality of arrow gobies in Mission Bay following settlement was 91% in the first year and nearly 99% thereafter. He also calculated that the annual mortality rates after settlement were 66–74% for cheekspot gobies, and 62–69% for shadow gobies.

CIQ goby larvae hatch at a size of 2–3 mm (0.08-0.12 in) (Moser 1996). Using data available in Brothers (1975), the average growth rate of this group was estimated at 0.16 mm/day (0.006 in/day) for the 60-day period from hatching until settlement. Brothers (1975) estimated that larval mortality for this period was 98.3% for arrow gobies, 98.6% for cheekspot, and 99.2% for shadow. Based on the total mortality for this period average daily survival was calculated at 0.93 for the three species. Juveniles settle to the bottom at a size of about 10–15 mm (0.39-0.59 in) SL (Moser 1996)

4.5.4.1.4 Population Trends and Fishery

There is no known recreational or commercial goby fishery in southern California. No population estimates or trends are available for southern California gobies. Densities of arrow goby have been reported for two locations within 22 km (13.7 mile) of the HBGS. During the final year of a five-year monitoring project, MBC (2003) reported seasonal densities of 0.72 to 4.53 individuals/m^2 at the Golden Shore Marine Reserve. The study site was a created wetland at the mouth of the Los Angeles River. At Anaheim Bay, MacDonald (1975) reported densities of arrow goby of 4 to 5 individuals/m^2, though investigation of individual burrows resulted in much higher densities (up to 20 fishes per m^2).

4.5.4.1.5 Sampling Results

The CIQ goby complex larvae were the most abundant taxon collected during this study from both the entrainment and source water stations, comprising 37% of the total larvae collected (Tables 4-1 and 4-3). CIQ gobies were abundant at the entrainment station throughout the sampling period but were in highest abundance during July (Figure 4-15a). Mean abundance in the source water samples was highest in the September survey and lowest during the November survey (Figure 4-15b). The source water stations weren’t sampled during the July survey when the highest abundances occurred at the entrainment station. The number and concentration of larval CIQ gobies collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution of measured CIQ gobies (Figure 4-16) illustrates that the majority of the larvae were recently hatched based on the reported hatch length of 2–3 mm (0.08-0.12 in) (Moser 1996). The mean, maximum, and minimum sizes for the measurements were 3.8, 19.2, and 1.9 mm (0.15, 0.76, 0.08 in), respectively. A larval growth rate of 0.16 mm/day (0.006 in/day) was estimated from Brothers (1975) using his reported transformation lengths for the three species and an estimated transformation age of 60 days. The difference in the lengths of the first (1.9 mm [0.08 in]) and 95th (7.4 mm [0.29 in]) percentiles of the measurements was used with the larval growth rate to estimate that the larvae were exposed to entrainment for a period of 34.4 days.

4.5.4.1.6 Impact Assessment

The following sections present the results for demographic and empirical transport modeling of the effects of the HBGS circulating water system. A comprehensive comparative study of the three goby species in the CIQ complex by Brothers (1975) provided the necessary life history information for both the *FH* and *AEL* demographic models. Total entrainment was estimated at approximately 113 million larvae for the period of September 2003 through August 2004. The estimated mean entrainment concentration per survey was variable, ranging from zero to about 490 CIQ goby larvae per 1,000 m^3 (Figure 4-15a).

*4.5.4.1.6.1 Fecundity Hindcasting (*FH*)*

The entrainment estimate for CIQ gobies for the September 2003 through August 2004 study period was used to estimate the number of breeding females needed to produce the number of larvae entrained (Table 4-1). No estimates of egg survival for gobies were available, but because egg masses in gobies are demersal (Wang 1981) and parental care, usually provided by the adult male, is common in the family (Moser 1996), egg survival is probably high and was assumed to be 100%. Estimates of larval survival for the three species from Brothers (1975) were used to estimate an average daily survival of 0.93. Survival to the average age at entrainment (11.6 days) was then estimated as $0.93^{11.6} = 0.44$. An average batch fecundity estimate of 615 eggs was based on calculations from Brothers (1975) on size-specific fecundities for the three species. Brothers (1975) found eggs with two to three different vitellogenic stages in the ovaries. Therefore, an estimate of 2.5 spawns per year was used in calculating *FH* (615 eggs/spawn times 2.5 spawns/year = 1,538 eggs/year). Average ages of maturity and longevity of 1.0 and 3.3 years, respectively, from Brothers (1975) for the three species were used in the model.

The estimated number of adult females whose lifetime reproductive output was entrained through the HBGS circulating water system for the September 2003 – August 2004 study period was 101,269 (Table 4-6). The results show that the variation in our estimate of entrainment had much less of an effect on the range of the *FH* estimate than the life history parameters used in the model.

Table 4-6. Results of *FH* modeling for CIQ goby complex larvae entrained during the September 2003 – August 2004 sampling period. The upper and lower estimates are based on a 90% confidence interval of the mean. The upper and lower estimates for total entrainments were calculated by using the range of entrainment estimates in the *FH* calculations.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	101,269	89,398	23,703	432,662	408,959
Total Entrainment	113,166,834	19,372,798	72,751	129,787	57,035

4.5.4.1.7 Adult Equivalent Loss (*AEL*)

The parameters required for calculating *AEL* include larval survival from entrainment to settlement and survival from settlement to the average age of reproduction for a mature female. Larval survival from mean age at entrainment through settlement was estimated as $0.93^{60-11.6} = 0.03$ using the same daily survival rate used in formulating *FH*. Brothers (1975) estimated that mortality in the first year following settlement was 99% for arrow, 66–74% for cheekspot, and 62–69% for shadow goby. These estimates were used to calculate a daily survival of 0.995 that was used to estimate a finite survival of 0.21 for the first year following settlement. Daily survival through the average female age of 1.71 years from life table data for the three species (Brothers 1975) was estimated as 0.994 and was used to calculate a finite survival of 0.195.

The estimated number of larvae entrained through the HBGS circulating water system for the September 2003 – August 2004 study period was used to calculate an estimate of 147,493 equivalent adults (Table 4-7). The results show that the variation in our estimate of entrainment had much less of an effect on the variation of the *AEL* estimate than the life history parameters used in the model. If all of our life history parameters and assumptions regarding lifetime fecundity were accurate the *AEL* estimate should approximately equal twice the *FH* estimate. The results show that $2 \cdot FH$ is approximately 35% greater than the *AEL* estimate, but is within the range of the 90% confidence interval around the estimate.

Table 4-7. Results of *AEL* modeling for CIQ goby complex larvae entrained during the September 2003-August 2004 sampling period. The upper and lower estimates are based on a 90% confidence interval of the mean. The upper and lower estimates for total entrainments were calculated by using the range of entrainment estimates in the *AEL* calculations.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
AEL	147,493	167,545	22,763	955,676	932,913
Total Entrainment	113,166,834	19,372,798	105,958	189,027	83,069

4.5.4.1.8 Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for CIQ gobies was based on the difference between the lengths of the 1st (1.9 mm [0.08 in]) and 95th (7.4 mm [0.29 in]) percentiles and a growth rate of 0.16 mm/day (0.006 in/day). These values were used to estimate that CIQ goby larvae were vulnerable to entrainment for a period of approximately 34 days.

The *PE* estimates used to calculate *ETM* estimates for CIQ gobies for the September 2003 – August 2004 ranged from 0.0003 to 0.006 (Table 4-8). The average *PE* was very close to the ratio of the entrainment volume to source water volume of 0.0021. The values of f_i show that the highest numbers of CIQ goby larvae were collected during the August 2004 survey. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. These two estimates of P_M were identical for CIQ gobies because the densities decreased with increasing distance offshore resulting in an extrapolated density of zero that was inside the limits of the sampling area (Table 4-9). Therefore the P_S estimate for the extrapolated offshore P_M was calculated with only alongshore current displacement; the same data used for the alongshore estimate. The estimate of P_M for the 34-day period of exposure was 0.0099 (0.99%) over an area that was estimated to extend 60.9 km (37.8 mile) alongshore.

Table 4-8. *ETM* data for CIQ goby complex larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00248	0.00250	0.09340	0.06636
13-Oct-03	0.00138	0.00217	0.15955	0.10306
10-Nov-03	0.00115	0.00245	0.00218	0.00179
8-Dec-03	0.00034	0.00054	0.07560	0.07003
5-Jan-04	0.00264	0.00380	0.03845	0.02670
9-Feb-04	0.00069	0.00073	0.06557	0.05367
8-Mar-04	0.00138	0.00191	0.09670	0.08870
5-Apr-04	0.00417	0.00549	0.01810	0.01134
3-May-04	0.00381	0.00307	0.09705	0.05630
1-Jun-04	0.00156	0.00178	0.05763	0.04882
12-Jul-04	0.00608	0.00901	0.10986	0.08383
31-Aug-04	0.00185	0.00237	0.18591	0.18621
Average =	0.00229			

Table 4-9. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for CIQ gobies. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1714 (60.9)	0.00993	0.29534	0.30527	0
Offshore Extrapolated	0.1714	0.00993	0.29534	0.30527	0

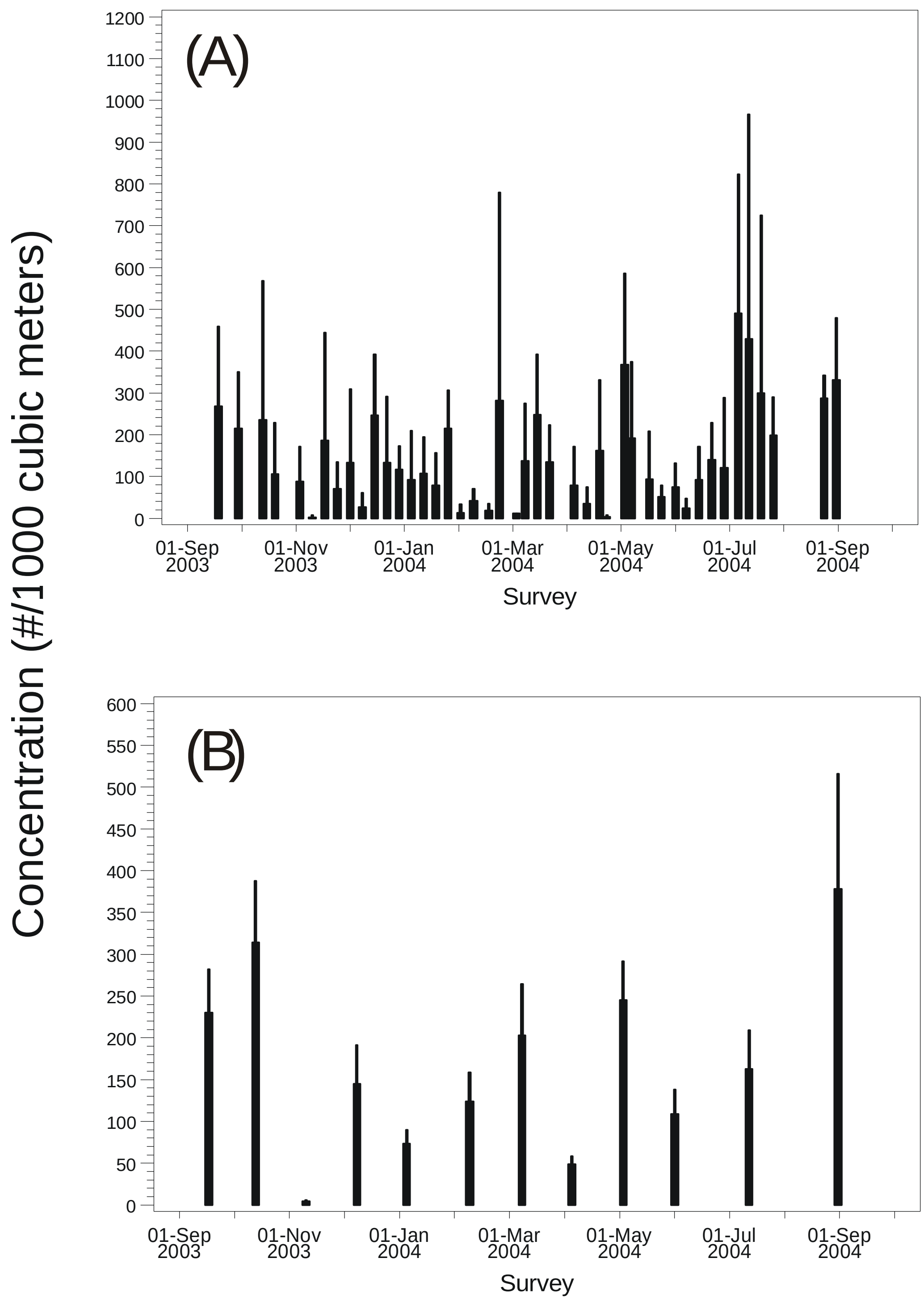


Figure 4-15. Survey mean concentration (#/1000 m^3) of CIQ goby larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Note that the Y-axis range is different on the two graphs.

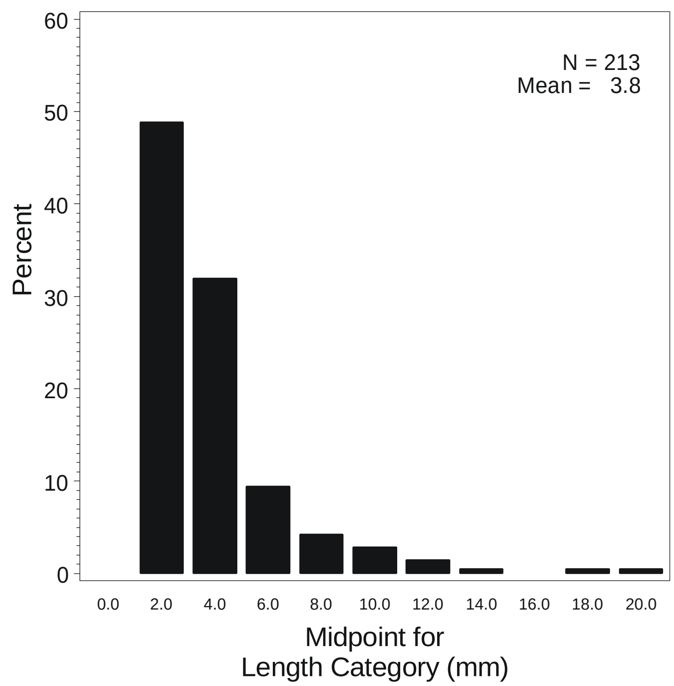


Figure 4-16. Length frequency distribution (mm) of CIQ goby larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.2 Northern Anchovy (*Engraulis mordax*)

Northern anchovy (*Engraulis mordax* Girard 1854) range from Cape San Lucas, Baja California to Queen Charlotte Island, British Columbia, and offshore to 480 km (298.3 mile) (Hart 1973). They are most common from Magdalena Bay, Baja California to San Francisco Bay and within 157 km (97.6 mile) of shore (Hart 1973; MBC 1987). Northern anchovy is one of four species of anchovies (Family Engraulidae) that occurs off California (Miller and Lea 1972). Deepbody anchovy (*Anchoa compressa*) and slough anchovy (*Anchoa delicatissima*) are found in the vicinity of the HBGS, while the anchoveta (*Cetengraulis mysticetus*) is considered rare north of Magdalena Bay, Baja California.

Three genetically distinct subpopulations are recognized for northern anchovy; (1) Northern subpopulation, from northern California to British Columbia; (2) Central subpopulation, off southern California and northern Baja California; and (3) Southern subpopulation, off southern Baja California (Emmett et al. 1991).

4.5.4.2.1 Habitat Requirements

The reported depth range of northern anchovy is from the surface to depths of 300 m (984 ft) (PFMC 1983). Juveniles are generally more common inshore and in estuaries. Eggs are found from the surface to 50 m (164 ft), and larvae are found from the surface to 75 m (246 ft) in epipelagic and neritic waters (Garrison and Miller 1982). Northern anchovy larvae feed on dinoflagellates, rotifers, and copepods (MBC 1987). Juveniles and adults feed on zooplankton, including planktonic crustaceans and fish larvae (Fitch and Lavenberg 1971; Frey 1971; Hart 1973; PFMC 1983). Northern anchovy feed largely during the night, though they were previously thought to feed during the day (Allen and DeMartini 1983).

4.5.4.2.2 Reproduction

Northern anchovy spawn throughout the year off southern California, with peak spawning between February and May (Brewer 1978). Most spawning takes place within 100 km (62.1 mile) from shore (MBC 1987). On average, female anchovies off Los Angeles spawn every 7 to 10 days during peak spawning periods, approximately 20 times per year (Hunter and Macewicz 1980, MBC 1987). In 1979, it was determined that most spawning occurs at night (2100 to 0200 hr), with spawning complete by 0600 hr (Hunter and Macewicz 1980). Northern anchovies off southern and central California can reach sexual maturity by the end of their first year of life, with all individuals being mature by four years of age (Clark and Phillips 1952; Daugherty et al. 1955; Hart 1973). Bergen and Jacobsen (2001) stated that they are mature by two years of age, and that maturation of younger individuals is dependent on water temperature. Love (1996) reported that they release 2,700-16,000 eggs per batch, with an annual fecundity of up to 130,000 eggs per year in southern California. Parrish et al. (1986) and Butler et al. (1993) stated that the total annual fecundity for one-year old females was 20,000-30,000 eggs, while a five-year old could release up to 320,000 eggs per year.

4.5.4.2.3 Age and Growth

The northern anchovy egg hatches in two to four days, has a larval phase lasting approximately 70 days, and undergoes transformation into a juvenile at about 35–40 mm (1.4-1.6 in) (Hart 1973; MBC 1987, Moser 1996). Larvae begin schooling at 11 to 12 mm (0.43-0.47 in) SL (Hunter and Coyne 1982). Northern anchovy reach 102 mm (4 in) in their first year, and 119 mm (4.7 mm) in their second (Sakagawa and Kimura 1976). Growth in length is most rapid during the first four months, and growth in weight is most rapid during the first year (Hunter and Macewicz 1980; PFMC 1983). They mature at 78 to 140 mm (3.1 to 5.5 in) in length, in their first or second year (Frey 1971; Hunter and Macewicz 1980). Maximum size is about 230 mm (9 in) and 60 g (2.1 ounces) (Fitch and Lavenberg 1971; Eschmeyer et al. 1983). Maximum age is about seven years (Hart 1973), though most live less than four years (Fitch and Lavenberg 1971).

4.5.4.2.4 General Ecology

Northern anchovy are random planktonic feeders, filtering plankton as they swim (Fitch and Lavenberg 1971). They feed mostly on larval crustaceans, but also on fish eggs and larvae (Fitch and Lavenberg 1971). Temperatures above 25°C (77°F) are avoided by juveniles and adults (Brewer 1974). Numerous fishes and marine mammals feed on northern anchovy. Elegant tern and California brown pelican production is strongly correlated with abundance of northern anchovy (Emmett et al. 1991).

Larval survival is strongly influenced by the availability and concentration of appropriate phytoplankton species (Emmett et al. 1991). Storms and strong upwelling reduce larval food availability, and strong upwelling may transport larvae out of the Southern California Bight (Power 1986). However, strong upwelling may benefit juveniles and adults.

4.5.4.2.5 Population Trends and Fishery

Northern anchovy are fished commercially for reduction (e.g., fish meal, oil, and paste) and live bait (Bergen and Jacobsen 2001). This species is the most important bait fish in southern California, and is also used in Oregon and Washington as bait for sturgeon (*Acipenser* spp.), salmonids (*Oncorhynchus* spp.), and other species (Emmett et al. 1991). Northern anchovy populations increased dramatically during the collapse of the Pacific sardine (*Sardinops sagax*) fishery, suggesting competition between these two species (Smith 1972).

Estimates of the central subpopulation averaged about 325,700 metric tons (MT) (359,000 tons) from 1963 through 1972, then increased to over 1,542,200 MT (1.7 million tons) in 1974, then declined to 325,700 MT (359,000 tons) in 1978 (Bergen and Jacobsen 2001). Anchovy biomass in 1994 was estimated at 391,900 MT (432,000 tons). The stock is thought to be stable, and the size of the anchovy resource is largely dependent on natural influences such as ocean temperature.

In the seven commercial Catch Blocks off Huntington Beach, northern anchovy were reported in landings from five blocks from 1999 through 2001 (CDFG 2002). Maximum annual landings in Catch Block 738 by weight were in 2000 (355,029.9 kg [782,707 lbs] worth $32,760). During the three-year period 1999–2001, northern anchovy were among the top five species landed (by weight) in all five blocks.

4.5.4.2.6 Sampling Results

Engraulidae larvae (over 95% northern anchovy) were the second most abundant taxon at the entrainment and source water stations during the September 2003 through August 2004 sampling period (Tables 4-1 and 4-3). The larvae that were identified as Engraulidae, and not northern anchovy, were either very small or damaged specimens and could not be identified beyond the family level. The estimated mean entrainment concentration per survey was variable, ranging from zero to almost 400 larvae per 1,000 m^3 with high abundances in May, June and July (Figure 4-17a). Highest mean abundances of larvae sampled in the source water occurred in June 2004 (about 320 larvae per 1000 m^3), while abundances were low in January and February 2004 (Figure 4-17b). The number and concentration of larval northern anchovies collected during each entrainment and source water survey are presented in an appendix to this report.

The length frequency distribution of measured northern anchovy larvae show a bimodal distribution with approximately 20% being recently hatched larvae based on the reported hatch length of 2–3 mm (0.08-0.12 in) (Moser 1996) and a large number of larger larvae ranging from 8–16 mm (0.31-0.63 in) (Figure 4-18). The mean, maximum, and minimum sizes for the measurements were 10.6, 26.2, and 1.4 mm (0.42, 1.03, 0.06 in), respectively. A larval growth rate of 0.49 mm/day (0.02 in/day) was estimated from Methot and Kramer (1979) and used with the difference in the lengths of the first (1.7 mm [0.07 in]) and 95th (20.2 mm [0.79 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of approximately 38 days.

4.5.4.2.7 Impact Assessment

The following sections present the results for demographic and empirical transport modeling of circulating water system effects on northern anchovy larvae. Total entrainment was estimated at 54.3 million larvae for the study period.

4.5.4.2.8 Fecundity Hindcasting (*FH*)

The entrainment estimate for northern anchovy for the September 2003 – August 2004 sampling period was used to estimate the number of breeding females needed to produce the estimated number of larvae entrained (Table 4-10). Butler et al. (1993) modeled annual fecundity and egg and larval survivorship for northern anchovy. Their “best” estimate can be derived by fitting the range of mortality estimates from field collections to the assumption of a stable and stationary population age structure. Instantaneous daily mortality estimates from Butler et al. (1993) were converted, over their average stage durations, to finite survivorship rates for each developmental stage. Egg survival for the period of 2.9 days was estimated as 0.51 using an instantaneous mortality rate of 0.23 from Butler et al. (1993). Fishes at the mean age of entrainment include yolk sac, early, and late stage larvae. Therefore, survival estimates for all three stages were combined to obtain a finite survival value up to the mean age at entrainment (18.3 days) of 0.015.

Clark and Phillips (1952) reported age at sexual maturity as 1–2 years. Similarly, Bergen and Jacobsen (2001) report that 47 to 100% of one-year olds may be mature in a given year while all are mature by two years. For modeling purposes we used a mid-value of 1.5 years. For longevity, Hart (1973) reports a value of seven years, but Bergen and Jacobsen (2001) state that northern anchovy in the fished population rarely exceed four years of age. A value of four years was used to represent the most likely reproductive life span. The reproductive life span was used to estimate an average annual fecundity of 147,622 over the four-year period using the data presented in Butler et al. (1993).

The estimated number of adult female northern anchovies whose lifetime reproductive output was entrained through the HBGS circulating water system for the September 2003 –August 2004 study period was 26,745 (Table 4-10). The results show that the variation in our estimate of entrainment had much less of an effect on the variation of the *FH* estimate than the life history parameters used in the model.

Table 4-10. Results of *FH* modeling for northern anchovy larvae entrained during the September 2003-August 2004 sampling period. The upper and lower estimates are based on a 90% confidence interval of the mean. The upper and lower estimates for total entrainments were calculated by using the range of entrainment estimates in the *FH* calculations.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	26,745	24,093	6,076	117,715	111,638
Total Entrainment	54,349,017	13,485,655	15,828	37,661	21,833

4.5.4.2.9 Adult Equivalent Loss (*AEL*)

The larval entrainment estimate for northern anchovy was used to estimate the number of equivalent adults lost to entrainment. Stage-specific instantaneous mortality rates used to compute finite survival were estimated from the life table produced by Butler et al. (1993) in which survivorship from larvae to recruitment was apportioned into several developmental stages. *AEL* was estimated for the average age of sexually mature females (2.75 years; midpoint between 1.5 and 4 years) used in the *FH* model estimates.

The estimated number of adult northern anchovies equivalent to the number of larvae entrained through the HBGS circulating water system for the one-year study period was 304,125 (Table 4-11). The results show that the variation in our estimate of entrainment had much less of an effect on the variation of the *AEL* estimate than the life history parameters used in the model. If all of our life history parameters and assumptions regarding lifetime fecundity were accurate the *AEL* estimate should approximately equal twice the *FH* estimate. The results show that the range of *AEL* estimates greatly exceed the *FH* estimate although the large range of the estimate does encompass the *FH* estimate. The large range also indicates the high level of uncertainty associated with the life history parameters that are available and used in the model.

Table 4-11. Results of *AEL* modeling for northern anchovy larvae entrained during the September 2003 – August 2004 sampling period. The upper and lower estimates are based on a 90% confidence interval of the mean. The upper and lower estimates for total entrainments were calculated by using the range of entrainment estimates in the *AEL* calculations.

Parameter	Estimate	Std. Error	*AEL* Lower Estimate	*AEL* Upper Estimate	*AEL* Range
AEL	304,125	359,787	43,439	2,129,225	2,085,785
Total Entrainment	54,349,017	13,485,655	179,989	428,261	248,273

4.5.4.2.10 Empirical Transport Model (*ETM*)

The *PE* estimates used to calculate *ETM* for northern anchovies for the September 2003 – August 2004 study period ranged from 0.001 to 0.004 (Table 4-12). The average *PE* was very close to the ratio of the entrainment volume to source water volume of 0.0021. As shown in the values of f_i the largest abundance of anchovy larvae were collected during the June 2004 survey. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 38-day period of exposure calculated using offshore extrapolated densities (0.007, 0.7%) is less than the estimate calculated using alongshore current displacement (0.012, 1.2%) because of the larger overall volume of the source area calculated due to the offshore extrapolation (Table 4-13). The P_S estimates indicate that the ratio of the sampled source water to the total population for the offshore and alongshore P_M estimates were 4.5 and 15.5%, respectively. The alongshore estimate of P_M was extrapolated over a shoreline distance of 72.0 km (12.6 mile).

Table 4-12. *ETM* data for northern anchovy larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* > 0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00366	0.00465	0.03292	0.03400
13-Oct-03	0.00193	0.00261	0.07234	0.04127
10-Nov-03	0.00148	0.00160	0.03914	0.02047
8-Dec-03	0.00308	0.00393	0.01453	0.01320
5-Jan-04	0.00279	0.00509	0.00852	0.01003
9-Feb-04	0.00150	0.00342	0.00352	0.00391
8-Mar-04	0.00381	0.00727	0.01642	0.01736
5-Apr-04	0.00119	0.00166	0.05654	0.02337
3-May-04	0.00304	0.00348	0.12008	0.06606
1-Jun-04	0.00249	0.00347	0.34788	0.14091
12-Jul-04	0.00246	0.00250	0.23432	0.09584
31-Aug-04	0.00241	0.00335	0.05380	0.02862
Average =	0.00249			

Table 4-13. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for northern anchovy. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1450 (72.0)	0.01242	0.22369	0.23610	0
Offshore Extrapolated	0.0450	0.00713	0.21241	0.21954	0

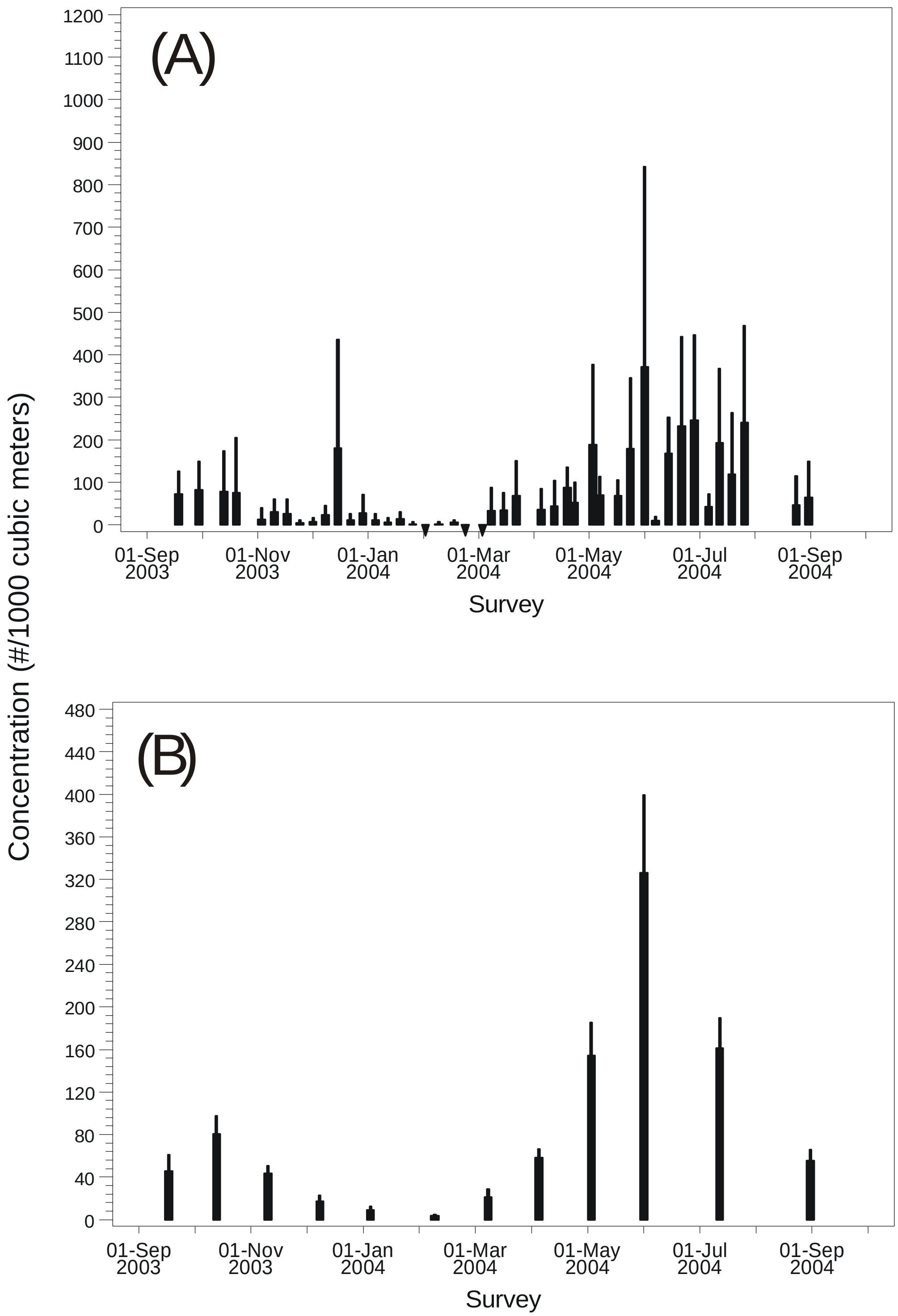


Figure 4-17. Survey mean concentration (#/1000 m^3) of northern anchovy larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no northern anchovy larvae were collected.

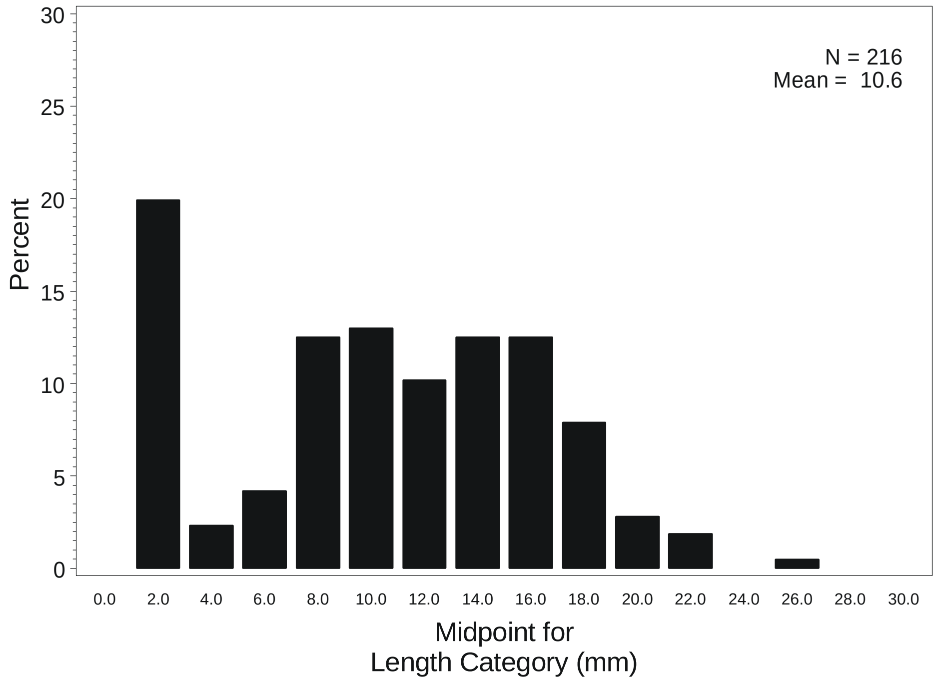


Figure 4-18. Length frequency distribution (mm) of northern anchovy larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.3 Spotfin Croaker (*Roncador stearnsii*)

Spotfin croaker (*Roncador stearnsii*) is a croaker (Family Sciaenidae) common to the San Diegan fauna, which ranges from Mazatlan, Mexico to Point Conception, California, including the Gulf of California and occurs in depths ranging from the surf zone to 17 m (55.8 ft) (Miller and Lea 1972). Seven species of croaker, in addition to spotfin croaker, are common to the Southern California Bight (SCB). These include white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), yellowfin croaker (*Umbrina roncador*), white seabass (*Atractoscion nobilis*), California corbina (*Menticirrhus undulatus*), black croaker (*Cheilotrema saturnum*), and shortfin corvina (*Cynoscion parvipinnis*) (Miller and Lea 1972). Two species [orangemouth corvina (*Cynoscion xanthulus*) and bairdiella (*Bairdiella icistia*)] are currently believed to be restricted to the Salton Sea, California (Nelson et al. 2004). Individuals from all species common to coastal California waters, except shortfin corvina, have been observed in impingement samples at HBGS since 1979 (MBC 2004).

4.5.4.3.1 Habitat Requirements

Pondella and Allen (2000) noted a predominantly coastal distribution throughout the SCB, indicated by an absence in samples from the California Channel Islands. Allen (1985) indicated spotfin croaker to be a common member of the open-coast, sandy-beach ichthyofauna, with seasonal occurrences in bays and harbors within the SCB. Love et al. (1984) observed spotfin croaker primarily on the 6.1-m (20-ft) isobath over soft-substrate, with diminishing abundances with increasing depth. Limbaugh (1955) reported sporadic occurrences of spotfin croaker in the rocky bottom/kelp bed biotope. Valle and Oliphant (2001) noted spotfin croaker prefer depressions in the sandy bottom in water depths greater than 3 m.

4.5.4.3.2 Reproduction

Spotfin croaker is an oviparous broadcast spawner with pelagic eggs and larvae (Moser 1996). Gonosomatic index (GSI [gonad weight expressed as percent of gonad-free body weight]) peaked for both sexes in June (Miller et al. in prep a), while peak larval abundances were observed from June to September (Moser 1996). Although usually found in small groups (< 5 individuals), observations have been made of large aggregations (> 50 individuals; Feder et al. 1974). Initially thought to migrate offshore to spawn (Valle and Oliphant 2001), recent observations within the SCB indicate an inshore spawning ground, such as Seal Beach, California, based on seasonal fluctuations in catch per unit effort and GSI (Miller et al. in prep a). Within spawning aggregations, gender ratios were significantly skewed towards males with nearly a 10:1 male to female ratio (Miller et al. in prep a). In groups not exhibiting reproductive activity (high GSI), the gender ratio is nearly 1:1 (Miller et al. in prep a). Valle and Oliphant (2001) estimated males to mature at two years old and 228.5 mm (8.9 in) SL, while females mature, on average, in their third year and 317.4 mm (12.5 in) SL.

4.5.4.3.3 Age and Growth

At hatching, spotfin croaker yolk sac larvae are 2.1 mm (0.08 in) NL (notochord length), 5.5 mm (0.22 in) NL at flexion, and greater than 11 mm (0.43 in) SL (standard length) at transformation (Moser

1996). Miller and Lea (1972) indicate the maximum length for spotfin croaker at 685.8 mm (25.9 in) SL. Joseph (1962) observed the maximum age for spotfin croaker at ten years based on scale aging. Spotfin croaker exhibit the greatest growth rate during the first and second year, with a mean increase of 100 mm (3.9 in) SL, quickly tapering off to less than 30 mm (1.2 in) SL per year after age five (Joseph 1962). No information on variation in growth by gender or mortality estimations is available for spotfin croaker.

4.5.4.3.4 General Ecology

Spotfin croaker feeds primarily on benthic invertebrates commonly found in sandy environments, such as clams and polychaetes, but also mysids (Joseph 1962). This species undergoes seasonal migrations, indicated by individuals tagged near Los Angeles, California and subsequently recaptured near Oceanside, California (Valle and Oliphant 2001). California corbina (*Menticirrhus undulatus*) is frequently encountered with spotfin croaker, due to the strong similarities in habitat affinities between the two species (Miller et al. in prep a). Within southern California, spotfin croaker populations are historically known to exhibit "runs" (Valle and Oliphant 2001) due to the formation of large aggregations, principally during spawning season (Miller et al. in prep a). Notably absent during the majority of the year near Seal Beach, California, spotfin croaker abundance rises dramatically between April and August, with peaks in abundance typically occurring in June (Miller et al. in prep a).

4.5.4.3.5 Population Trends and Fishery

Spotfin croaker is the least frequently impinged croaker at coastal generating stations within the SCB (Herbinson et al. 2001). Since 1977, four generating stations within the SCB between San Onofre and Redondo Beach have reported spotfin croaker in impingement samples (Herbinson et al. 2001). Based on these impingement samples, spotfin croaker populations in southern California have been low since 1983, although their abundance was less than all other croakers except white seabass (Herbinson et al. 2001). Nearshore gillnet sampling within the SCB has indicated a general rise in abundance, corresponding to a general rise in sea surface temperatures (Miller et al. in prep a).

Spotfin croaker has been reserved for recreational angling within California State waters since 1915, with a ban on the use of nets imposed in 1909 and a ban on commercial sale in 1915 (Valle and Oliphant 2001). Incidental catches were possible in the nearshore gillnet white seabass fishery, which was closed in 1992 by legislative action. Recreational angling, specifically surf-fishing, continues, as anglers enjoy greater success during periods of dense aggregation, such as spawning periods.

4.5.4.3.6 Sampling Results

Spotfin croaker larvae had the third highest mean concentration of all taxa collected in the entrainment samples for the study period with a mean concentration of 53.1 larvae per 1,000 m^3 (35,314.7 ft^3) (Table 4-1), but was relatively scarce in the combined source water samples with an overall mean concentration of only 1.6 larvae per 1000 m^3 (Table 4-3). The higher abundance in the entrainment samples resulted from very high concentrations of larvae during a single survey in August 2004 when the mean concentration was measured at over 1,800 larvae per 1000 m^3 (35,314.7 ft^3) (Figure 4-19a). The high, localized larval concentrations substantiate observations of nearshore spawning aggregations of spotfin croaker in summer. Spotfin croaker larvae in the source water samples were absent from September 2003 through April 2004 and were most abundant during August/September 2004 (Figure 4-19b). The number and concentration of larval spotfin croaker collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution of measured spotfin croaker larvae show an extremely limited size range dominated by recently hatched larvae based on the reported hatch length of 2.1 mm (0.08 in) (Moser 1996) (Figure 4-20). The mean, maximum, and minimum sizes for the measurements were 2.0, 2.5, and 1.3 mm (0.08, 0.1, and 0.5 in), respectively. A larval growth rate of 0.20 mm/day (0.008 in) for white croaker (Murdoch et al. 1989) was used with the difference in the lengths of the first (1.4 mm [0.06 in]) and 95th (2.4 mm [0.09 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 5 days.

4.5.4.3.7 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on spotfin croaker larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of life history information necessary to parameterize the models. A total of nearly 70 million spotfin croaker larvae was calculated to have been entrained through the HBGS cooling water system during the study.

4.5.4.3.8 Empirical Transport Model (*ETM*)

Only two *PE* estimates were calculated for spotfin croaker for the September 2003 – August 2004 study period (Table 4-14). These estimates do not necessarily reflect the actual abundance of spotfin croaker because the highest abundances occurred during surveys when only the entrainment station was sampled (Figure 4-19). In addition to the large temporal variation in abundances, during one of the paired entrainment source water surveys the larvae were collected at the source water stations but not at the entrainment station indicating that the larvae may also be patchily distributed. Even though there were only two estimates the average of the two was very close to the ratio of the entrainment volume to source water volume of 0.0021. The two P_M estimates, one based on alongshore current movement (0.003, 0.3%) and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement (0.003, 0.3%) (Table 4-15) are both low reflecting the short period of time (5 days) that the larvae were exposed to entrainment. The alongshore estimate of P_M was extrapolated over a shoreline distance of 16.9 km (10.5 mile), which was much less than the values for gobies or anchovies due to the shorter period of time the spotfin croaker larvae were exposed to entrainment.

Table 4-14. *ETM* data for spotfin croaker larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00000	0.00000	0.00000	0.00000
13-Oct-03	0.00000	0.00000	0.00000	0.00000
10-Nov-03	0.00000	0.00000	0.00000	0.00000
8-Dec-03	0.00000	0.00000	0.00000	0.00000
5-Jan-04	0.00000	0.00000	0.00000	0.00000
9-Feb-04	0.00000	0.00000	0.00000	0.00000
8-Mar-04	0.00000	0.00000	0.00000	0.00000
5-Apr-04	0.00000	0.00000	0.00000	0.00000
3-May-04	0.00361	0.00568	0.16060	0.19528
1-Jun-04	0.00000	0.00000	0.00000	0.00000
12-Jul-04	0.00000	0.00000	0.08960	0.15792
31-Aug-04	0.00046	0.00103	0.74979	0.26538
Average =	0.00204			

Table 4-15. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for spotfin croaker. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.6163 (16.9)	0.00294	0.36785	0.37079	0
Offshore Extrapolated	0.5981	0.00287	0.36778	0.37065	0

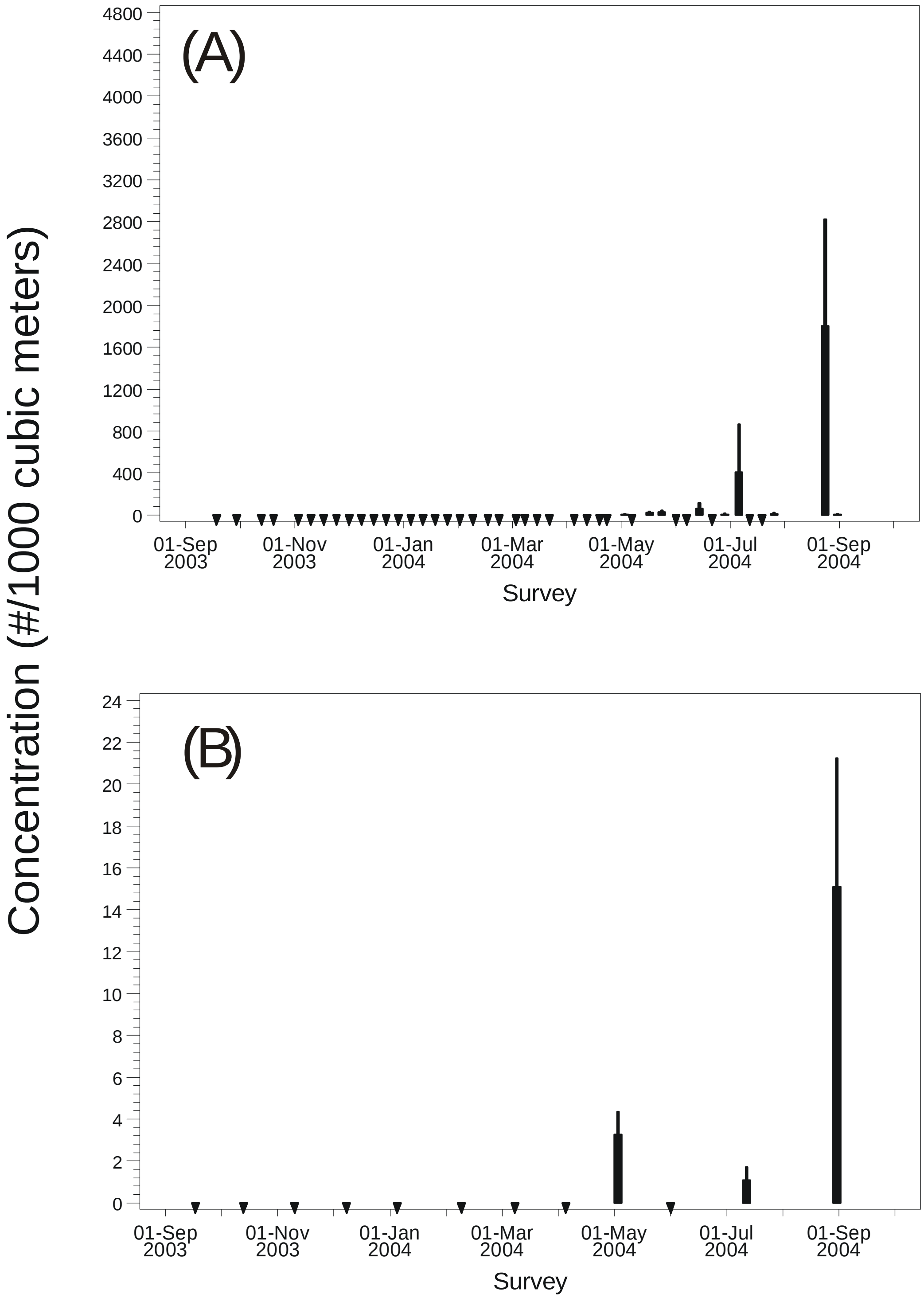


Figure 4-19. Survey mean concentration (#/1000 m^3) of spotfin croaker larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no spotfin croaker larvae were collected.

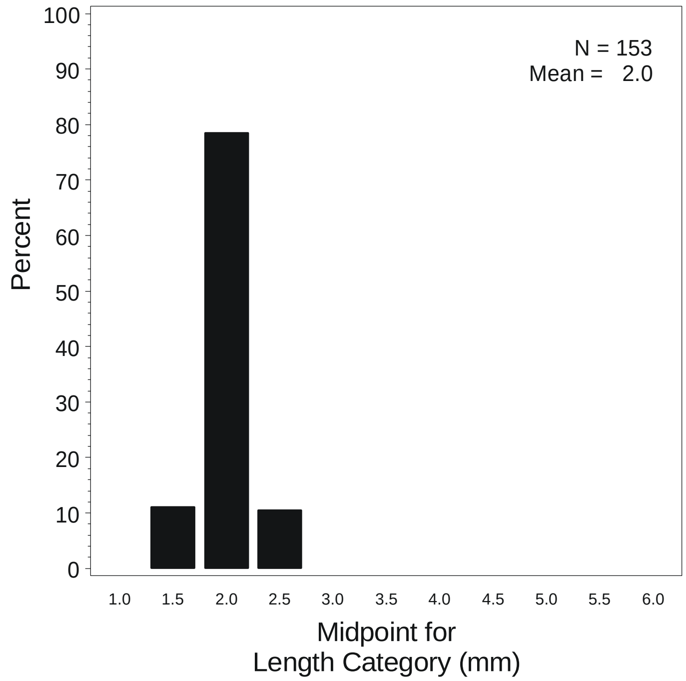


Figure 4-20. Length frequency distribution (mm) of spotfin croaker larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.4 Queenfish (*Seriphus politus*)

Queenfish (*Seriphus politus* Ayres 1860) range from west of Uncle Sam Bank, Baja California, north to Yaquina Bay, Oregon (Miller and Lea 1972). Queenfish are common in southern California, but rare north of Monterey. They are one of eight species of croaker or 'drums' (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), white croaker (*Genyonemus lineatus*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*). All but shortfin corvina have been collected in impingement samples at the HBGS since 1979 (MBC 2004).

4.5.4.4.1 Habitat Requirements

The reported depth range of queenfish is from the surface to depths of about 37 m (120 ft) (Miller and Lea 1972); however, in southern California, Allen (1982) found queenfish over soft bottoms between 10 and 70 m (32.8 and 229.7 ft), with highest abundance occurring at 10 m (32.8 ft). During the day, queenfish hover in dense, somewhat inactive schools close to shore, but disperse to feed in midwater after sunset (Hobson and Chess 1976). It is active throughout the night, and feeds several meters off the seafloor in small schools or as lone individuals.

4.5.4.4.2 Reproduction

Queenfish is a summer spawner. Goldberg (1976) found queenfish to enter spawning condition in April and spawn into August, while DeMartini and Fountain (1981) recorded spawning in queenfish between March and August. Spawning is asynchronous among females, but there are monthly peaks in intensity during the waxing (first quarter) of the moon (DeMartini and Fountain 1981). They also stated that mature queenfish spawn every 7.4 days on average, regardless of size. Duration of the spawning season is a function of female body size, ranging from three months (April–June) in recruit spawners to six months (March–August) in repeat spawners (>13.5 cm [5.3 in] SL). Based on the spawning frequency and number of months of spawning, these two groups of spawners can produce about 12 and 24 batches of eggs during their respective spawning seasons (DeMartini and Fountain 1981).

Goldberg (1976) found no sexually mature females less than 14.8 cm (5.8 in) SL in Santa Monica Bay. This differs from the findings of DeMartini and Fountain (1981) off San Onofre. They found females sexually mature at 10.0–10.5 cm (3.9-4.1 in) SL at slightly greater than age-1. Batch fecundities in queenfish off San Onofre ranged from 5,000 eggs in a 10.5-cm (4.1 in) female to about 90,000 eggs in a 25-cm (9.8 in) fish. The average-sized female in that study (14 cm [5.5 in], 42 g [1.5 oz]) had a potential batch fecundity of 12,000–13,000 eggs. Murdoch (1989a) estimated the average batch fecundity to be 12,700 for queenfish collected over a five-year period. Based on a female spawning frequency of 7.4 days, a 10.5-cm (4.1 in) female that spawns for three months (April–June) can produce about 60,000 eggs/year, while a 25-cm (9.8 in) female that spawns for six months (March through August) can produce nearly 2.3 million eggs/year (DeMartini and Fountain 1981).

4.5.4.4.3 Age and Growth

Queenfish mature at 10.5 cm (4.1 in) (DeMartini and Fountain 1981) to 12.7 cm (5 in) (Love 1996), during their first spring or second summer. Maximum reported size is 30.5 cm (12 in) (Miller and Lea 1972). Immature individuals grow at a rate of about 2.5 mm/day (0.1 in/day), while early adults grow about 1.8 mm/day (0.07 in/day) (Murdoch et al. 1989b). Mortality estimates are unavailable for this species.

4.5.4.4.4 General Ecology

Queenfish feed mainly on crustaceans, including amphipods, copepods, and mysids, along with polychaetes and fishes (Quast 1968; Hobson and Chess 1976; Hobson et al. 1981; Feder et al. 1974).

4.5.4.4.5 Population Trends and Fishery

Queenfish was the most abundant croaker impinged at five generating stations (including the HBGS) from 1977 to 1998, and accounted for over 60% of the total fishes impinged (Herbinson et al. 2001). Annual abundance fluctuated from year to year, with notable declines during the strong El Niño events of 1982-83, 1986-87, and 1997-98. However, abundance remained relatively high throughout the over 20-year study period.

4.5.4.4.6 Sampling Results

Queenfish larvae were the fifth most abundant taxon collected from the entrainment station and the third most abundant from the source water stations during the sampling period (Tables 4-1 and 4-3). They comprised about 4.6 and 9.9% of the larvae collected at the entrainment and source water stations, respectively. This species was found in the entrainment samples collected from May through August, with a peak concentration of over 300 larvae per 1,000 m^3 (35,314.7 ft^3) during August 2004 (Figure 4-21a). Queenfish larvae were found at the source water stations during the same period of the year with a few individuals also being seen in October 2003 and January 2004 at the source water stations (Figure 4-21b). The number and concentration of larval queenfish collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution of the measured queenfish at the entrainment station is presented in Figure 4-22. The mean, maximum and minimum measurements were 5.0, 20.4 and 1.5 mm (0.2, 0.8, and 0.06 in), respectively. The majority of the larvae collected were not newly hatched, as Moser (1996) reported a hatch length of about 1.6 mm (0.06 in) for queenfish. Only about 15% of the collected queenfish larvae were between 1 and 3 mm (0.04 and 0.12 in) in total length.

4.5.4.4.7 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on queenfish larvae. Demographic model estimates of entrainment effects (*FH* and *AEL*) were not calculated because of the absence of information on life history parameters necessary for model calculations. It was estimated that approximately 17.8 million queenfish larvae are entrained annually by the HBGS cooling water system.

4.5.4.4.8 Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for queenfish was based on the difference between the lengths of the 1st (1.5 mm [0.06 in]) and 95th (7.7 mm [0.3 in]) percentiles and a growth rate of 0.2 mm/day (0.008 in/day). These values were used to estimate that queenfish larvae were vulnerable to entrainment for a period of 30.6 days.

Only two *PE* estimates could be calculated for queenfish for the September 2003 – August 2004 period (Table 4-16). This was due to queenfish larvae only being present in two of the paired entrainment and source water surveys (Figure 4-21). Although queenfish larvae were collected at only the source water stations in three additional surveys, over 99% of the total source population were collected during the two surveys when they were also collected at the entrainment station. These two *PE* values for these surveys were similar in value, 0.0017 and 0.0015. The average of the two estimates was less than the ratio of the entrainment volume to source water volume of 0.0021. The P_S estimates (Table 4-17) were 0.123 (12.3%) for the alongshore current and 0.089 (8.9%) for offshore-extrapolated current movement for the 30.6-day exposure period. The two estimates of mortality, P_M, were 0.006 (0.6%) using the alongshore current and 0.005 (0.5%) using the offshore extrapolation. The alongshore estimate of P_M was extrapolated over a shoreline distance of 84.9 km (52.8 mile).

Table 4-16. *ETM* data for queenfish larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00000	0.00000	0.00000	0.00000
13-Oct-03	0.00000	0.00000	0.00309	0.00647
10-Nov-03	0.00000	0.00000	0.00000	0.00000
8-Dec-03	0.00000	0.00000	0.00000	0.00000
5-Jan-04	0.00000	0.00000	0.00249	0.00507
9-Feb-04	0.00000	0.00000	0.00000	0.00000
8-Mar-04	0.00000	0.00000	0.00000	0.00000
5-Apr-04	0.00000	0.00000	0.00000	0.00000
3-May-04	0.00000	0.00000	0.00122	0.00245
1-Jun-04	0.00000	0.00000	0.00305	0.00382
12-Jul-04	0.00165	0.00245	0.23174	0.19339
31-Aug-04	0.00146	0.00188	0.75841	0.19441
Average =	0.00156			

Table 4-17. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for queenfish. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.1230 (84.9)	0.00626	0.28409	0.29036	0
Offshore Extrapolated	0.0891	0.00496	0.28222	0.28718	0

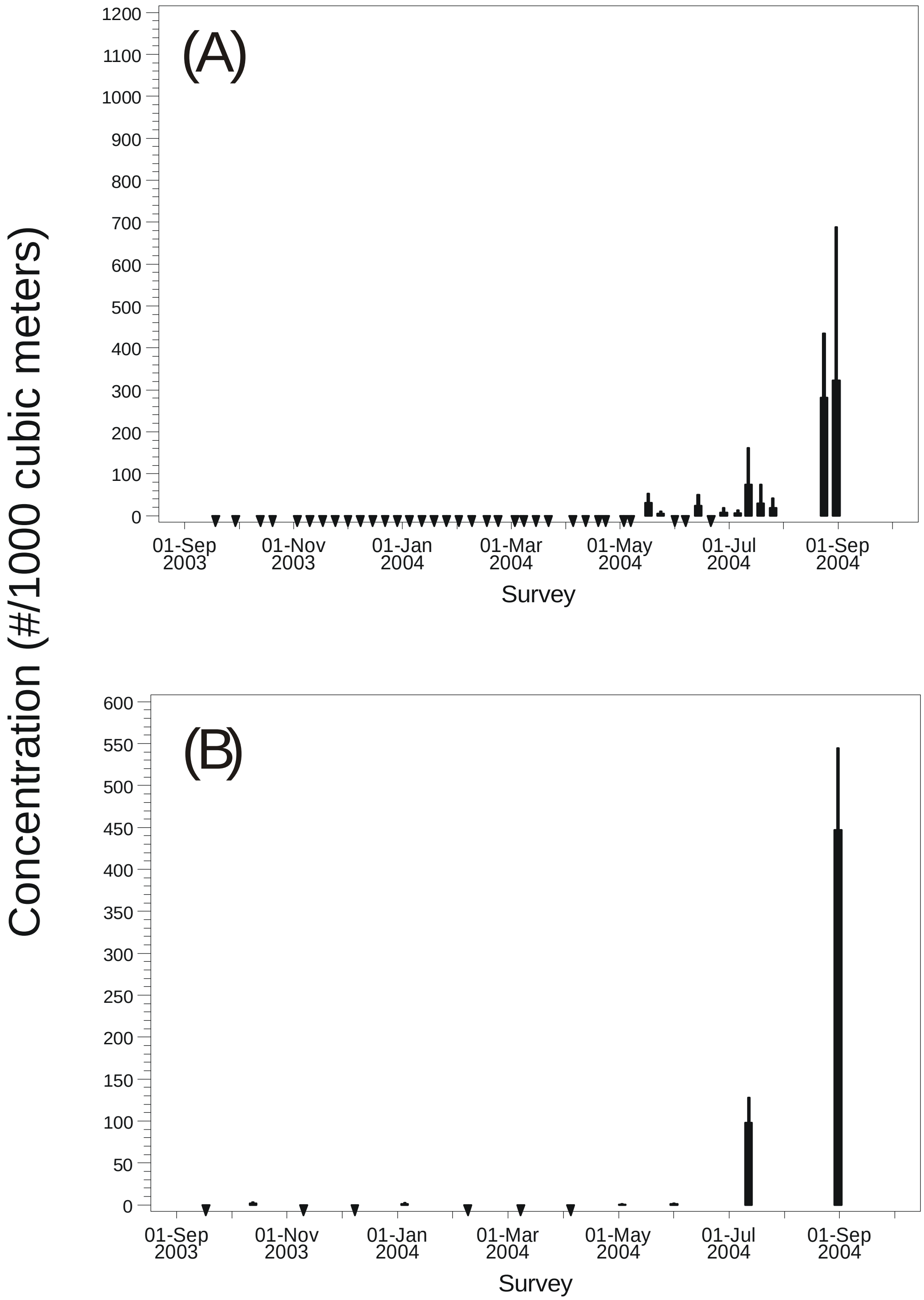


Figure 4-21. Survey mean concentration (#/1000 m^3) of queenfish larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no queenfish larvae were collected.

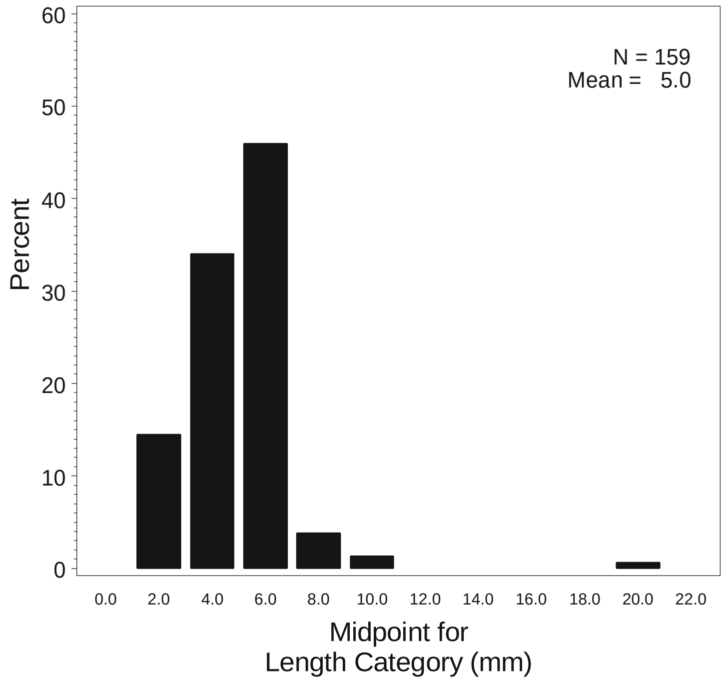


Figure 4-22. Length frequency distribution (mm) of queenfish larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.5 White Croaker (*Genyonemus lineatus*)

White croaker (*Genyonemus lineatus*) range from Magdalena Bay, Baja California, north to Vancouver Island, British Columbia (Miller and Lea 1972). They are one of eight species of croakers (Family Sciaenidae) found off California. The other croakers include: white seabass (*Atractoscion nobilis*), black croaker (*Cheilotrema saturnum*), queenfish (*Seriphus politus*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), yellowfin croaker (*Umbrina roncador*), and shortfin corvina (*Cynoscion parvipinnis*). All but shortfin corvina have been collected in impingement samples at the HBGS since 1979 (MBC 2004).

4.5.4.5.1 Habitat Requirements

The reported depth range of white croaker is from the surface to depths of 183 m (600 ft) (Miller and Lea 1972, Love et al. 1984); however, in southern California, Allen (1982) found white croaker over soft bottoms between 10 and 130 m (32.8 and 426.5 ft), and it was most frequently collected at 10 m (23.8 in).

4.5.4.5.2 Reproduction

White croakers are oviparous broadcast spawners. White croaker mature between about 130 and 190 mm (5.1 and 7.5 in) TL, somewhere between the first and fourth years. About one-half of males mature by 140 mm (5.5 in) TL, and one-half of females by 150 mm (5.9 in) TL, and all fishes are mature by 190 mm (7.5 in) TL in their third to fourth year (Love et al. 1984). Off Long Beach, California, white croaker spawn primarily from November through August, with peak spawning from January through March (Love et al. 1984). However, some spawning can occur year-round. Batch fecundities ranged from about 800 eggs in a 155-mm (6.1 in) female to about 37,200 eggs in a 260-mm (10.5 in) female, with spawning taking place as often as every five days (Love et al. 1984). In their first and second years, females spawn for three months for a total of about 18 times per season. Older individuals spawn for about four months and about 24 times per season (Love et al. 1984). Some older fish may spawn for seven months. The nearshore waters from Redondo Beach (Santa Monica Bay, California) to Laguna Beach, California, are considered an important spawning center for this species (Love et al. 1984). A smaller spawning center occurs off Ventura, California (Love et al. 1984).

4.5.4.5.3 Age and Growth

Newly hatched white croaker larvae are 1–2 mm (0.04-0.08 in) SL and not well developed (Watson 1982). Larvae are principally located within 4 km (2.5 mile) from shore, and as they develop tend to move shoreward and into the epibenthos (Schlotterbeck and Connally 1982). Murdoch et al. (1989) estimated a daily larval growth rate of 0.20 mm/day (0.008 in/day). Maximum reported size is 414 mm (16.3 in) (Miller and Lea 1972), with a life span of 12–15 years (Frey 1971, Love et al. 1984). White croakers grow at a fairly constant rate throughout their lives, though females outgrow males from age 1. Growth rates of white croaker from Dana Point and Palos Verdes are described in Moore (2001). No mortality estimates are available for any of the life stages of this species.

4.5.4.5.4 General Ecology

White croaker are primarily nocturnal benthic feeders, though juveniles may feed in the water column during the day (Allen 1982). Important prey items include polychaetes, gammaridean amphipods, reptantian decapods, and chaetognaths (Allen 1982). In Outer Los Angeles Harbor, Ware (1979) found important prey items to include polychaetes, benthic crustaceans, free-living nematodes, and zooplankton. Younger individuals feed on holoplanktonic crustaceans and polychaete larvae. White croaker may move offshore into deeper water during winter months (Allen and DeMartini 1983); however, this pattern is apparent only south of Redondo Beach, California (Herbinson et al. 2001).

4.5.4.5.5 Population Trends and Fishery

White croaker was the second most abundant croaker impinged at five generating stations (including the HBGS) from 1977 to 1998 (Herbinson et al. 2001). Annual abundance declined during that period, with marked decreases during the strong El Niño events of 1982-83, 1986-87, and 1997-98.

White croaker is an important constituent of the commercial and sport fisheries of California. Prior to 1980, most of the croaker catch was in southern California. However, since 1980, the majority of the commercial catch occurred in central California, and has been attributed to the entrance of Southeast Asian refugees into the fishery (Moore and Wild 2001). Most of the recreational catch is still in southern California from piers, breakwaters, and private boats.

Before 1980, statewide white croaker landings averaged 310,710.7 kg (685,000 lbs) annually, exceeding 453,592.4 kg (1,000,000 lbs) in several years (Moore and Wild 2001). Highest landings in 1952 corresponded with the collapse of the Pacific sardine fishery. Since 1991, landings averaged 209,106.1 kg (461,000 lbs) and steadily declined to an all-time low of 64,636.9 kg (142,500 lbs) in 1998. Statewide landings by recreational fishermen aboard commercial passenger fishing vessels (CPFVs) averaged about 12,000 fish per year from 1990-1998, with most of the catch in southern California (Moore and Wild 2001).

From 1999 through 2001, white croaker commercial landings off Huntington Beach were far more substantial in Catch Blocks 738, 739, and 740 compared with the other five blocks (CDFG 2002). Landings ranged from 0 to 39,294.7 kg (0 lbs to 86,630 lbs) ($64,817) in Catch Block 740 south of San Pedro in 1999. In Block 738, off Huntington Beach, landings ranged from 2,429 kg (5,355 lbs) ($10,710 in 2001) to 6,142.1 kg (13,541 lbs) ($23,532 in 2000). Most commercially caught white croaker are caught by gillnet and hook-and-line (Moore and Wild 2001).

4.5.4.5.6 Sampling Results

White croaker was the fourth most abundant taxon collected during the study from both the entrainment and source water stations, comprising about 7% of all of the larvae collected at the entrainment station (Tables 4-1 and 4-3). The estimated mean concentration per survey was variable, ranging from zero to about 135 white croaker larvae per 1,000 m^3 (Figure 4-23a). Peaks in abundance occurred during April and May 2004. The May peak in abundance coincided with the peak abundance at the source water stations (Figure 4-23b), but a second peak at the source water stations in August 2004 wasn't reflected in the data from the entrainment station. The number and concentration of larval white croakers collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution of measured white croaker larvae show a relatively wide size range which is dominated by recently hatched larvae based on the reported hatch length of 1-2 mm (0.04-0.08 in) (Watson 1982) (Figure 4-24). The mean, maximum, and minimum sizes for the measurements were 3.4, 8.6, and 1.5 mm (0.13, 0.34, and 0.06 in), respectively. A larval growth rate of 0.20 mm/day (0.008 in/day) for white croaker (Murdoch et al. 1989c) was used with the difference in the lengths of the first (1.6 mm [0.06 in]) and 95th (7.0 mm [0.3 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 27 days.

4.5.4.5.7 Impact Assessment

The following sections present the results for empirical transport modeling of circulating water system effects on white croaker larvae. No age-specific estimates of survival for later stages of development were available from the literature for white croaker; therefore no estimates of *FH* or *AEL* were calculated. Total entrainment through HBGS was estimated at approximately 18 million white croaker larvae for the period of September 2003 through August 2004.

4.5.4.5.8 Empirical Transport Model (*ETM*)

The *PE* estimates used to calculate *ETM* for white croaker for the September 2003 – August 2004 period varied considerably among surveys and ranged from nearly 0 to 0.003 (Table 4-18). The average PE was slightly less than the ratio of the entrainment volume to source water volume of 0.0021. The largest *PE* estimate was calculated for the September 2003 survey, but the largest proportions of the source population were present during the May and August 2004 surveys. The small *PE* estimate during the August survey indicates that larvae were not abundant at the entrainment station (Figures 4-23a and b). The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 27-day period of exposure calculated using offshore extrapolated densities (0.004, 0.4%) is less than the estimate calculated using alongshore current displacement (0.007, 0.7%) because the effects of entrainment are spread over a much larger source population (Table 4-19). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 21.8 and 7.0%, respectively. The alongshore estimate of P_M was extrapolated over a shoreline distance of 47.8 km (29.7 mile).

Table 4-18. *ETM* data for white croaker larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00340	0.00611	0.01722	0.01426
13-Oct-03	0.00144	0.00241	0.02892	0.02256
10-Nov-03	0.00028	0.00035	0.07104	0.03526
8-Dec-03	0.00087	0.00162	0.11844	0.07330
5-Jan-04	0.00181	0.00314	0.05064	0.02916
9-Feb-04	0.00252	0.00333	0.02628	0.01944
8-Mar-04	0.00227	0.00366	0.02362	0.01357
5-Apr-04	0.00049	0.00103	0.02002	0.01315
3-May-04	0.00195	0.00170	0.28073	0.10793
1-Jun-04	0.00132	0.00216	0.06375	0.06356
12-Jul-04	0.00000	0.00000	0.02898	0.02505
31-Aug-04	0.00004	0.00008	0.27036	0.15099
Average =	0.00149			

Table 4-19. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for white croaker. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.2183 (47.8)	0.00711	0.23364	0.24074	0
Offshore Extrapolated	0.0701	0.00359	0.22654	0.23013	0

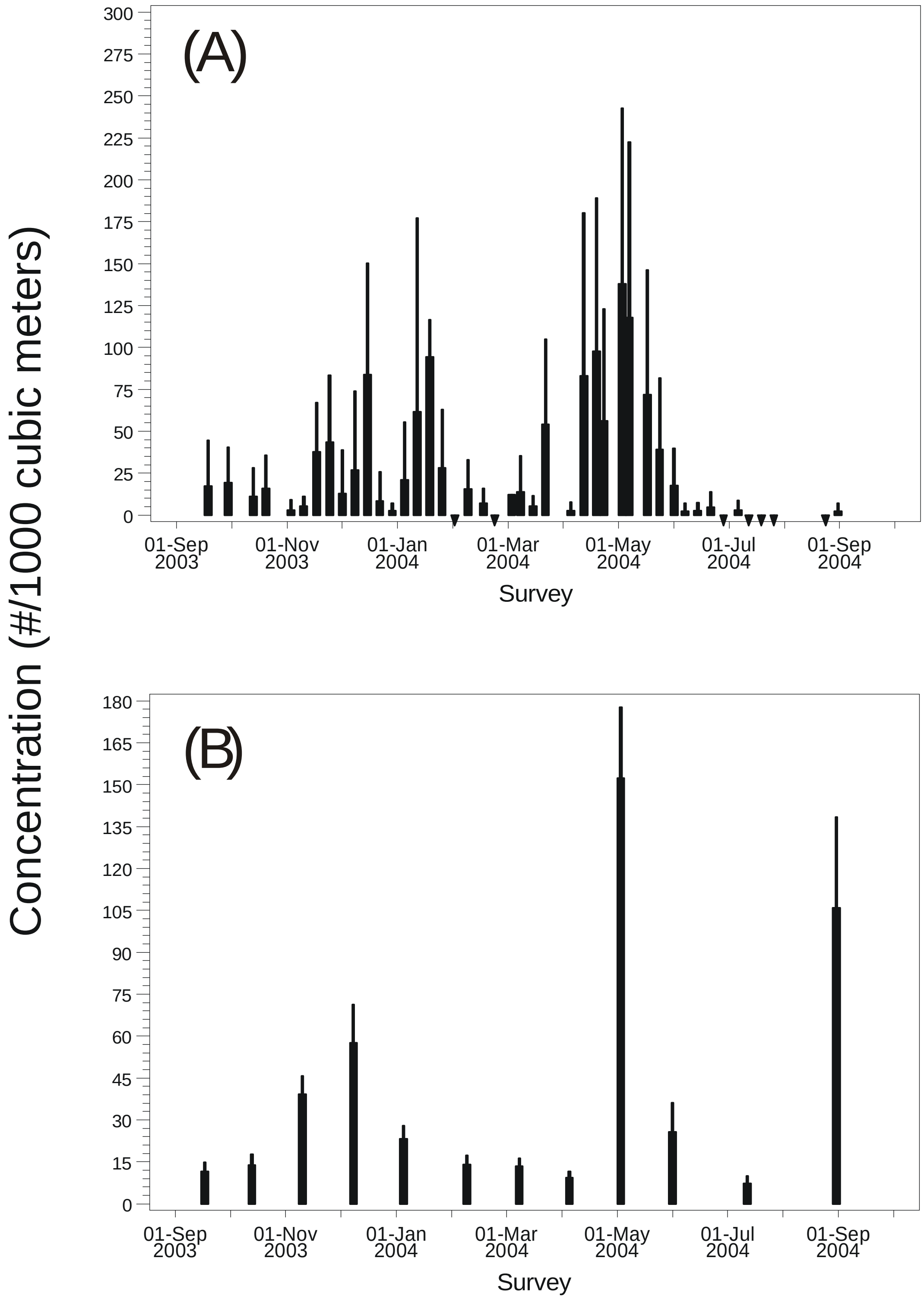


Figure 4-23. Survey mean concentration (#/1000 m^3) of white croaker larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no white croaker larvae were collected.

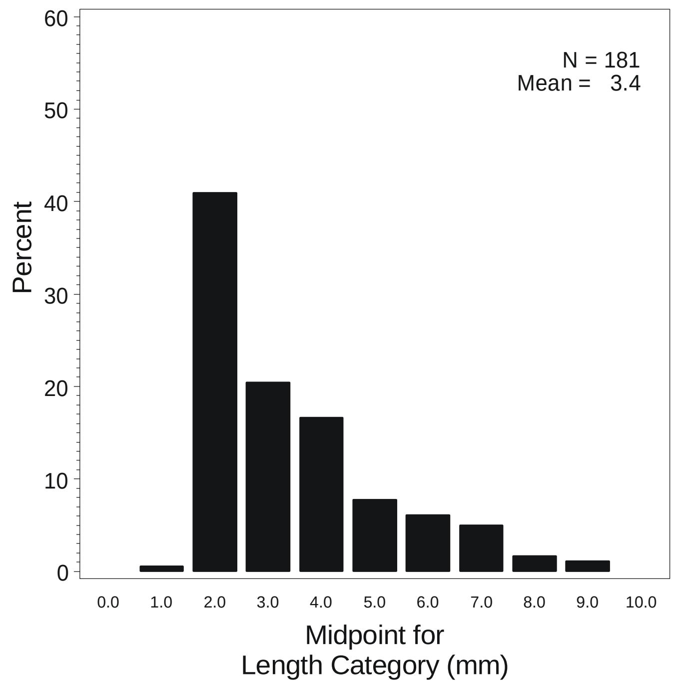


Figure 4-24. Length frequency distribution (mm) of white croaker larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.6 Black Croaker (*Cheilotrema saturnum*)

Black croaker (*Cheilotrema saturnum*) is a member of the drums and croakers family (Sciaenidae) and ranges from Point Conception, California to central Baja California (including the Gulf of California) in depths from 3–50 m (9.8-164 ft) (Limbaugh 1961, Miller and Lea 1972). Seven species of croaker, in addition to black croaker, are common to the Southern California Bight (SCB), including white croaker (*Genyonemus lineatus*), queenfish (*Seriphus politus*), yellowfin croaker (*Umbrina roncador*), white seabass (*Atractoscion nobilis*), California corbina (*Menticirrhus undulatus*), spotfin croaker (*Roncador stearnsii*), and shortfin corvina (*Cynoscion parvipinnis*; Miller and Lea 1972).

4.5.4.6.1 Habitat Requirements

Black croaker is common to open-coast, shallow rocky reefs and kelp beds (Limbaugh 1961, Allen 1985) with large adults occupying shelters within the reef structure and smaller individuals typically occurring above the sand substrate in and around the reef (Limbaugh 1961). Nocturnal in nature, aggregations have been observed migrating away from the reef to feed and reproduce at night, while remaining relatively sessile within the reef area during the day (Limbaugh 1961). Limbaugh (1961) observed aggregations of adults concentrated near the 7-m (22.9) isobath, but as deep as 50 m (164 ft). He noted that individuals were more abundant in the shallower portion of their depth distribution.

4.5.4.6.2 Reproduction

Black croaker is an oviparous broadcast spawner with pelagic eggs and larvae (Moser 1996). Greater than 50% of both males and females are reproductively mature by 150 mm (5.9 in) standard length (SL) or approximately one year of age (Miller et al., in prep b). Spawning is most prevalent in the late spring to summer months, with a peak in June and July based on histological examination (Goldberg 1981) and seasonal gonosomatic index (GSI) analysis (Miller et al. in prep b). Late-stage larvae have been collected as early as July (Miller et al., in prep b), with regular collections from August through October (Limbaugh 1961, Moser 1996). Spawning populations were found to be statistically skewed towards males at a ratio of 1.22:1 (male:female), with each sex represented in all size and age classes (Miller et al., in prep b).

4.5.4.6.3 Age and Growth

Moser (1996) reported newly hatched black croaker larvae to be 1.5 mm (0.06 in) NL (notochord length). Flexion occurs at approximately 5.6 mm (0.22 in) NL and transformation occurs at standard lengths in excess of 11 mm (0.43 in) (Moser 1996). Black croaker grows rapidly during the first six years, attaining an average length of 200 mm (7.87 in) SL before growth rates slow (Miller et al., in prep b). Black croaker reportedly grows to 380 mm SL (14.9 in) (Miller and Lea 1972) and 22 years old with no significant differences in the growth rates between males and females (Miller et al., in prep b). The strongest recruitment year within the last decade occurred in 1997, which corresponded to the highest sea surface temperature in the same time period (Miller et al. in prep b). The estimated annual survivorship rate for black croaker is 0.85 (0.15 mortality) (Miller et al., in prep b).

4.5.4.6.4 General Ecology

Gut contents of adults indicate their diet consists primarily of demersal crustaceans such as crabs, shrimp, and amphipods (Limbaugh 1961). Recent anecdotal observations of one adult black croaker gut contents included two blackeye gobies (*Rhinogobiops nicholsii*) (Miller, personal observation). Nearshore gillnet sampling from Newport Beach to Santa Barbara, California, including Santa Catalina Island, indicated the largest sustaining population to occur near the Palos Verdes Peninsula, California (Miller et al. in prep b). Pondella and Allen (2000) also noted higher population densities occurred at mainland sites compared to Santa Catalina Island sites. However, the individuals collected at the island sites were larger on average than those encountered along the mainland (Miller et al. in prep b). Black croaker is commonly found in association with sargo (*Anisotremus davidsonii*) and salema (*Xenistius californiensis*), with the juveniles of both species displaying similar body coloration to those of young black croaker (Limbaugh 1961).

4.5.4.6.5 Population Trends and Fishery

Historically, black croaker has been the third most abundant croaker species among impingement samples at southern California coastal generating stations since 1976, surpassed only by white croaker and queenfish (Herbinson et al. 2001). Long-term trends in impingement observations indicate an overall declining abundance, with a minor upturn in 1997. Currently, no commercial fisheries target black croaker, and only incidental catches occur in the recreational fishery.

4.5.4.6.6 Sampling Results

Black croaker larvae ranked 11th in mean concentration in entrainment samples (5.41 per 1,000 m^3; Table 4-1) and 19th in the source water samples (1.90 per 1,000 m^3; Table 4-3). They were collected from April though September 2004 with peak concentrations recorded in August in both the entrainment and source water samples (Figure 4-25). The highest entrainment concentrations occurred in late August when average concentrations exceeded 160 larvae per 1,000 m^3.

The length frequency distribution of measured black croaker larvae show an extremely limited size range dominated by recently hatched larvae based on the reported hatch length of 1.5 mm (0.06 in) NL (Moser 1996) (Figure 4-26). The mean, maximum, and minimum sizes for the measurements were 2.1, 11.5, and 1.5 mm (0.08, 0.45, and 0.06 in), respectively. A larval growth rate of 0.20 mm/day (0.008 in/day) for white croaker (Murdoch et al. 1989) was used with the difference in the lengths of the first (1.5 mm [0.06 in]) and 95th (2.9 mm [0.11 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 7 days.

4.5.4.6.7 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on black croaker larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of information on life history necessary to parameterize the models. Total entrainment through HBGS was estimated at approximately 7.1 million black croaker larvae for the period of September 2003 through August 2004.

4.5.4.6.8 Empirical Transport Model (*ETM*)

Only two *PE* estimates were calculated for black croaker for the September 2003 – August 2004 period (Table 4-20). As shown in Figure 4-22 these estimates were not necessarily reflective of actual black croaker abundances because the highest abundance at the entrainment station occurred during a survey when the source water stations were not sampled. The values of f_i show that almost 60% of the black croaker larvae were collected during surveys when no entrainment occurred. In addition, the *PE*s were calculated from surveys that represent two separate spawning seasons. The two P_M estimates calculated from these estimates (Table 4-21) were both low reflecting the short period of time (7 days) that the larvae were exposed to entrainment. This was also reflected in the estimate of the shoreline distance of 19.4 km (12 mile) which was shorter than the value for taxa with longer larval durations.

Table 4-20. *ETM* data for black croaker larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00155	0.00382	0.09932	0.13513
13-Oct-03	0.00000	0.00000	0.00000	0.00000
10-Nov-03	0.00000	0.00000	0.00000	0.00000
8-Dec-03	0.00000	0.00000	0.00000	0.00000
5-Jan-04	0.00000	0.00000	0.00000	0.00000
9-Feb-04	0.00000	0.00000	0.00000	0.00000
8-Mar-04	0.00000	0.00000	0.00000	0.00000
5-Apr-04	0.00000	0.00000	0.00000	0.00000
3-May-04	0.00000	0.00000	0.11678	0.11218
1-Jun-04	0.00000	0.00000	0.11582	0.14993
12-Jul-04	0.00000	0.00000	0.36378	0.22890
31-Aug-04	0.00050	0.00107	0.30430	0.19281
Average =	0.00103			

Table 4-21. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for black croaker. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.5375 (19.4)	0.00119	0.37910	0.38029	0
Offshore Extrapolated	0.2287	0.00050	0.37849	0.37899	0

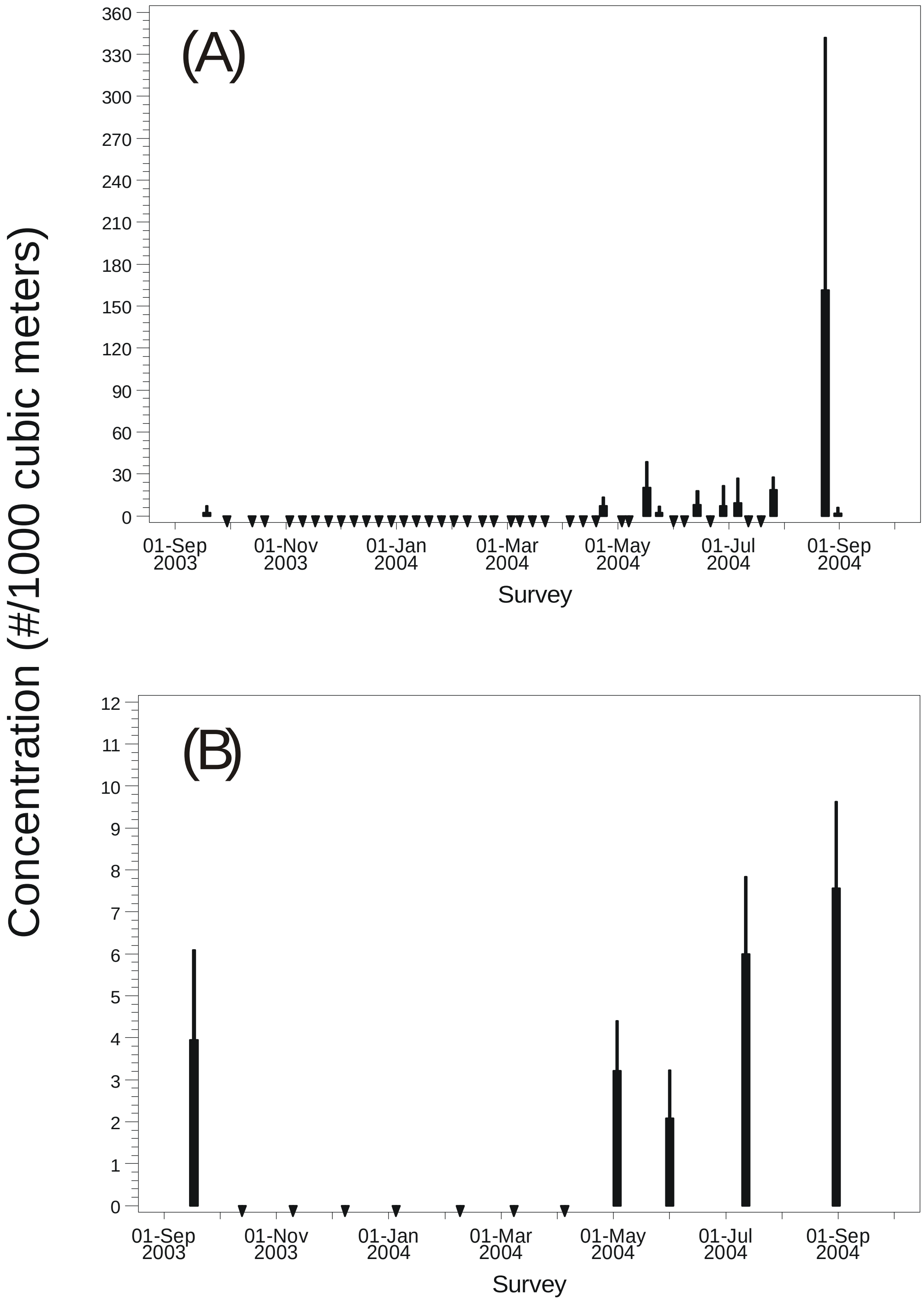


Figure 4-25. Survey mean concentration (#/1000 m^3) of black croaker larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no black croaker larvae were collected.

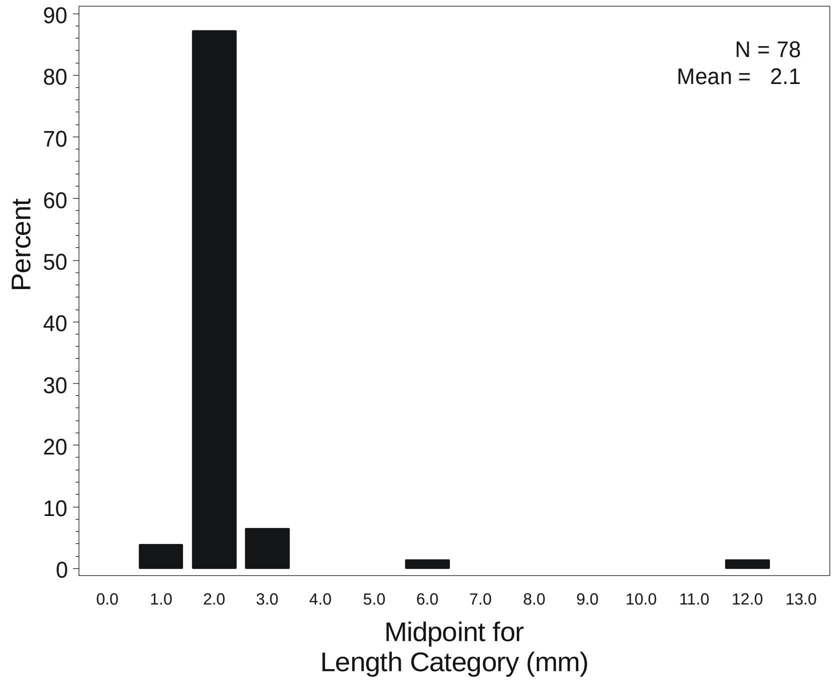


Figure 4-26. Length frequency distribution (mm) of black croaker larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.7 Salema (*Xenistius californiensis*)

Salema (*Xenistius californiensis*) is one of two grunts (Family Haemulidae) common to southern California, and ranges from Peru to Monterey Bay, California, including the Gulf of California in depths ranging from 1–12 m (3.28-39.37 ft) (Miller and Lea 1972). Sargo (*Anisotremus davidsonii*) is the other representative of the grunt family common to southern California (Miller and Lea 1972). Both are common in impingement samples from southern California coastal generating stations. Life history information for salema is scarce.

4.5.4.7.1 Habitat Requirements

Salema are mainly found in shallow rocky reefs and kelp bed habitats throughout the Southern California Bight (SCB), areas also frequented by black croaker (*Cheilotrema saturnum*) (Quast 1968, Allen 1985). Salema are nocturnal and can form large schools around piers and on algae-covered rocky reefs (Robertson and Allen 2002). They were found to be quite abundant during nocturnal sampling of mid-water plankton by diver operated plankton nets (Hobson and Chess 1976).

4.5.4.7.2 Reproduction

Moser (1996) indicated that salema are oviparous, producing planktonic eggs and larvae during the summer months. Preliminary observations of salema gonads indicate reproductive activity from June to September, with gonads being reduced to being nearly unidentifiable during April (E. Miller, MBC, personal observation). Gonosomatic index analyses indicate peak spawning in August with dramatic declines by October in both sexes (Miller unpubl. data). Gillnet sampling resulted in significantly higher percentages (Chi squared test, x^2=6.28, df=1, p=0.01) of females during peak spawning periods (Miller unpubl. data). No further information was found on salema or sargo reproduction within the primary literature.

4.5.4.7.3 Age and Growth

No information on the age and growth of salema is currently available. The recorded hatch length of the larvae is less than 2.2 mm (0.09 in) (Moser 1996). Miller and Lea (1972) reported that salema have a maximum length of 25.4 cm (10 in.).

4.5.4.7.4 General Ecology

Adult salema generally occur in greatest abundance during nocturnal periods, and are notably absent during the day (Hobson and Chess 1976). The species is planktivorous, feeding mainly on crustaceans, including gammaridean amphipods and mysids available in the midwater in kelp beds and above rocky reefs (Quast 1968; Hobson and Chess 1976). Sikkel (1986) reported that salema were preyed upon by yellowtail (*Seriola lalandi*) and kelp bass (*Paralabrax clathratus*), at La Jolla Cove, San Diego County, California.

4.5.4.7.5 Population Trends and Fishery

Quast (1968) noted salema densities to be 2.57 kg/acre in kelp beds near Corona Del Mar, California. Salema have been observed in impingement samples at most coastal generating stations throughout the SCB, especially those in the vicinity of kelp beds. Impingement rates for salema at ESGS since 1978 indicate an increase in salema populations (MBC and Herbinson, unpublished data). Currently, no commercial or recreational fishery targets salema, probably due to their nocturnal activity and small size. Incidental catches may have occurred in nearshore gillnet fisheries prior to the legislative ban in 1992, which removed gillnets from state waters within three miles of shore.

4.5.4.7.6 Sampling Results

Although salema ranked as the sixth most abundantly entrained fish species (Table 4-1), it was only collected in substantial numbers during a single entrainment survey in late August 2004 (Figure 4-27a). The concentrations during this survey (>300 per m^3), however, were high enough to make it an important entrained taxon in the overall annual sampling. It was present in much lower abundances at the source water stations in July and August 2004 (Figure 4-27b). This indicates a strong inshore distribution and a highly seasonal reproduction period. The number and concentration of larval salema collected during each entrainment and source water survey are presented in an appendix to this report.

The length frequency distribution of measured salema larvae (Figure 4-28) shows an extremely limited size range dominated by recently hatched larvae, based on the reported hatch length of 2.2 mm (0.09 in) NL (Moser 1996). The mean, maximum, and minimum sizes for the measurements were 2.0, 2.6, and 1.7 mm (0.08, 0.1, and 0.07 in), respectively.

4.5.4.7.7 Impact Assessment

Total annual entrainment of salema was calculated as 11.7 million larvae. Because no salema larvae were collected in the entrainment samples and source water samples during the same survey, proportional losses were not able to be calculated for the *ETM* modeling. Salema larvae were present in the entrainment samples during the week previous to the final source water survey (Figure 4-247, b), but the modeling methods are based on a comparison of paired larval concentrations in the entrainment and source water from the same surveys. The lack of co-occurrence further highlights the high temporal and spatial variation of these larvae.

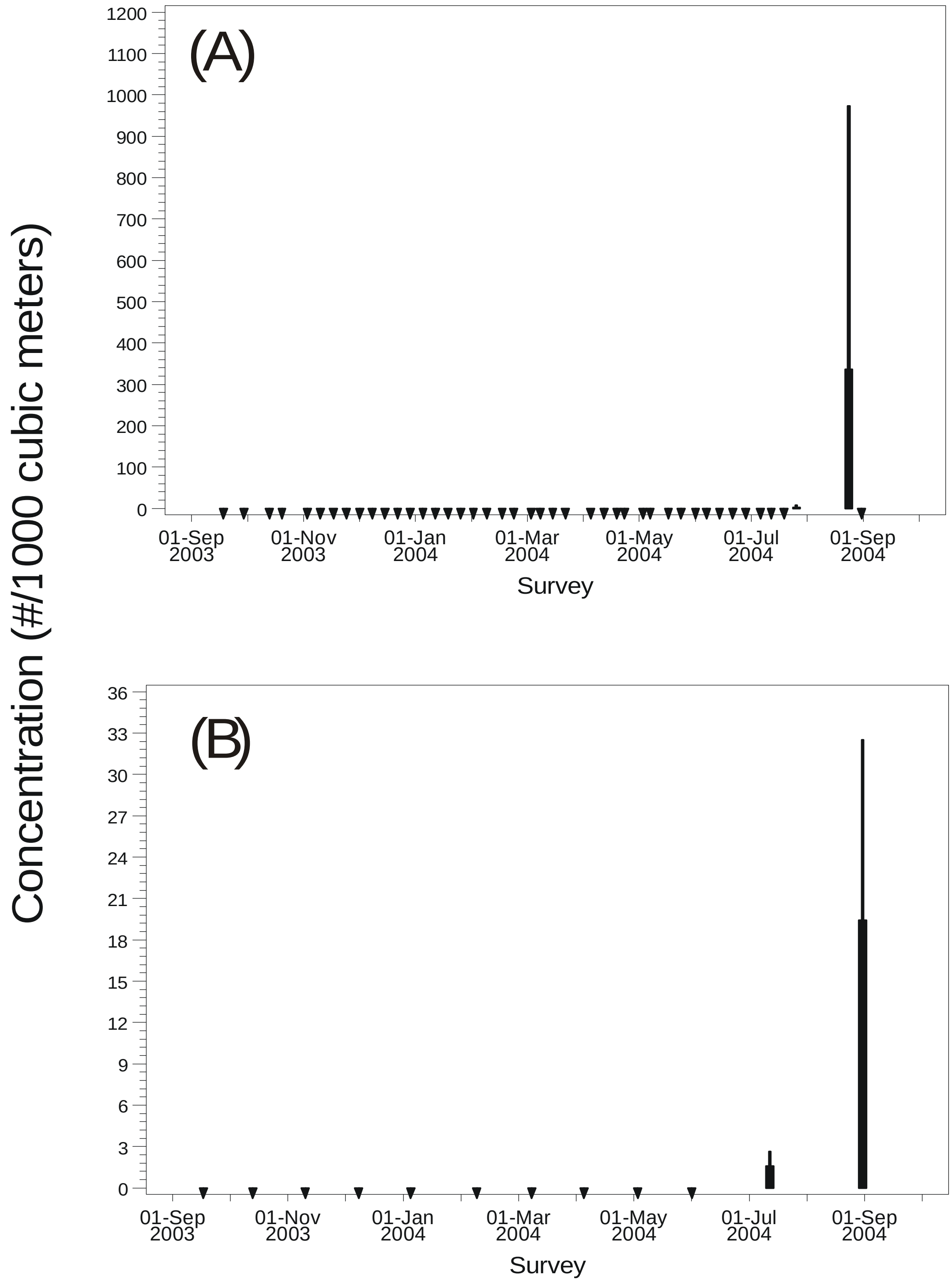


Figure 4-27. Survey mean concentration (#/1000 m^3) of salema larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no salema larvae were collected.

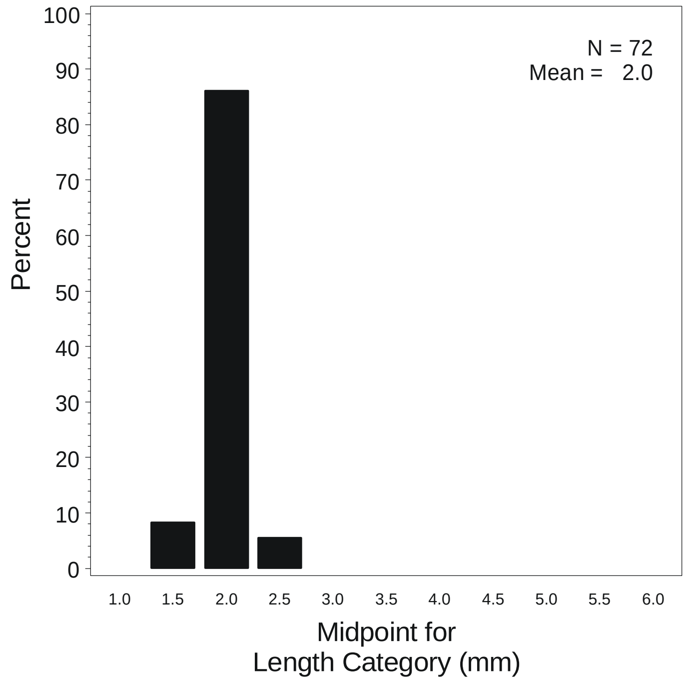


Figure 4-28. Length frequency distribution (mm) of salema larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.8 Combtooth Blennies (*Hypsoblennius* spp.)

Combtooth blennies form a prominent group among the subtropical and tropical fish fauna that inhabit inshore rocky habitats throughout much of the world. They are members of the family Blenniidae within the order Blennioidei. The family Blenniidae, the combtooth blennies, contains about 345 species in 53 genera (Nelson 1994; Moser 1996). They derive their common name from the arrangement of closely spaced teeth in their jaws.

Combtooth blennies are all relatively small fishes that typically grow to a total length of less than 200 mm (7.9 in.) (Moser 1996). Most have blunt heads that are topped with some arrangement of cirri (Moyle and Cech 1988, Moser 1996). Their bodies are generally elongate and without scales. Dorsal fins are often continuous and contain more soft rays than spines (Moyle and Cech 1988). Coloration in the group is quite variable, even among individuals of the same species (Stephens et al. 1970).

Combtooth blennies are represented along the California coast by three members of the genus *Hypsoblennius*: bay blenny (*H. gentilis*), rockpool blenny (*H. gilberti*), and mussel blenny (*H. jenkinsi*). These species co-occur throughout much of their range although they occupy different habitats. The bay blenny is found along both coasts of Baja California and up the California coast to as far north as Monterey Bay, (Miller and Lea 1972; Robertson and Allen 2002). The rockpool blenny occurs from Magdalena Bay, Baja California to Point Conception, California (Miller and Lea 1972, Stephens et al. 1970). The range of the mussel blenny extends from Morro Bay to Magdalena Bay, Baja California and in the northern Gulf of California (Tenera 2001; Robertson and Allen 2002).

The three species of *Hypsoblennius* found in California waters are morphologically similar as early larvae (Moser 1996; Ninos 1984). For this reason most *Hypsoblennius* identified in HBGS plankton tows collections were identified as *Hypsoblennius* spp. Certain morphological features (e.g., preopercular spines) develop at larger sizes and allow taxonomists to identify some larvae to the species level.

4.5.4.8.1 Habitat Requirements

Blennies inhabit a variety of hard substrates in the intertidal and shallow subtidal zones of tropical and subtropical marine habitats throughout the world. They may occur to depths of 24 m (80 ft) but are more frequently found in water depths of less than 5 m (15 ft) (Love 1996). Combtooth blennies are common in rocky tidepools, reefs, breakwaters, and on pier pilings. They are also frequently observed on encrusted buoys and boat hulls.

The California blennies have different habitat preferences. The mussel blenny is only found subtidally and inhabits mussel beds, the empty drill cavities of boring clams, barnacle tests, or in crevices among the vermiform snail tubes *Serpulorbis* spp. (Stephens 1969; Stephens et al. 1970). They generally remain within one meter of their chosen refuge (Stephens et al. 1970). The bay blenny is usually found subtidally but appears to have general habitat requirements and may inhabit a variety of intertidal and subtidal areas (Stephens et al. 1970). They are commonly found in mussel beds and on encrusted floats, buoys, docks, and even fouled boat hulls (Stephens 1969; Stephens et al. 1970). Bay blennies are also typically found in bays as the common name implies and are tolerant of estuarine conditions (Stephens et al. 1970). They are among the first resident fish species to colonize new or disturbed marine habitats such as new breakwaters or mooring floats after the substrate is first colonized by attached invertebrates (Stephens et al. 1970; Moyle and Cech 1988). Rockpool blennies are mainly found along shallow rocky shorelines and kelp forests along the outer coast.

4.5.4.8.2 Reproduction

Female blennies mature quickly and reproduce within the first year, reaching peak reproductive potential in the third year (Stephens 1969). The spawning season typically begins in spring and may extend into September (Stephens et al. 1970). Blennies are oviparous and lay demersal eggs that are attached to the nest substrate by adhesive pads or filaments (Moser 1996). Males are responsible for tending the nest and developing eggs. Females spawn 3–4 times over a period of several weeks (Stephens et al. 1970). Males guard the nest aggressively and will often chase the female away; however, several females may occasionally spawn with a single male. The number of eggs a female produces varies proportionately with size (Stephens et al. 1970). The mussel blenny spawns approximately 500 eggs in the first reproductive year and up to 1,500 eggs by the third year (Stephens et al. 1970). Total lifetime fecundity may be up to 7,700 eggs (Stephens 1969).

4.5.4.8.3 Age and Growth

Larvae are pelagic and hatch at a size of 2.3–2.6 mm (0.09–0.10 in) (Moser 1996). The planktonic phase for *Hypsoblennius* spp. larvae may last for 3 months (Stephens et al. 1970; Love 1996). *Hypsoblennius* larvae are visual swimmers (Ninos 1984). Captured larvae released by divers have been observed to orient to floating algae, bubbles on the surface, or the bottoms of boats or buoys. The size at settlement ranges from 12–14 mm (0.5–0.6 in.). After the first year mussel and bay blenny averaged 40 and 45 mm (1.6 and 1.8 in.) total length, respectively (Stephens et al. 1970). The bay blenny grows to a slightly larger size and lives longer than the mussel blenny, reaching a size of 15 cm (5.9 in.) and living for 6–7 years (Stephens 1969; Stephens et al. 1970; Miller and Lea 1972). Mussel blennies grow to 13 cm (5.1 in.) and have a life span of 3–6 years (Stephens et al. 1970; Miller and Lea 1972). Male and female growth rates are similar.

4.5.4.8.4 General Ecology

Juvenile and adult combtooth blennies are omnivores and eat both algae and a variety of invertebrates, including limpets, urchins, and bryozoa (Stephens 1969; Love 1996).

4.5.4.8.5 Population Trends and Fishery

There is no fishery for combtooth blennies and therefore no records on adult population trends based on landings data.

4.5.4.8.6 Sampling Results

Combtooth blenny was the eighth most abundant taxon collected in the entrainment samples and sixth most abundant in the source water samples (Tables 4-1 and 4-3). Combtooth blenny concentrations at the entrainment and source water stations peaked in summer (June–August 2004) and were present in the study area throughout the year (Figures 4-29a and b). Maximum concentrations were recorded at the entrainment station in late June 2004 (105 per 1000 m^3), and source water concentrations peaked in late August 2004 (66 per 1000 m^3). Minimum entrainment and source water concentrations generally occurred from January through April. The number and concentration of larval combtooth blennies collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution for a representative sample of combtooth blenny larvae is presented in Figure 4-30. The mean, maximum and minimum lengths were 2.3, 13.0, and 1.6 mm (0.09, 0.5, and 0.06 in), respectively. The majority of the larvae were recently hatched based on a reported hatch size of 2.5 mm (0.1 in) (Moser 1996).

4.5.4.8.7 Impact Assessment

The following sections present the results for demographic and empirical transport modeling of HBGS circulating water system effects. Species-specific life history information for combtooth blennies is scarce. Larval survival was estimated using data from Stephens (1969) and Stevens and Moser (1982). There was enough information on reproduction to parameterize the *FH* demographic model, but not to calculate the *AEL* model. Larval growth was estimated from information from Stevens and Moser (1982). The total annual entrainment estimate for the September 2003 through August 2004 sampling period was 7.17 million larvae (Table 4-1).

4.5.4.8.8 Fecundity Hindcasting (*FH*)

The annual entrainment estimate for combtooth blenny larvae was used to estimate the number of breeding females needed to produce the entrained larvae (Table 4-22). No estimates of egg survival for combtooth blenny were available, but because egg masses are attached and guarded by the male (Stephens et al. 1970), egg survival is probably high and was assumed to be 100%. The mean length for larval combtooth blenny larvae in entrainment samples was 2.3 mm (0.09 in). A larval growth rate of 0.20 mm/day (0.08 in/day) was derived from growth rates using data in Stevens and Moser (1982). The mean length and the length at the 1st percentile (1.9 mm [0.07 in]) were used with the growth rate to estimate that the mean age at entrainment was 3.3 days. A daily survival rate of 0.89 computed from Stephens (1969) was used to calculate survival to the average age at entrainment as $0.89^{3.8} = 0.63$. An average batch fecundity estimate of 550 eggs was based on data from Stephens (1969), and an estimate of 2.3 spawns per year based on information from Stevens and Moser (1982) were used to calculate an annual fecundity of 1,281 eggs. An average longevity for mussel blenny of 3–6 yr from Stephens (1969) and an age of maturation of 0.4 yr from Stevens and Moser (1982) were used in the model.

The estimated numbers of adult female combtooth blennies whose lifetime reproductive output was entrained through the HBGS circulating water system for the September 2003 through August 2004 period was 3,233 (Table 4-22). This was based on an annual entrainment of about 7.2 million larvae.

Table 4-22. Results of *FH* modeling for combtooth blenny larvae entrained during the September 2003 – August 2004 sampling period. The upper and lower estimates are based on a 90% confidence interval of the mean. The upper and lower estimates for total entrainments were calculated by using the range of entrainment estimates in the *FH* calculations.

Parameter	Estimate	Std. Error	*FH* Lower Estimate	*FH* Upper Estimate	*FH* Range
FH	3,233	2,907	736	14,191	13,455
Total Entrainment	7,165,513	1,735,739	1,945	4,521	2,576

4.5.4.8.9 Empirical Transport Model (*ETM*)

The larval duration used to calculate the *ETM* estimates for combtooth blenny was based on the lengths of entrained larvae. The difference between the lengths of the 1st (1.7 mm [0.07 in]) and 95th (3.5 mm [0.14 in]) percentiles was used with a growth rate of 0.20 mm/day (0.01 in/day) to estimate that combtooth blenny larvae were vulnerable to entrainment for a period of about 9.3 days.

The monthly estimates of proportional entrainment (*PE*) for combtooth blennies for the September 2003 – August 2004 period varied among surveys and ranged from 0 to 0.021 (Table 4-23). The average estimate was 0.00430 which was almost twice the volumetric ratio of the entrainment to source water volumes, but the average was affected by the large *PE* estimate for February 2004 which occurred when the proportion of blennies in the source waters were low. A weighted average, similar to the calculation for P_M, would reduce the value. While the largest *PE* estimate was calculated for the February survey, the largest proportion of the source population was present during the August survey (f_i = 0.42 or 42%). The small *PE* estimate for the August survey (0.00025) indicates that larvae were not abundant at the entrainment station during this survey (Figures 4-29a and b). The results also show that there were several surveys when blenny larvae were collected at the source water stations, but not at the entrainment stations. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 9.3-day period of exposure calculated using offshore extrapolated densities (0.0029, 0.29%) was less than the estimate calculated using alongshore current displacement (0.0077, 0.77%) because the effects of entrainment are spread over a larger source population that includes offshore areas (Table 4-24). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 81.4 and 41.7%, respectively. The alongshore estimate of P_M was extrapolated over a shoreline distance of 12.8 km (7.9 mile).

Table 4-23. *ETM* data for combtooth blenny larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	PE Estimate	PE Std. Error	f_i	f_i Std. Error
17-Sep-03	0.00000	0.00000	0.04350	0.02820
13-Oct-03	0.00000	0.00000	0.03255	0.03161
10-Nov-03	0.00423	0.00812	0.06645	0.05730
8-Dec-03	0.00167	0.00347	0.03080	0.02040
5-Jan-04	0.00133	0.00292	0.02438	0.02325
9-Feb-04	0.02108	0.07994	0.00138	0.00447
8-Mar-04	0.00000	0.00000	0.00000	0.00000
5-Apr-04	0.00000	0.00000	0.00147	0.00393
3-May-04	0.00000	0.00000	0.02012	0.01690
1-Jun-04	0.00071	0.00097	0.12027	0.06204
12-Jul-04	0.00082	0.00125	0.23727	0.17700
31-Aug-04	0.00025	0.00033	0.42181	0.16879
Average =	0.00430			

Table 4-24. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for combtooth blenny. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.8145 (12.8)	0.00768	0.27717	0.28485	0
Offshore Extrapolated	0.4166	0.00285	0.26937	0.27222	0

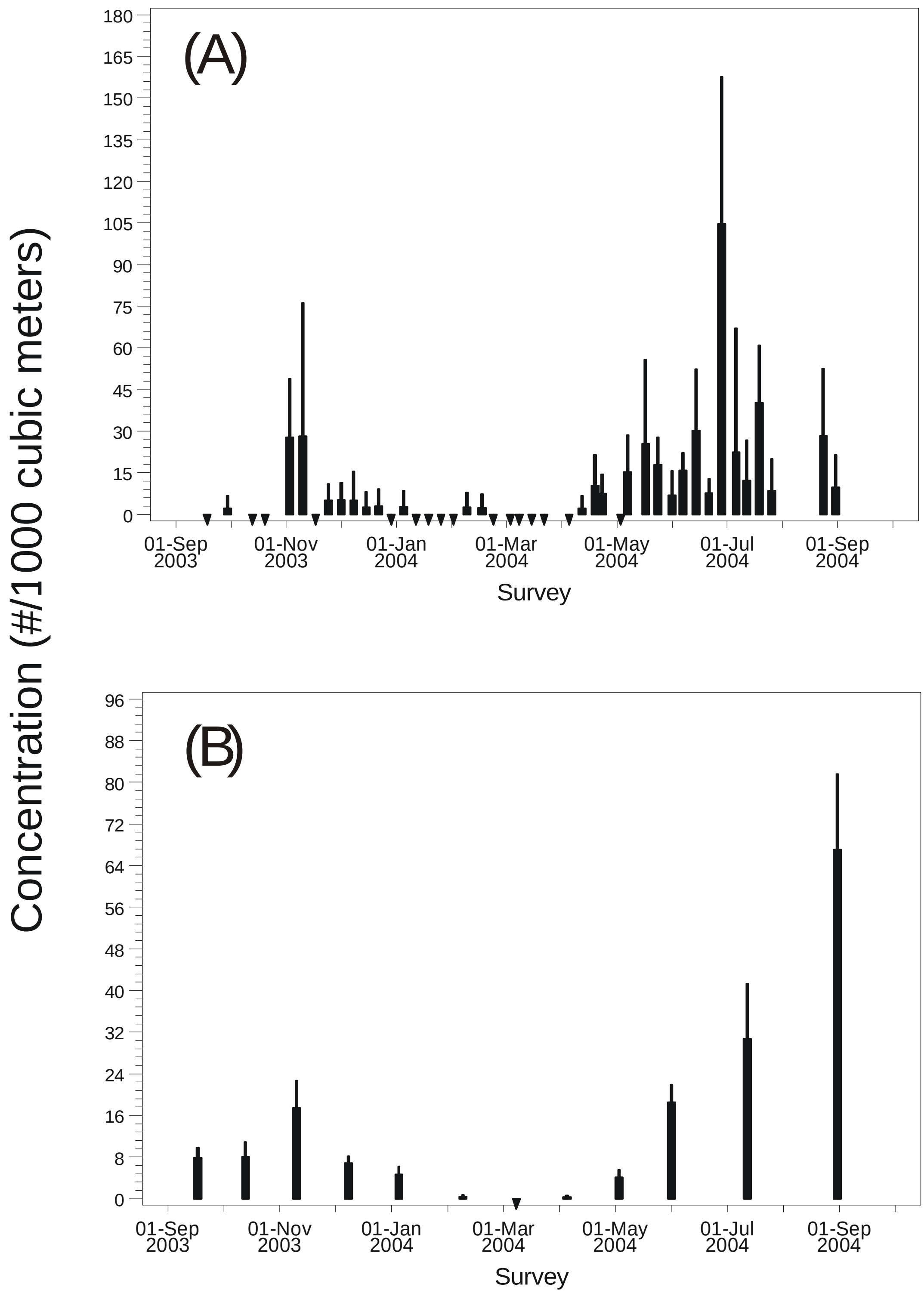


Figure 4-29. Survey mean concentration (#/1000 m^3) of combtooth blenny larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no combtooth blenny larvae were collected.

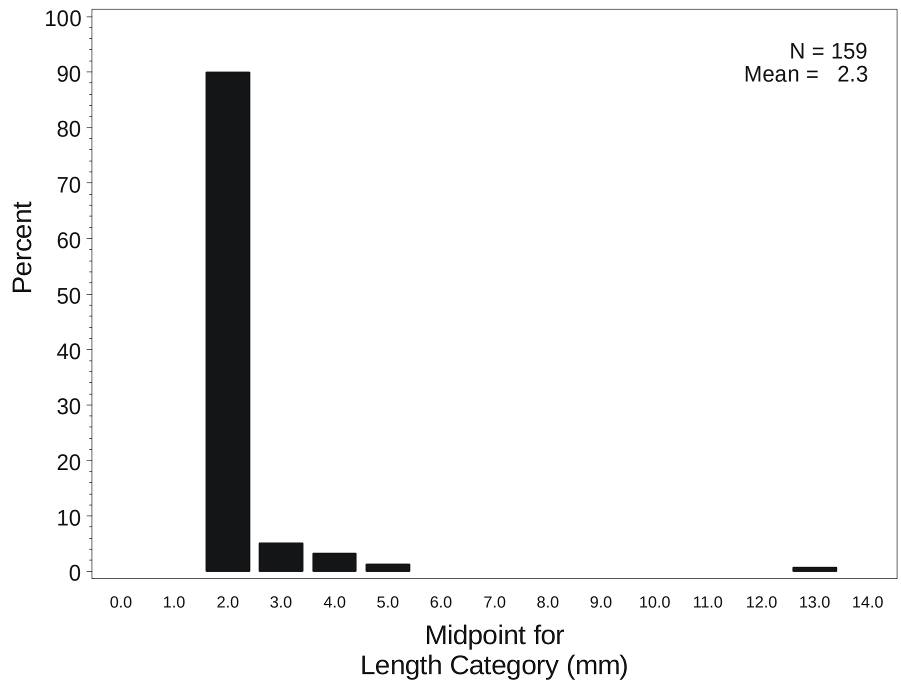


Figure 4-30. Length frequency distribution (mm) of combtooth blenny larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.9 Diamond Turbot (*Hypsopsetta guttulata*)

Diamond turbot *Hypsopsetta guttulata* is classified in the family of right-eyed flatfishes (Pleuronectidae). It is one of twenty pleuronectid species that occur off California, and ranges from Cape San Lucas, Baja California to Cape Mendocino, California (Eldridge 1975). An isolated population has also been reported from the upper Gulf of California (Miller and Lea 1972). The scientific name of this species changed from *Hypsopsetta guttulata* to *Pleuronichthys guttulatus* during the course of this study (Nelson et al. 2004). *H. guttulata* is used in this report to maintain consistency with the Six-Month and Nine-Month Reports.

4.5.4.9.1 Habitat Requirements

This species is found on muddy or sandy substrates in bays or along nearshore coastal areas. The diamond turbot occurs in water depths between less than 1 m and 50 m (3.28 and 164 ft), but is most common in shallow water less than 10 m (32.8 ft) (Lane 1975).

4.5.4.9.2 Reproduction

Little is known of the reproductive habits of the diamond turbot. Females become sexually mature at two to three years (Fitch and Lavenberg 1975), but no equivalent information is available concerning the males. Both sexes are sexually mature at a total length of 16.5 cm (6.5 in.) (Love 1996). Spawning occurs year-round and appears to peak during the winter months (Eldridge 1975). Eggs collected in San Francisco Bay averaged 0.8 mm in diameter (Eldridge 1975).

4.5.4.9.3 Age and Growth

The largest diamond turbot reported in the literature was 46 cm (18 in.) in total length (Lane 1975). The maximum age for this species, based on otoliths and scales, is about eight years (Love 1996; Fitch and Lavenberg 1975). Newly hatched larvae collected in San Francisco Bay averaged 1.6 mm (0.06 in) NL (Eldridge 1975). Larvae are planktonic and settle to the bottom in shallow water after about five to six weeks. Standard length at the time of settlement is about 1.1-1.2 cm (0.43-0.47 in) (Eldridge 1975, Love 1996). Early growth rates appear to be similar to other flatfishes including the California halibut (*Paralichthys californicus*). Gadomski et al. (1990) calculated the growth rate to flexion of California halibut to be 0.23 mm/day (0.01 in/day). Total length of diamond turbot at one year is about 14 cm (5.5 in.) (Lane 1975).

4.5.4.9.4 General Ecology

Diamond turbot are found in bays and shallow coastal waters with sandy or muddy bottoms. They feed primarily on invertebrates that live on top of, or in the upper layers of the substrate. Gut contents of diamond turbot collected in Anaheim Bay, California included polychaete worms, crustaceans, and mollusks (Lane 1975). This species feeds primarily during daylight hours. Predators include angel shark, Pacific electric ray, and other piscivorous fishes.

4.5.4.9.5 Population Trends and Fishery

Diamond turbot makes up a minor portion of the California marine sport fishery (Leos 2001). They are taken by anglers fishing from the shore, piers, or boats in shallow bays and estuaries. This species has little commercial importance but is taken occasionally as part of the incidental catch. It is usually reported under the grouping of ‘turbot’ along with several other flatfish species. California Department of Fish and Game reported annual landings of ‘turbot’ in California of about 5896.7 and 2993.7 kg (13,000 and 6,600 lbs) for the years 2001 and 2002 respectively. The proportion of this total contributed by diamond turbot is not known.

4.5.4.9.6 Sampling Results

Diamond turbot was the 12th most abundant taxon collected from the entrainment station and 14th most abundant at the source water stations, comprising about 1.3% of all of the larvae collected at the entrainment station (Tables 4-1 and 4-3). The estimated mean entrainment per survey was variable, ranging from zero to about 100 diamond turbot larvae per 1,000 m^3 (Figure 4-31a). Diamond turbot larvae were present during many of the surveys with a pronounced peak during August 2004. The peak concentration at the source water stations occurred in October 2003 (Figure 4-31b). The number and concentration of larval diamond turbot collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution of measured diamond turbot larvae showed that the samples were dominated by recently hatched larvae based on the reported hatch length of 1.6 mm (0.06 in) SL (Eldridge 1975) (Figure 4-32). The mean, maximum, and minimum sizes for the measurements were 2.3, 4.7, and 1.3 mm (0.09, 0.18, and 0.05 in), respectively. A larval growth rate of 0.23 mm/day (0.01 in/day) calculated from data in Gadomski et al. (1990) for California halibut was used with the difference in the lengths of the first (1.3 mm [0.05 in]) and 95th (4.3 mm [0.17 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 13 days.

4.5.4.9.7 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on diamond turbot larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of information on life history necessary to parameterize the models. Total entrainment was estimated at approximately 5.4 million larvae for the period of September 2003 through August 2004.

4.5.4.9.8 Empirical Transport Model (*ETM*)

The *PE* estimates for diamond turbot ranged from 0 to 0.02 (Table 4-25). The average *PE* estimate was 0.00517, which is greater than the ratio of the entrainment and source water volumes of 0.00211. As shown in Table 4-25 the values of f_i indicate that diamond turbot larvae were present throughout much of the year in the source water and there were several surveys when they were present at the source water stations, but were not collected at the entrainment station. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 13-day period of exposure calculated using offshore extrapolated densities (0.003, 0.3%) is less than the estimate calculated using alongshore current displacement (0.006, 0.6%) because the effects of entrainment are spread over a much larger population for the offshore extrapolated estimate (Table 4-26). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 61.7 and 28.7%, respectively, and the alongshore estimate was extrapolated over a shoreline distance of 16.9 km (10.5 mile).

Table 4-25. *ETM* data for diamond turbot larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i Estimate	f_i Std. Error
17-Sep-03	0.00000	0.00000	0.07266	0.07101
13-Oct-03	0.00120	0.00155	0.20314	0.10636
10-Nov-03	0.00163	0.00373	0.08881	0.09327
8-Dec-03	0.00000	0.00000	0.03104	0.04430
5-Jan-04	0.00079	0.00166	0.19283	0.11089
9-Feb-04	0.00000	0.00000	0.04220	0.05032
8-Mar-04	0.00115	0.00255	0.13051	0.11381
5-Apr-04	0.02108	0.07994	0.00564	0.01816
3-May-04	0.00000	0.00000	0.08152	0.07454
1-Jun-04	0.00000	0.00000	0.00000	0.00000
12-Jul-04	0.00000	0.00000	0.00000	0.00000
31-Aug-04	0.00000	0.00000	0.15164	0.11536
Average =	0.00517			

Table 4-26. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for diamond turbot. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.6166 (16.9)	0.00578	0.28065	0.28643	0
Offshore Extrapolated	0.2866	0.00275	0.27619	0.27894	0

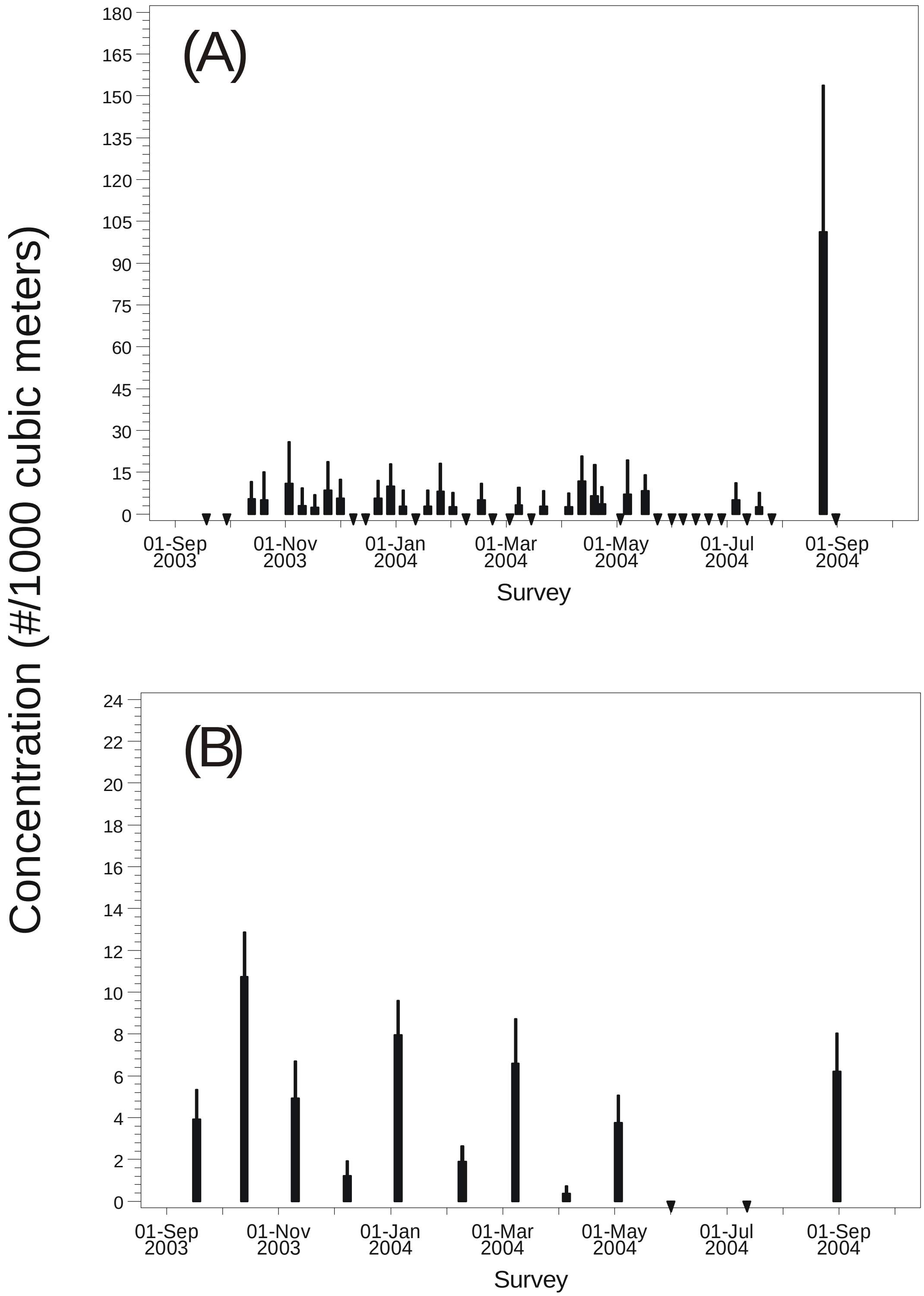


Figure 4-31. Survey mean concentration (#/1000 m^3) of diamond turbot larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no diamond turbot larvae were collected.

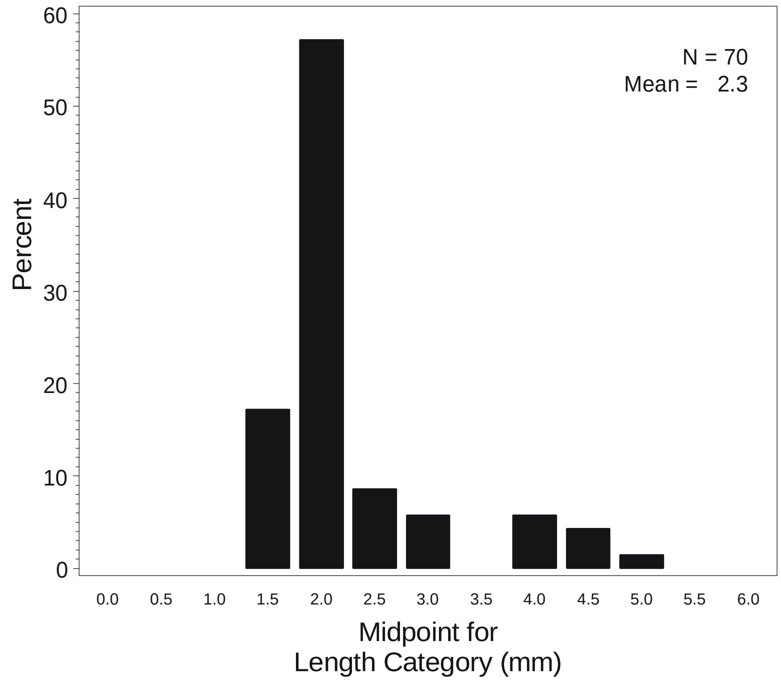


Figure 4-32. Length frequency distribution (mm) of diamond turbot larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.10 California Halibut (*Paralichthys californicus*)

California halibut is an important part of California's commercial and recreational fisheries (Starr et al. 1998; Kramer and Sunada 2001). It ranges from northern Washington to Bahia Magdalena, southern Baja California and is found from very shallow nearshore waters in bay nursery grounds to depths of at least 185 m (607 ft) (Miller and Lea 1972; Haaker 1975).

4.5.4.10.1 Habitat Requirements

Juveniles and adults typically occur on sandy sediments at depths less than 30 m (98.5 ft) but sometimes concentrate near rocks, algae, or Pacific sand dollar (*Dendraster excentricus*) beds (Feder et al. 1974). As with other flatfishes, they frequently lie buried or partially buried in the sediment. Newly settled and juvenile halibut often occur in unvegetated shallow embayments and occasionally on the outer coast, suggesting that bays are an important nursery habitat for this species (Kramer and Sunada 2001).

4.5.4.10.2 Reproduction

California halibut is a broadcast spawner with eggs being fertilized externally. The spawning season is generally thought to extend from February to August with most spawning occurring in May (Frey 1971), although some fall spawning may also occur. The average number of eggs per spawn is 313,000–589,000 with an average reproductive output of approximately 5.5 million eggs per spawning season (Caddell et al. 1990). During spawning season females may release eggs every 7 days and the largest individuals may produce in excess of 50 million eggs per year (Caddell et al. 1990). Captive specimens were observed to spawn at least 13 times per season (Caddell et al. 1990). Halibut eggs are 0.7–0.8 mm (0.027-0.031 in) in diameter (Ahlstrom et al. 1984) and are most abundant in the water column at depths less than 75 m (246 ft) and within 6.5 km (4.0 mile) from shore (Kramer and Sunada 2001).

4.5.4.10.3 Age and Growth

Upon hatching, the larvae (1.6–2.1 mm (0.06-0.08 in) NL [Moser 1996]) are pelagic (Frey 1971), and most abundant between Santa Barbara, California, and Punta Eugenia, Baja California Sur (Ahlstrom and Moser 1975) from January through April and June through August (Moser 1996). California halibut have a relatively short pelagic larval stage, from 20–29 days (Gadomski et al. 1990). Larval transformation occurs at a length of about 7.5–9.4 mm (0.3-0.4 in) SL (Moser 1996) at which time the young fish settle to the bottom, generally in bays but also occasionally in shallow substrates along the open coast (Haugen 1990). Kramer (1991) found that 6–10 mm (0.2-0.4 in) California halibut larvae grew <0.3 mm/day (0.012 in/day), while larger 70–120 mm (2.8-4.7 in) halibut grew about 1.0 mm/day (0.04 in/day). In a laboratory study, California halibut held at 16°C (60.8°F) grew to a length of 11.1 mm ± 2.61 (0.44 in ± 0.1) (SD) in two months from an initial hatch length of 1.9 mm (0.07 in) (Gadomski et al. 1990). After settling in the bays, the juveniles may remain there for about two years until they emigrate to the outer coast. Males mature at 2–3 years and 20–23 cm (7.9-9.0 in) SL; females mature at 4–5 years and 38–43 cm (14.9-16.9 in) SL (Fitch and Lavenberg 1971; Haaker 1975). Males emigrate out of the bays when they mature (i.e. at 20 cm [7.9 in]) but females migrate out as subadults at a length of about 25 cm (9.8 in) (Haugen 1990). Subadults remain nearshore at depths of 6–20 m (19.7-65.6 ft) (Clark 1930; Haaker 1975). California halibut may reach 152 cm (60 in) and 33 kg (73 lbs) (Eschmeyer et al. 1983). Individuals may live as long as 30 years (Frey 1971).

4.5.4.10.4 General Ecology

California halibut feed during the day and night, but show a preference for daytime feeding (Haaker 1975). The species is an ambush feeder, typically lying partially buried in the sand until prey approaches. They prey on Pacific sardine (*Sardinops sagax*), anchovies, squid, and other nektonic nearshore fish species (Kramer and Sunada 2001). Small halibut in bays eat small crustaceans and become increasingly piscivorous with size. Other similar species of flatfishes such as sand sole and bigmouth sole may compete with California halibut within their range (Haugen 1990). Because of an extensive overlap in diet, habitat, geographic and bathymetric distributions, and probable foraging behavior, the California lizardfish may be the most important potential competitor of medium-sized California halibut (Allen 1982).

4.5.4.10.5 Population Trends and Fishery

California halibut have a high commercial and recreational fishery value. The fishery for California halibut was reviewed by Kramer and Sunada (2001) and recent catch statistics are available through the PSMFC PacFIN (commercial) and RecFIN (recreational) databases. Historically, halibut have been commercially harvested by three principal gear types: otter trawl, set gill and trammel net, and hook and line. Presently there are numerous gear, area, and seasonal restrictions that have been imposed on the commercial halibut fishery for management purposes. Since 1980 the statewide commercial catch has averaged approximately one million pounds per year. In southern California (San Diego, Orange and Los Angeles counties) the average annual commercial catch and ex-vessel revenue from halibut for the years 2000–2004 was approximately 25,401.2 kg (56,000 lbs) and $202,000 respectively. During this time the greatest catches were in 2000 (39,111 kg [82,225 lbs]) and the least were in 2003 (17,287.8 kg [38,113 lbs]).

It appears that the size of the California halibut population may be limited by the availability of shallow-water nursery habitat, and a long-term decline in landings corresponds to a decline in these habitats in southern California associated with dredging and filling of bays and wetlands (Kramer and Sunada 2001). A fishery-independent trawl survey for halibut conducted in the early 1990s estimated that the southern California biomass was 6.9 million pounds (3.9 million adult fish) and the central California biomass was 2.3 million pounds (0.7 million fish) (Kramer and Sunada 2001).

4.5.4.10.6 Sampling Results

California halibut was the ninth most abundant taxon collected from the entrainment station and eighth most abundant at the source water stations, comprising about 1.5% of all of the larvae collected at the entrainment station (Tables 4-1 and 4-3). The estimated mean entrainment per survey was variable, ranging from zero to about 130 California halibut larvae per 1,000 m^3, with most larvae occurring from April through August (Figure 4-33a). The peak concentration at the entrainment station was recorded in June but the peak source water concentrations occurred in August (Figure 4-33b). The number and concentration of larval California halibut collected during each entrainment and source water survey is presented in an appendix to this report.

The length frequency distribution of measured California halibut larvae showed a bi-modal size distribution which was dominated by recently hatched larvae based on the reported hatch length of 1.6–2.1 mm (0.06-0.08 in) (Moser 1996) and a second peak at 7.0 mm (0.3 in) (Figure 4-34). The mean, maximum, and minimum sizes for the measurements were 2.1, 7.4, and 1.1 mm (0.08, 0.29, and 0.04 in), respectively. A larval growth rate of 0.23 mm/day (0.01 in/day) calculated from data in Gadomski et al. (1990) was used with the difference in the lengths of the first (1.1 mm [0.4 in]) and 95th (6.8 mm [0.3 in]) percentiles of the measurements to estimate that the larvae were exposed to entrainment for a period of 25 days.

4.5.4.10.7 Impact Assessment

The following sections present the results for empirical transport modeling of entrainment effects on California halibut larvae. Demographic model estimates of entrainment effects were not calculated because of the absence of information on life history necessary to parameterize the models. Total entrainment was estimated at approximately 5 million larvae for the period of September 2003 through August 2004.

4.5.4.10.8 Empirical Transport Model (*ETM*)

The *PE* estimates for California halibut correspond to both the 2003 and 2004 spawning periods (Table 4-27). The values of f_i indicate increasing abundances of California halibut larvae in the source waters when the study was completed at the end of August 2004. This isn't necessarily problematic if the assumption that the *PE* estimates are not related to changing abundances in source water is correct. The values of f_i also indicate that although there were surveys when no larvae were collected at the entrainment station (*PE*=0), *PE* estimates were available for the surveys when the majority of the halibut larvae were found in the source water samples. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. The estimate of P_M for the 25-day period of exposure calculated using offshore extrapolated densities (0.0008, 0.08%) is less than the estimate calculated using alongshore current displacement (0.0025, 0.25%) because the effects of entrainment are spread over a much larger population for the offshore extrapolated estimate (Table 4-28). The P_s estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 33.8 and 11.3%, respectively and the alongshore estimate was extrapolated over a shoreline distance of 30.9 km (19.2 mile).

Table 4-27. *ETM* data for California halibut larvae. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i Estimate	f_i Std. Error
17-Sep-03	0.00000	0.00000	0.02009	0.01309
13-Oct-03	0.00000	0.00000	0.00987	0.01394
10-Nov-03	0.00142	0.00200	0.03617	0.03166
8-Dec-03	0.00000	0.00000	0.00000	0.00000
5-Jan-04	0.00000	0.00000	0.00616	0.01307
9-Feb-04	0.00000	0.00000	0.00158	0.00498
8-Mar-04	0.00000	0.00000	0.00873	0.01183
5-Apr-04	0.00000	0.00000	0.00599	0.00930
3-May-04	0.00137	0.00184	0.05424	0.02912
1-Jun-04	0.00043	0.00091	0.10875	0.08657
12-Jul-04	0.00089	0.00116	0.13504	0.06103
31-Aug-04	0.00010	0.00020	0.61338	0.16245
Average =	0.00084			

Table 4-28. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for California halibut. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.3378 (30.9)	0.00250	0.20636	0.20886	0
Offshore Extrapolated	0.1125	0.00079	0.20246	0.20324	0

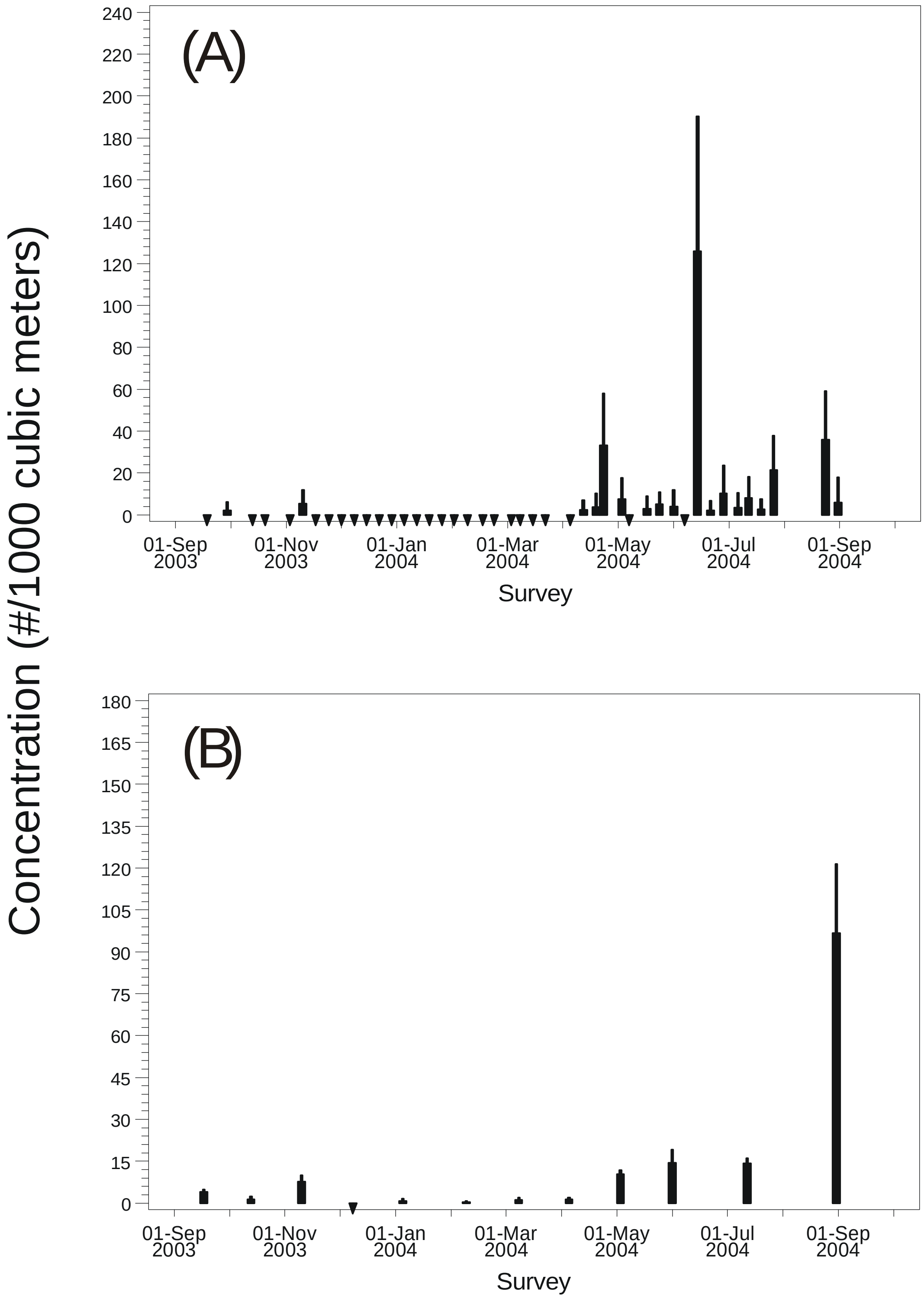


Figure 4-33. Survey mean concentration (#/1000 m^3) of California halibut larvae collected at the HBGS entrainment (A) and source water (B) stations with standard error indicated (+1 SE). Down arrows indicate surveys when no California halibut larvae were collected.

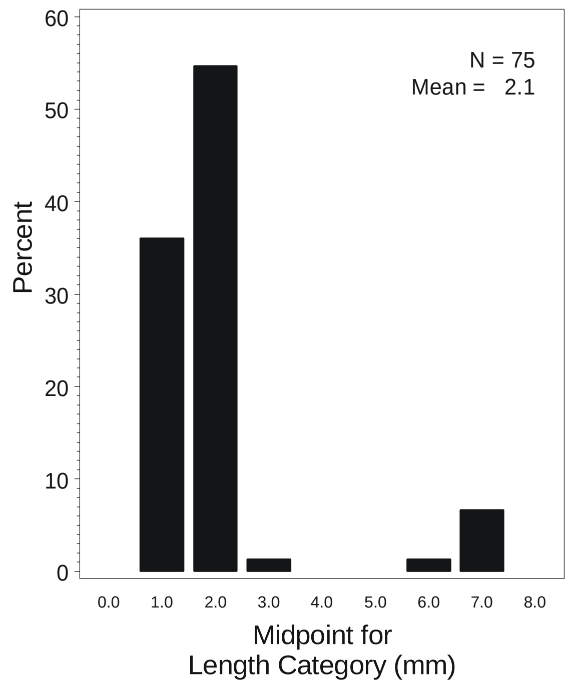


Figure 4-34. Length frequency distribution (mm) of California halibut larvae collected from the HBGS entrainment station from September 2003 through August 2004.

4.5.4.11 Sand Crab (*Emerita analoga*)

The sand crab, also known as the Pacific mole crab, is a common filter-feeding crustacean that occurs intertidally along sandy beaches of the Pacific coast of North and South America. The species ranges in the northeastern Pacific from Kodiak Island, Alaska, to Magdalena Bay, Baja California, and in the southeastern Pacific from Salavery, Peru south to False Bay, Argentina (Efford 1970). An isolated population has also been reported to occur in the northern Gulf of California (Efford 1969). A similar but larger species, the spiny mole crab (*Blepharipoda occidentalis*), occurs in the low intertidal and subtidal zone from Stinson Beach, California to Bahia Ballenas, Baja California (Morris et al. 1980).

4.5.4.11.1 Habitat Requirements

Juvenile and adult sand crabs inhabit sandy beaches, where they burrow in the swash zone just under the sand surface. Prime locations are on exposed beaches at, or above, the low tide line where waves and surf action is highest (Johnson 1939). Dense aggregations of up to 40,000 animals per square meter have been observed (Richards 1996). Larvae are planktonic and occur in nearshore coastal waters.

4.5.4.11.2 Reproduction

Mating occurs in spring and summer, with the main breeding period from March to November (Morris et al. 1980). During breeding season, females carry the eggs under the telson attached to their abdominal appendages. Several males collect near the female when she is ready to deposit her eggs, and sperm is deposited about 12 hr before eggs are laid (MacGinitie 1938). During the reproductive season females can produce one clutch per month of approximately 50–50,000 eggs with larger crabs producing more eggs per clutch. Eggs are incubated through the cleavage and embryonic stages while attached to the female and take approximately 30 days to develop fully. The larvae are released as free-swimming organisms in the first zoeal stage. Wenner et al. (1987) found that egg production varies by age class, location, and season. Females may breed repeatedly if conditions are favorable, and in the laboratory, females produced up to four consecutive egg masses (Cox and Dudley 1968). In southern California, the bulk of larvae are hatched during July and early August (Johnson and Lewis 1942). Fusaro (1980a) determined that water temperature strongly affected egg production, with seven times as many females producing eggs at 25°C (77°F) than at 12°C (53.6°F).

4.5.4.11.3 Age and Growth

Sand crab larvae are planktonic zoeae, which are in the plankton for about four and one-half months. The pelagic larvae molt through five zoeal stages increasing in size from 0.53 mm (0.02 in) carapace length (CL) in the first zoeal stage to 3.50 mm (0.14 in) CL in the fifth zoeal stage (Johnson and Lewis 1942). Based on a laboratory rearing experiment, the first zoeal stage can last up to 34 days before molting to the second stage (Johnson and Lewis 1942). However, cultured larvae experienced difficulty in feeding, and Johnson (1939) speculated that the time required to complete each developmental stage is less under natural conditions where suitable food resources are more readily available and growth is more rapid. The longevity of subsequent stages can only be inferred from the abundances of specimens collected in the field because later stages were not successfully reared under laboratory conditions.

Each of the stage 2–5 zoea probably lasts from approximately 20-30 days depending on environmental conditions. During this time, zoeae are subject to alongshore and onshore/offshore currents, and Stage 4 larvae have been found >100 miles offshore beyond the Channel Islands (Johnson 1939). Stage 5 larvae were scarce in Johnson's samples, presumably due to downward movement in preparation for assuming a benthic existence. The final larval stage is the megalops in which the body form resembles the first benthic crab stage. In one study, megalopae arrived at Scripps Beach in La Jolla, California, beginning in early August, with peak numbers arriving in early June (Efford 1970). However, in Santa Barbara, megalopae arrived on the beach in fall (Barnes and Wenner 1968). Once on the beach, megalopae molt and develop into juveniles, then into small males and females. Sand crabs reproduce in the first summer following settlement, and the females (at least) live to the second summer when they reproduce and die the following autumn.

While sand crabs range widely from Alaska to Baja, the population structure differs from beach to beach (Barnes and Wenner 1968). Crabs from southern sites tend to reproduce at smaller sizes and younger ages and attain smaller maximum sizes than crabs from northern sites (Dugan et al. 1991). Adult male sand crabs are smaller than females, and in some areas the ratio of males to females shifts with season (Morris et al. 1980). Sexually mature females range from 9–38 mm (0.35-1.5 in) carapace length (CL), while mature males range from 6–12 mm (0.24-0.47 in) CL (Dudley 1967; Dugan et al. 1991). Fusaro (1978) found large differences in growth rates between sand crabs at Goleta Bay and at Santa Cruz Island, which are only 42 km (26.1 mile) apart—sand crabs grew more rapidly on the mainland than at the island. He attributed this to the colder water and reduced filterable material suspended in the water at the island site. Dugan et al. (1991) also found that size at maturity and the size distribution of ovigerous crabs were inversely correlated with water temperature.

4.5.4.11.4 General Ecology

When moving up or down the beach, sand crabs swim until the flow of water slackens, then immediately burrow, facing toward the sea (MacGinitie 1938). Feeding is performed by screening out microorganisms such as dinoflagellates as water passes over their plumose antennae, which protrude from the surface of the shifting sands. Food items are transferred to the mouth by wiping the antennae through the mouthparts. Efficient feeding occurs with the receding wash of the breakers, and the animals tend to maintain themselves at a tidal level where the maximum wash occurs (MacGinitie 1938).

Dillery and Knapp (1970) determined that sand crabs made longshore movements corresponding to alongshore current and sediment movement. At Goleta, California, the overall mean eastward movement of 114 crabs was about 15 m (48 ft) per day. The most rapidly moving sand crab was one that was tracked 693 m (2,275 ft) in five days, a mean of 139 m (455 ft) per day. Diel movements were also reported by Fusaro (1980b), with distribution shifting seaward daily and shoreward nightly relative to the same tidal level. In southern California, a portion of the *Emerita* population tends to move offshore to subtidal waters in winter when wave motion increases, and return to beaches in spring (Morris et al. 1980). The beach population is augmented by the settlement of megalops larvae.

4.5.4.11.5 Population Trends and Fishery

Sand crabs are fished primarily for bait, and the recently molted soft-shelled individuals are targeted. The first commercial catch was reported in 1963, with 2119.6 kg (4,673 lbs) landed state-wide (Herbinson and Larson 2001). By 1967 landings totaled over 3764.8 kg (8,300 lbs) worth $17,152. Since 1977, however, catch decreased greatly, averaging only 10 kg (22 lbs) per year. This is likely due to reduced harvest effort and replacement of sand crab with other bait species, such as ghost shrimp, clams, and mussels. There were no reported commercial landings of sand crabs within any of the CDFG catch blocks off the HBGS in 2003 (CDFG 2004) and sport catches are not reported.

4.5.4.11.6 Sampling Results

Sand crab larvae were the most abundant of the targeted invertebrates in entrainment (average of 659 zoea per 1,000 m^3; Table 4-2) and source water samples (average of 173 larvae per 1,000 m^3; Table 4-5). All of the zoea larvae collected were Stage 1. The entrainment estimate for the study period was 465,806,877 zoea (Table 4-1). Larval abundances in entrainment and source water surveys showed an increasing trend with the highest abundances in the August 2004 surveys (see appendix). The greater abundances at the inshore stations are consistent with the littoral distribution of the adult spawning population. Only two megalops (at a concentration of 0.17 megalopae per 1,000 m^3; Table 4-2) were collected at the entrainment station, and none were collected at the source water stations.

4.5.4.11.7 Impact Assessment

No impact assessment modeling of entrainment effects on sand crabs was done because megalops larvae were not collected in sufficient abundance, and did not occur in paired entrainment and source water surveys during the study.

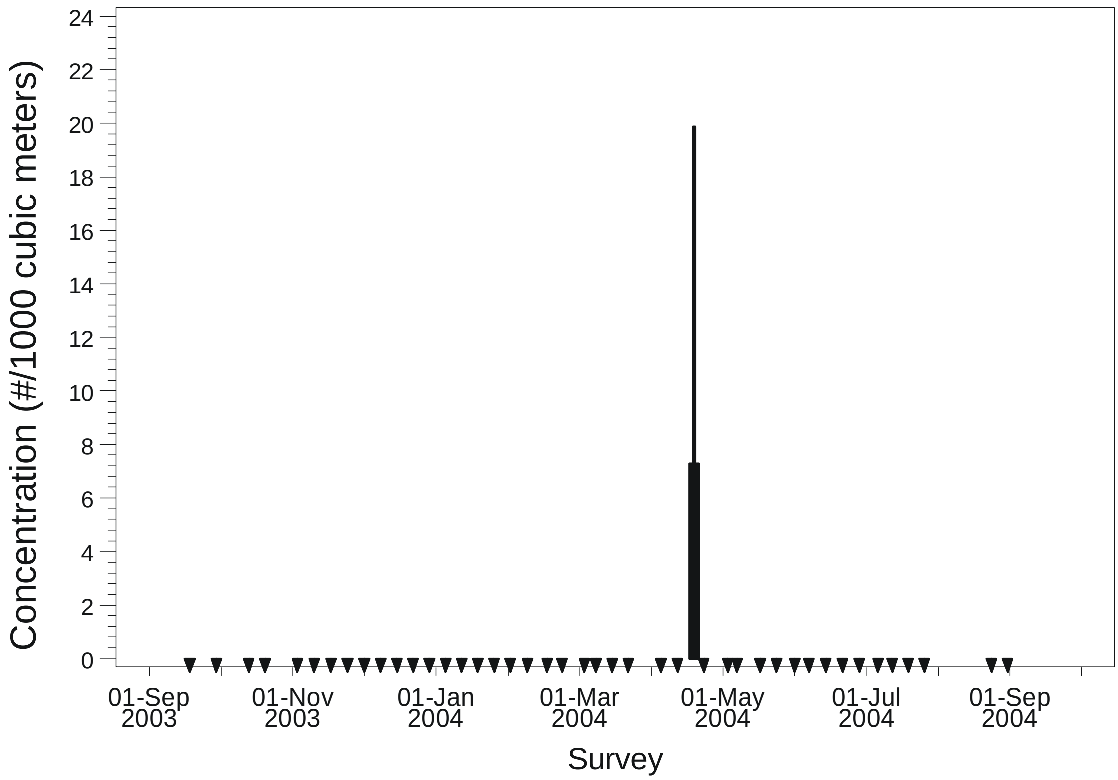


Figure 4-35. Survey mean concentration (#/1000 m^3) of sand crab megalops larvae collected at the HBGS entrainment station with standard error indicated (+1 SE). There were no sand crab megalops collected at the source water stations. Down arrows indicate surveys when no sand crab larvae were collected.

4.5.4.12 California Spiny Lobster (*Panulirus interruptus*)

California spiny lobster ranges from Monterey Bay, California, to Manzanillo, Mexico, and there is also a small population along the northwestern shore of the Gulf of California (MBC 1987). They are the only representative of the spiny lobster family (Palinuridae) in southern California.

4.5.4.12.1 Habitat Requirements

During the first two years, juveniles inhabit surfgrass beds from the lower intertidal to depths of about 5 m (16 ft). Juveniles and adults are considered benthic, though they have been observed swimming near the surface, and occur from the intertidal zone to about 80 m (262 ft). Preferred habitats include mussel beds, rocky areas, and in kelp beds (Morris et al. 1980; Barsky 2001).

4.5.4.12.2 Reproduction

California spiny lobster are oviparous, the sexes are separate, and fertilization is external. With few exceptions, adult females spawn every year. Barsky (2001) reported that mating occurs from November through May, and Wilson (1948) indicated the primary spawning season was from March to August. Mating takes place on rocky bottoms in water depths of 10–30 m (33–98 ft) (Mitchell et al. 1969). Spawning occurs from the Channel Islands off southern California to Magdalena Bay, Baja California, including other offshore islands and banks, such as Cortez and Tanner (MBC 1987). Females move inshore to depths less than 10 m (33 ft) to extrude and fertilize the eggs. At San Clemente Island, females carried between 120,000 eggs (66 mm [2.6 in] CL) and 680,000 eggs (91 mm [3.6 in] CL) (Barsky 2001).

4.5.4.12.3 Age and Growth

Hatching occurs from March to December. Larvae are pelagic and are found from the surface to depths of 137 m (449 ft), and within 530 km (329 mi) of shore (MBC 1987). Upon hatching, transparent larvae (phyllosoma) go through 12 molts, increasing in size in each subsequent molt. Phyllosoma larvae are infrequently collected in the Southern California Bight (Johnson 1956; MBC 1987). After five to ten months, the phyllosoma transforms into the puerulus larval stage which resembles the adult form but is still transparent. The puerulus actively swims inshore where it settles in shallow water. At La Jolla, puerulus appeared in nearshore waters in late May and occurred there through mid-September (Serfling and Ford 1975). It is hypothesized that the puerulus stage of California spiny lobster lasts approximately two to three months (Serfling and Ford 1975).

A 6.1-mm (0.24 in) CL juvenile specimen goes through 20 molts to reach 45.7 mm (1.8 in) CL at the end of its first year (Barsky 2001). Spiny lobsters molt four times during the second year, and three times during the third year. Mitchell et al. (1969) found adult spiny lobsters (larger than 41 mm [1.6 in] CL) molt once yearly. Both sexes reach maturity at approximately 5–6 years at a mean size of 63.5 mm (2.5 in) CL (Barsky 2001). It takes a spiny lobster 7–11 years to reach the legal fishery size of 83 mm (3.27 in) CL. Females grow faster (4.4 mm/yr [0.17 in/year]) than males (3.7 mm/yr [0.15 in/year]) (Mitchell et al. 1969). Males may live up to 30 years, and reach a maximum length of 91 cm (35.8 in)

TL and weight of 15.8 kg (34.8 lbs). Females may live up to 17 years, and reach a maximum size of 50 cm (19.7 in) TL and 5.5 kg (12.1 lbs) (MBC 1987).

4.5.4.12.4 General Ecology

Lobsters are nocturnal, seeking crevices in which to hide during the day, and moving about the bottom at night (Wilson 1948). *Panulirus* is an omnivorous bottom forager, feeding on snails, mussels, urchins, clams, and fishes (Tegner and Levin 1983, Barsky 2001). A large portion of the population makes seasonal migrations stimulated by changes in water temperature, with an offshore migration in winter, and an inshore migration in late-spring and early summer (Mitchell et al. 1969; Barsky 2001). By the end of August, berried females and juveniles comprise the bulk of the shallow-water population. Warmer water temperatures shorten the development time of lobster eggs. By late September, the thermocline breaks down and lobsters move to deeper water (10–30 m [33–98 ft]) where they remain for the winter (MBC 1987).

4.5.4.12.5 Population Trends and Fishery

California spiny lobster have been fished commercially in southern California since the late 1800s (Barsky 2001). They are fished with traps, most of which are constructed of wire mesh. Most traps are fished in shallow rocky areas in waters shallower than 31 m (100 ft) deep. Landings in Catch Block 738 off the HBGS totaled 8,970 kg (19,776 lbs) ($136,930) in 2003 and 5,939.8 kg (13,095 lbs) ($86,707) in 2002 (CDFG 2004). Landings were substantially smaller in the other two catch blocks off the HBGS, totaling 656.8 kg (1,448 lbs) in 2003 and 690.8 kg (1,523 lbs) in 2002 in Block 739, and 1,215.6 kg (2,680 lbs) in 2003 and 2,680.3 kg (5,909 lbs) in 2002 in Block 740. Almost all landings were from crab/lobster traps, though some were reported from set longlines.

4.5.4.12.6 Sampling Results

Only a single spiny lobster puerulus larva was collected from the source water samples. It was collected during the first source water survey at Station U2. No spiny lobster puerulus larvae were collected from the entrainment station samples.

4.5.4.12.7 Impact Assessment

No impact assessment modeling of entrainment effects on spiny lobster was done because only a single lobster puerulus larva was collected in all of the samples.

4.5.4.13 Ridgeback Rock Shrimp (*Sicyonia ingentis*)

Ridgeback rock shrimp (ridgeback prawn) ranges from Monterey, California to Isla Maria Madre, Nayarit, Mexico, including the Gulf of California (MBC 1987). Major concentrations of ridgeback rock shrimp occur in the Santa Barbara Channel between Point Conception and Ventura, off Santa Monica Bay, and off Oceanside, California (Sunada 1984; MBC 1987; Sunada et al. 2001). Another sicyoniid, the target shrimp (*Sicyonia penicillata*), was one of several southern decapods collected in southern California during and after the 1997–1998 El Niño (MBC 1999; LACSD 2000). It normally occurs in the Gulf of California and off the southern half of Baja California (Word and Charwat 1976; Blake and Scott 1997).

4.5.4.13.1 Habitat Requirements

Sunada (1984) and Sunada et al. (2001) reported a depth range for ridgeback rock shrimp of 45 to 162 m (147.6 to 531.5 ft); however, MBC (1987) listed a depth range of 5 to 307 m (16.4 to 1,007.2 ft). Off the Palos Verdes Peninsula (Los Angeles County) from 1978 through 2000, ridgeback rock shrimp was most abundant on the 137-m (449.5 ft) isobath, less abundant on the 61-m (200.1 ft) isobath, and did not appear to be collected on the 23-m (75.5 ft) isobath (LACSD 2000). They were the most abundant invertebrate collected in 2000 on the 55-m (180.4 ft) isobath off Huntington Beach (OCSD 2000). Eggs and larvae are pelagic and neritic, while juveniles and adults are benthic (MBC 1987). They occur on substrates of sand, shell, and mud (Sunada et al. 2001).

4.5.4.13.2 Reproduction

Ridgeback rock shrimp are oviparous. Spawning in the Santa Barbara Channel occurs from June through October, with possible multiple spawning occurring throughout summer (Anderson et al. 1985a). The sexes are separate, and fertilization is likely external, occurring as eggs are extruded (MBC 1987). Fecundity is estimated at 47,000 to 131,000 embryos per spawn, with an average of 86,000 (Anderson 1985b).

4.5.4.13.3 Age and Growth

The maximum life span of ridgeback rock shrimp is about five years (Sunada et al. 2001). Females reach a maximum length of 45 mm (1.77 in) CL, and males 37 mm (1.46 in) CL (Sunada 1984). Ridgeback rock shrimp move deeper as they grow; hence, smaller individuals are usually found closer to shore. In one study, monthly sampling of rock shrimp revealed a narrow size range (23–47 mm [0.9-1.85 in] CL) at 145 m (475.7 ft) depth, while shrimp collected at 60 m (196.8 ft) were usually smaller, with a length-frequency distribution peak at about 30 mm (1.2 in) CL (Anderson et al. 1985b). In that same study, shrimp collected at 40 m (131.2 ft) were most commonly 10–25 mm (0.4-0.98 in) CL.

Molt frequency is high in late spring, prior to the onset of spawning (Anderson et al. 1985a). Females begin a synchronous molt cycle in June that lasts until late-October or early-November, after the spawning season. Males exhibit a similar molt synchrony, but with a shorter period and more variability.

4.5.4.13.4 General Ecology

Ridgeback rock shrimp feed on detritus, diatoms, sponges, snails, polychaetes, copepods, ostracods, amphipods, and euphausiids (Mearns 1982; MBC 1987).

4.5.4.13.5 Population Trends and Fishery

In one study of the mainland shelf of southern California, ridgeback rock shrimp was one of the most frequently occurring species; it occurred in 61% of the area surveyed, and accounted for 15% of the abundance and 9% of the biomass (Allen et al. 1998). Off the Palos Verdes Peninsula, highest catches of ridgeback rock shrimp occurred during and after El Niño events (e.g. 1982–1984, 1986–1987, and 1998–2000) (LACSD 2000).

The commercial take of ridgeback rock shrimp is exclusively by trawl, and there is a closed season between 1 October and 31 May (CDFG 1999). Ridgeback rock shrimp enter the fishery at age 1 (Anderson et al. 1985b). In 1998, 35 vessels participated in the ridgeback rock shrimp fishery, and over 98% of rock shrimp were caught in the Santa Barbara Channel. A total of 185 tons was landed in 1998, compared with 174 tons in 1997 (CDFG 1999). There were no reported landings of ridgeback rock shrimp in the catch blocks off Huntington Beach in 2002 or 2003.

4.5.4.13.6 Sampling Results

No ridgeback rock shrimp late-mysid stage larvae were collected in any of the entrainment or source water samples.

4.5.4.13.7 Impact Assessment

No impact assessment modeling of entrainment effects on ridgeback rock shrimp was done because no late-mysid stage larvae were collected.

4.5.4.14 Market Squid (*Loligo opalescens*)

Market squid range from offshore British Columbia to Bahia Asuncion, Baja California, including Guadalupe Island off Baja California (Morris et al. 1980; MBC 1987). However, they are found in highest numbers between Monterey and San Diego, California, and are found north of Puget Sound only during or following El Niño events. The distribution of this species is classified as 'Transitional Endemic' since market squid are limited to the California Current and the eastern portion of the Northeast Pacific Transition Zone. Market squid are managed under the Coastal Pelagic Species Fishery Management Plan (PFMC 1998).

4.5.4.14.1 Habitat Requirements

Eggs of the market squid are benthic, while juveniles and adults are considered pelagic (Fields 1965). They are actually found over the continental shelf from the surface to depths of at least 800 m (PFMC 1998). Recksiek and Kashiwada (1979) found larvae in much higher concentrations near bottom than in the water column. Mature squid form large spawning aggregations in nearshore waters, and in southern California, these usually occur from November through August (Fields 1965).

4.5.4.14.2 Reproduction

During copulation, a male holds the female from below, and a bundle of spermatophores is subsequently transferred from the mantle cavity of the male to a position near the female's oviduct (Hurley 1977). In southern California, squid spawn primarily in winter (November through August), though spawning has also been recorded in July (Morris et al. 1980). Fields (1965) suggested nighttime spawning in market squid; however, recent observations suggest this species spawns exclusively during daytime (Forsythe et al. 2004). Market squid are terminal spawners, spawning once then dying.

Age at first reproduction is 24–28 weeks (Yang et al. 1986). Egg capsules are usually deposited on sandy substrate, often at the edges of canyons or rocky outcroppings (McGowan 1954). Egg deposition occurs between depths of 5 and 55 m (16.4 and 180.4 ft), and is most common between 20 and 35 m (65.6 and 114.8 ft) (PFMC 1998). Each egg capsule contains 180 to 300 eggs (Morris et al. 1980). Egg development is dependent on water temperature; eggs hatch at 19–25 days at 17°C (62.6°F), 27–30 days at 15°C (59°F), and 30–35 days at 14°C (57.2°F) (Yang et al. 1986). Females produce 20–30 egg capsules, and each capsule is individually attached to the substrate (PFMC 1998). Fields (1965) reported four females depositing 17,000 eggs in 85 capsules in one evening, equivalent to about 21 capsules and 4,250 eggs per squid. Recksiek and Frey (1978) reported a fecundity of 4,000 to 9,000 eggs per female (MBC 1987). Macewicz et al. (2004) report an average fecundity of 3,844 oocytes based on an average female length of 129 mm (5.1 in) dorsal mantle length (DML).

4.5.4.14.3 Age and Growth

Young squid hatch within three to five weeks after the capsule is deposited (McGowan 1954; Fields 1965). Newly hatched squid (paralarvae) resemble miniature adults and are about 2.5–3.0 mm (0.1-0.12

in) in length. After hatching, young *Loligo* swim upward toward the light, bringing them to the sea surface (Fields 1965).

Butler et al. (1999) determined growth averages about 0.6 mm (0.02 in) dorsal mantle length (DML) per day, and maximum ages in 1998 were 238 days for females and 243 days for males. Yang et al. (1986) recorded a maximum life span of 235 and 248 days for two laboratory-reared populations. Yang et al. (1986), Butler et al. (1999), and Jackson (1998) determined that Fields (1965) and Spratt (1979) underestimated growth and overestimated longevity—squid were initially reported to live as long as three years. Growth increases exponentially during the first two months, and then slows to logarithmically thereafter (Yang et al. 1986). Schooling behavior has been observed in squid as small as 15 mm (0.6 in) DML (Yang et al. 1986).

Squid spawned in early summer (August -May) will grow rapidly during the summer growing season when nutrients from increased upwelling cause plankton blooms. As spawning continues from June through September, newly hatched squid have less time available in the growing season, which can slow the growth rate (Spratt 1979). Adults measure up to 305 mm (12 in) total length and weigh between 56 and 84 g (1.9 and 2.9 oz) (Vojkovich 1998), with spawning males normally being larger than females. Males reach 19 cm (7.4 in) DML, a maximum weight of about 130 g (4.6 oz), and have larger heads and thicker arms than females (PFMC 1998). Females reach about 17 cm (6.7 in) DML and a maximum weight of 90 g (3.2 oz).

4.5.4.14.4 General Ecology

Planktonic invertebrates are the primary food source of young squid (Spratt 1979). Squid feed mostly on crustaceans, and to a lesser degree fishes, cephalopods, gastropods, and polychaetes (Karpov and Cailliet 1979). The diet of market squid changes with water depth and location, but does not differ much among size classes or between sexes (Karpov and Cailliet 1979). Squid captured in deeper water feed more frequently on euphausiids and copepods, whereas squid captured near the surface feed predominantly on euphausiids, as well as cephalopods, fishes, mysids, and megalops larvae. In spawning schools, 75% of stomachs examined had remains of market squid (Fields 1965).

Cailliet et al. (1979) determined affinities of multiple species with market squid. In Monterey Bay, the species with the highest affinities with market squid were northern anchovy, Pacific electric ray (*Torpedo californica*), Scyphomedusae (jellies), plainfin midshipman (*Porichthys notatus*), Pacific sanddab (*Citharichthys stigmaeus*), and white croaker.

4.5.4.14.5 Population Trends and Fishery

Large-scale fluctuations are characteristic of the squid stock, due primarily to its short life span and from the influence of wide variations in oceanographic conditions (NMFS 1999). However, the short life history of this species allows for squid to recover after natural population declines as soon as ocean conditions improve. The best information indicates squid have a high natural mortality rate (approaching 100% per year) and that the adult population is composed almost entirely of new recruits

(PFMC 1998). In 1997, California passed Assembly Bill AB 364, which not only initiated closures and established a fishery permit fee, but designated funds from the permits to be used for squid research and management.

The California fishery for market squid began in Monterey Bay in the late-1800s (Vojkovich 1998). It expanded into southern California only after the 1950s, and prior to 1987, catches in southern California rarely exceeded 20,000 metric tons. After that, landings increased four-fold until the fishery collapsed in 1998, and California squid fishers sought federal disaster assistance (Zeidberg et al. 2004). In California, most squid marketed for human consumption is frozen, but smaller amounts are canned or sold fresh (PFMC 1998). Squid are also sold live and frozen for bait.

Landings in Catch Block 738 off the HBGS totaled 15,540.1 kg (34,260 lbs) ($6,852) in 2003 and 1,877,066.4 kg (4,138,223 lbs) ($388,878) in 2002 (CDFG 2004). Landings in the other two catch blocks off the HBGS totaled 114,430.9 kg (252,277 lbs) ($42,813) in 2003 and 414,277.7 kg (913,326 lbs) ($109,728) in 2002 in Block 739, and 60,432.1 kg (133,230 lbs) ($27,544) in 2003 and 34,735.2 kg (76,578 lbs) ($7,658) in 2002 in Block 740. The majority of the landings were from purse seine and drum seine, though some were reported from brail (dip-nets).

4.5.4.14.6 Sampling Results

No newly hatched market squid were collected in any of the entrainment or source water samples.

4.5.4.15 Rock Crabs (*Cancer* spp.)

Crabs of the genus *Cancer* are widely distributed in the coastal waters of the west coast of North America. They occur in intertidal and shallow subtidal habitats on both rock and sand substrate. Of the nine species known to occur in the northeast Pacific, four species contribute to economically significant fisheries. Dungeness crab (*Cancer magister*) has the highest economic value among these, and three species of rock crabs (yellow crab *C. anthonyi*, brown rock crab *C. antennarius*, and red rock crab *C. productus*) comprise the remainder of the catches. These three species of rock crab, and the smaller slender crab (*C. gracilis*) may all be found in the vicinity of HBGS.

Each species in the genus has characteristic differences in distribution, preferred habitat, growth rates, and demographic parameters. For example, brown rock crab is a relatively large species (carapace width >200 mm [7.9 in]) that lives primarily on sand and mud substrates in estuarine and coastal shelf areas. Slender crab is a smaller species (carapace width >130 mm [5.1 in]) associated with mixed rock-sand substrates in shallow outer coast habitats. Maximum clutch sizes in *Cancer* crabs can range from as many as 5,000,000 eggs in *C. anthonyi* to approximately 50,000 in pygmy rock crab (*C. oregonensis*), one of the smaller *Cancer* species (Hines 1991). These types of differences imply that specific information on life history parameters cannot readily be generalized among *Cancer* species.

4.5.4.15.1 Habitat Requirements

The brown rock crab primarily inhabits rocky shores and rocky subtidal reefs, but may bury in coarse to silty sands adjacent to preferred habitat. Ovigerous brown rock crabs have been observed buried in sand at the base of rocks in shallow water and are found more commonly in water less than 18 m (59 ft) deep in southern California.

The nearshore distribution of crab larvae depends upon developmental stage. Shanks (1985) presented evidence that early stage larvae of rock crabs (probably yellow crab in his southern California study) generally occur near the bottom, in depths up to 80 m (262.5 ft); late stage larvae, however, were more abundant near the surface. He suggested that a combination of physical factors (primarily including wind-generated surface currents and tidally forced internal waves) caused megalopae to be transported shoreward. Late stage larvae (megalops) generally begin to recruit to the nearshore habitat in spring (Winn 1985).

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In one study in Monterey Bay, Graham (1989) found that brown rock crab Stage 1 zoea are most abundant close to shore and that subsequent zoeal stages tend to remain within a few kilometers of the coastline. The adult population primarily resides in relatively shallow rocky areas, and the nearshore retention of larvae in Graham's study (1989) was related to the formation of an oceanographic frontal zone in northern Monterey Bay that prevented substantial offshore transport during upwelling periods.

The slender crab is commonly found on mud flats and in beds of eelgrass although it is usually not found intertidally south of central California (Morris et al. 1980). It occurs from Prince William Sound, Alaska to Bahia Playa Maria, Mexico in the low intertidal to 143 m (470 ft) (Jensen 1995). Although seasonally found in bays, the slender crab does not tolerate brackish conditions.

4.5.4.15.2 Reproduction

All species of *Cancer* crabs share certain fundamental life history traits. Eggs are extruded from the ovaries through an oviduct and are carried in a sponge-like mass beneath the abdominal flap of the adult female. After a development period of several weeks, the eggs hatch and a pre-zoea larva emerges, beginning the planktonic life history phase. As in all crustaceans, growth progresses through a series of molts. The planktonic larvae advance through six stages of successive increases in size: five zoea (not including the brief pre-zoea stage) and one megalopal. After several weeks as planktonic larvae, the crabs metamorphose into the first crab stage (first instar) and settle out to begin their benthic life history phase. Maturity is generally attained within 1–2 years. Mature females mate while in the soft shell molt condition and extrude fertilized eggs onto the abdominal pleopods. Females generally produce one or two batches per year, typically in winter.

The main determinant of brood size and reproductive output in brachyuran crabs is body size, and the range of egg production in *Cancer* crabs generally reflects this relationship (Hines 1991). Yellow crab, the largest of the species found in the HBGS samples, produce on average 2.21 million eggs per brood. The next largest species, red rock crab, produces 877,000 eggs per brood. Brown rock crab females seem to be an exception to this relationship because they are, on average, smaller than the red rock crab, yet produce an average of 1.2 million eggs per batch. Slender crab is the smallest of the four species living near HBGS and their average egg production per brood is 454,000. Female *Cancer* crabs on average produce a single batch per year, generally in the winter; however, due to occasional multiple spawnings, the average number of batches per year may be greater than one (Carroll 1982; Hines 1991).

4.5.4.15.3 Age and Growth

Anderson and Ford (1976) described the growth of yellow crab under laboratory conditions. Total larval development times from hatching through the megalops stage were 33 days and 45 days at 22°C (71.6°F) and 18°C (64.4°F), respectively. The total time spent in the megalops stage averaged 8 days at 22°C (71.6°F) and 12 days at 18°C (64.4°F). Yellow crab can live at least 5 years and attain a carapace width of 170 mm (6.7 in) after 16 crab instars (molts).

Brown rock crab eggs require a development time of approximately 7–8 weeks from extrusion to hatching (Carroll 1982). Larval development in the brown rock crab was described by Roesijadi (1976). Eggs hatch into pre-zoea larvae that molt to first stage zoea in less than 1 hour. Average larval development time (from hatching through completion of the fifth stage) was 36 days at 13.8°C (56.8°F). Although some crabs molted to the megalops stage, none molted to the first crab instar stage, so the actual duration of the megalops stage is unknown. Based on a predicted megalops duration of approximately 12 days measured for the closely related yellow crab, the estimated length of time from hatching to settling for brown rock crab is approximately 48 days. Brown rock crabs mature at an age of about 18 months post-settlement with a size of approximately 60 mm carapace width and a weight of 73 g (Carroll 1982). Faster growth rates may occur in highly productive environments such as on the supporting members of offshore oil platforms and females may become reproductive in less than 1 year post-settlement (D. Dugan, pers. comm.). Brown rock crabs can probably live to a maximum age of about 6 yr. Size at recruitment to the fishery is approximately 125 mm (4.9 in) carapace width, at an age of 4 years for males and 4.5 years for females.

Slender crab larval development was described by Ally (1975). Eggs hatch into pre-zoea larvae, which quickly molt to first stage zoea. Average larval development time (from hatching through completion of the megalops stage) was 48.9 days at 17°C (62.6°F), with most zoeal stages lasting approximately one week. Ally (1975) found an average duration of the megalops stage of 14.6 days. Based on field growth studies, it was estimated that slender crabs matured at an age of about 10 months post-settlement to a size of approximately 60 mm (2.6 in) carapace width (Orensanz and Gallucci 1988). Growth occurs through 11–12 instars, with crabs attaining an estimated maximum age of 4 years post-settlement.

There are no published estimates of rock crab larval mortality. However, data from the abundance of brown rock crab zoea and megalops in the Diablo Canyon Power Plant 316(b) demonstration (Tenera 2000a) was used to estimate mortality between stages. First stage zoea of the taxa *Cancer antennarius*, *C. anthonyi*, and *C. gracilis* (combined because of uncertainties in identification) were substantially more abundant, on average, than all other stages combined. The proportions of each species of zoea stage 1 were derived by using the proportions of each species in zoea stage 2 that could be identified to species. An instantaneous larval mortality of 0.158/day was estimated by fitting an exponential curve to the estimated numbers of entrained concentrations of zoea stage 1 and megalops and using 38 days as the time between stages (i.e., 5 days and 43.3 days, respectively).

4.5.4.15.4 General Ecology

Cancrid crabs function as both scavengers and predators in the marine environment. Prey varies as a function of age and size of the individual but benthic invertebrates such as clams, worms, and snails comprise the majority of prey species. Claw morphology of each species is adapted to the types of preferred prey. For example, the heavier crusher claws of the brown rock crab and yellow crab facilitate the breaking of gastropod shells whereas the tapered dactyls of the slender crab are used to probe in soft sediments for worms and other soft-bodied prey. Winn (1985) documented the occurrence of cannibalism among rock crabs, particularly adults on juveniles. However, since juveniles generally inhabited shallower areas than adults, effects on the younger cohorts were diminished.

During their planktonic existence, crab larvae can become widely distributed in nearshore waters. In a study in Monterey Bay, Graham (1989) found that slender crab stage 1 zoeae were very abundant close to shore (within 6 km) during March and August. Later stage larvae, including megalopae, were found further from shore during all times of the year. This offshore larval distribution, compared to the nearshore distribution of brown rock crab larvae found by Tenera (2000a), probably reflects the fact that adult slender crabs are widely distributed in coastal shelf areas, further offshore than brown rock crabs. The megalops larvae and juvenile crabs are frequently found crawling unharmed on and under the bells, and even in the stomachs, of larger jellyfishes, especially *Chrysaora colorata* (Morris et al. 1980).

Juvenile rock crabs are an important prey item for a variety of fishes and invertebrates. In southern California, this includes barred sand bass (*Paralabrax nebulifer*), shovelnose guitarfish (*Rhinobatos productus*) and the sand star (*Astropecten verrilli*) (Roberts et al. 1984; VanBlaricom 1979).

4.5.4.15.5 Population Trends and Fishery

Rock crabs are fished along the entire California coast with crab pots, though some landings are reported from set gill nets and trawls as well (CDFG 2004). Three species are harvested commercially: brown rock crab, red rock crab, and yellow crab. There is no commercial fishery for the slender crab. The rock crab fishery is most important in southern California (from Morro Bay south), which produces a majority of the landings, and of lesser importance in northern areas of California where a fishery for the more desirable Dungeness crab takes place. Most rock crabs are landed alive for retail sale by fresh fish markets. The commercial harvest has been difficult to assess on a species-by-species basis because the fishery statistics are combined into the general “rock crab” category. From 1991 through 1999 state-wide rock crab landings (including claws) averaged 1.2 million lbs/year (Parker 2001).

Regulations currently specify a minimum harvest size of 108 mm (4.25 in) carapace width. A small recreational fishery for rock crabs also exists, with a 102 mm (4.00-inch) minimum carapace width and a personal bag limit of 35 crabs per day. Crabs are collected by divers or shore pickers with hoop nets and crab traps.

Recent catch statistics from the PSMFC PacFIN (commercial) database were examined for the years 2000–2004 for southern California (San Diego, Orange and Los Angeles counties). The average annual commercial catch and ex-vessel revenue from rock crab for the years 2000–2004 was approximately 44,905.6 kg (99,000 lbs) and $120,000, respectively, with most of the landings from San Diego County. During this period the greatest catches for all counties combined were in 2000 (54,196.6 kg [119,483 lbs]) and the least were in 2004 (31,067 kg [68,491 lbs]).

The following commercial landings statistics were compiled from California Department of Fish and Game landings records:

<u>Yellow rock crab</u>. There were no reported landings for yellow rock crab in Catch Blocks 738 and 739 off the HBGS in 2002 and 2003 (CDFG 2004). There were 24 kg (53 lbs) ($65) reported from Catch Block 740 in 2003, but no landing from that block in 2002.

<u>Rock crab – unspecified</u>. Landings in Catch Block 738 off the HBGS totaled 607.8 kg (1,340 lbs) ($730) in 2003 and 2,526 kg (5,569 lbs) ($5,121) in 2002 (CDFG 2004). Landings in the other two catch blocks off the HBGS totaled 1,312.2 kg (2,893 lbs) ($2,949) in 2003 and 291.2 kg (642 lbs) ($658) in 2002 in Block 739, and 1,691.4 kg (3,729 lbs) ($4,212) in 2003 and 4,432 kg (9,771 lbs) ($13,533) in 2002 in Block 740.

Crab claws – unspecified. Crab claw landings reported in Catch Block 738 off the HBGS totaled 4 kg (nine pounds) ($0) in 2003, with no landings in 2002 (CDFG 2004). Landings in the other two catch blocks off the HBGS totaled 30 kg (66 lbs) ($58) in 2003 and 6.4 kg (14 lbs) ($14) in 2002 in Block 739, and 84.8 kg (187 lbs) ($164) in 2003 and 325.2 kg (717 lbs) ($769) in 2002 in Block 740.

4.5.4.15.6 Sampling Results

Yellow crab were the most abundant rock crab megalops in the entrainment samples followed by slender crab, brown rock crab, and red rock crab (Table 4-2). In the source water samples yellow crab and slender crab megalops were collected in nearly equal concentrations, followed by brown rock crab and red rock crab (Table 4-5). There was a strong seasonal occurrence in summer months with a periodicity of approximately six weeks and increasing amplitude through the August survey. Greatest concentrations occurred in July in the source water samples.

4.5.4.15.7 Impact Assessment

The total annual estimated entrainment of megalops of the three commercially fished crab species (yellow crab, brown rock crab, and red rock crab) was 6,411,171 (including *Cancer* spp. megalops). The following section presents the results for empirical transport modeling of circulating water system effects on these combined species because they are not differentiated in catch records and all three species are similar and co-occur in the study area. There was not enough information available on mortality rates to parameterize the demographic models.

4.5.4.15.8 Empirical Transport Model (*ETM*)

The *PE* estimates for rock crabs range from 0 to 0.01 (Table 4-29). The values of f_i indicate that rock crab larvae were most abundant in the source water during the June through August period with a peak in July. There were four surveys when larvae were collected at the source water stations, but were not collected at the entrainment station. The values of f_i indicate that these were periods when crab larvae were less abundant in the source water. The values in the table were used to calculate two P_M estimates: one based on alongshore current movement, and the other based on alongshore current movement and an extrapolation of areal densities offshore to a distance bounded by either the extrapolated densities or onshore current movement. A megalops larval duration of 12 days was used for the number of days at risk to entrainment based on laboratory rearing data of larvae cultured at 18°C (64.4°F)(Anderson and Ford 1976). The estimate of P_M for the 12-day period of exposure calculated using offshore extrapolated densities (0.009, 0.9%) is less than the estimate calculated using alongshore current displacement (0.011, 1.1%) because the effects of entrainment are spread over a much larger population for the offshore extrapolated estimate (Table 4-30). The P_S estimates indicate that the ratio of the sampled source water to the total population for the alongshore and offshore P_M estimates were 39.4 and 24.5%, respectively and the alongshore estimate was extrapolated over a shoreline distance of 26.5 km (16.5 mile).

Table 4-29. *ETM* data for commercially fished *Cancer* crab megalops. *ETM* calculations based on sampling grid volume of 908,157,859 m^3, and daily circulating water volume of 1,919,204 m^3. Average *PE* estimate calculated from all surveys with *PE* >0.

Survey Date	*PE* Estimate	*PE* Std. Error	f_i Estimate	f_i Std. Error
17-Sep-03	0.00000	0.00000	0.00000	0.00000
13-Oct-03	0.00000	0.00000	0.00241	0.00766
10-Nov-03	0.00000	0.00000	0.00000	0.00000
8-Dec-03	0.00000	0.00000	0.01801	0.03054
5-Jan-04	0.01356	0.02684	0.00908	0.01540
9-Feb-04	0.00000	0.00000	0.00235	0.00714
8-Mar-04	0.00000	0.00000	0.00000	0.00000
5-Apr-04	0.00000	0.00000	0.00299	0.00811
3-May-04	0.00560	0.01466	0.00899	0.01596
1-Jun-04	0.00199	0.00282	0.16365	0.14691
12-Jul-04	0.00325	0.00622	0.66245	0.23482
31-Aug-04	0.00131	0.00310	0.13007	0.15900
Average =	0.00514			

Table 4-30. Average P_S values and *ETM* estimates for alongshore current and offshore extrapolated models for *Cancer* crab megalops. Current displacement (km) for alongshore extrapolation included in parentheses with estimate of P_S for alongshore estimate of P_M.

Parameter	Average P_S (displacement)	*ETM* Estimate (P_M)	*ETM* Std. Err.	Upper 95% CI	Lower 95%CI
Alongshore Current	0.3940 (26.5)	0.01070	0.33544	0.34614	0
Offshore Extrapolated	0.2453	0.00854	0.33268	0.34122	0

5.0 IMPINGEMENT STUDY

5.1 INTRODUCTION

The purpose of the impingement study is to determine the extent of potential impacts from the operation of the cooling water system of the Huntington Beach Generating Station on fishes and selected invertebrates. Impingement occurs when organisms larger than the traveling screen mesh size (9.5 mm or 3/8") become trapped against the screens, either because they are too fatigued to swim against the intake flow at the screens or they are dead. The sampling plan and analysis techniques were developed by the BRRT.

There are two facets to the impingement study: *normal operation* sampling and *heat treatment* sampling. Samples collected during normal operations were used to characterize fish loss from the day-to-day operation of the generating station. Normal operations samples were collected over a 24-hr period to determine the daily loss from operation of the CWIS. Samples were also collected during heat treatments, when waters within the CWIS were heated and essentially all fishes and invertebrates succumbed to the high temperatures. Heat treatment procedures were carried out at approximately eight-week intervals to control biofouling within the CWIS. Combined, normal operation and heat treatment samples were used to estimate the annual loss of juvenile and adult fishes and selected macroinvertebrates due to operation of the CWIS.

5.1.1 Species to Be Analyzed

Several types of organisms are susceptible to impingement by the generating station. All fishes and macroinvertebrates were processed (identified, enumerated, and where appropriate, measured) in impingement samples. However, assessment of impingement effects was limited to the most abundant fish and invertebrate taxa that together comprised 90% of all juveniles and adults impinged at the generating station.

5.2 HISTORICAL DATA

Impingement sampling is currently conducted monthly during normal operations and during all scheduled heat treatments at the HBGS under the Monitoring and Reporting Requirements of the plant's NPDES permit. Data from 1979 through 2005 are summarized to provide information on historical impingement at the HBGS. An extensive review of historical impingement data is presented in MBC (2006).

5.2.1 Summary of Historical Data

Since 1979, an average of 213,375 fish represented by 57 taxa and weighing 5,616 kg (12,381 lbs) was impinged annually (Table 5-1). Highest impingement occurred from 1979 through 1982, and then declined mostly due to reduced levels of operation. Lowest impingement was recorded in 1999; however, there were no heat treatments that year. Since Units 3 and 4 were refurbished and restarted in 2003, impingement increased slightly.

The most abundant fish species impinged since 1979 was queenfish (*Seriphus politus*), which accounted for 79% of total impingement abundance. Other abundant species included white croaker (*Genyonemus lineatus*; 7%), northern anchovy (*Engraulis mordax*; 4%), walleye surfperch (*Hyperprosopon argenteum*; 2%), and white seaperch (*Phanerodon furcatus*; 1%). The most abundant macroinvertebrates impinged since 1994 were yellow crab (*Cancer anthonyi*; 18%), tuberculate pear crab (*Pyromaia tuberculata*; 16%), and the nudibranchs *Hermissenda crassicornis* (13%) and *Dendronotus frondosus* (9%).

5.2.2 Relevance to Current Conditions

Historical impingement data is relevant for historical comparisons since sampling was done using the same procedures that were used in the sampling for this study.

5.2.3 QA/QC Procedures

During NPDES impingement surveys (1979-2005), sampling was conducted in accordance with specifications set forth by the SARWQCB in the NPDES permit for the HBGS. Specimens of uncertain identity were cross-checked against taxonomic voucher collections maintained by MBC, as well as available taxonomic literature. Occasionally, outside experts were consulted to assist in the identification of species whose identification was difficult. Scales used to measure biomass were calibrated every three months.

The following measures were employed to ensure the accuracy of all data entered into the computer databases and spreadsheets:

- Upon returning from the field, all field data sheets were checked by the project manager for completeness and obvious errors;
- Data were entered into pre-formatted spreadsheets;
- After data were entered, copies of spreadsheets were checked against field data sheets;
- Data were submitted annually to the SARWQCB, EPA Region IX, and the CDFG.

Table 5-1. Historical fish impingement totals and average daily cooling water flow (mgd) at the HBGS, 1979-2005.

Year	Units Operating	Annual Fish Impingement			Mean Daily Flow (mgd)
		No. of Taxa	Abundance	Biomass (kg)	
1979	1-4	83	649,179	20,980	418
1980	1-4	88	676,803	20,919	393
1981	1-4	76	905,003	18,347	458
1982	1-4	75	835,295	16,721	476
1983	1-4	81	435,336	13,690	390
1984	1-4	71	477,063	11,488	338
1985	1-4	74	487,639	12,672	305
1986	1-4	69	314,011	8,692	217
1987	1-4	64	71,386	2,462	201
1988	1-4	61	96,045	3,332	163
1989	1-4	57	70,126	3,017	170
1990	1-4	44	38,549	1,833	153
1991	1-4	50	3,679	296	135
1992	1-4	52	10,397	396	145
1993	1-4	47	15,833	410	140
1994	1-2	50	12,797	843	146
1995	1-2	55	89,342	2,927	152
1996	1-2	42	37,536	705	148
1997	1-2	54	29,588	639	147
1998	1-2	45	25,920	674	160
1999	1-2	9	417	31	144
2000	1-2	21	4,574	711	164
2001	1-2	34	11,964	616	180
2002	1-3	59	23,348	998	276
2003	1-4	59	51,320	1,512	286
2004	1-4	57	41,740	980	357
2005	1-4	70	346,230	5,743	355
Average		**57**	**213,375**	**5,616**	**241**

5.3 METHODS

The sampling plan and analysis techniques of the Entrainment and Impingement Study were developed by the BRRT, which was formed by the CEC. The BRRT consists of representatives of AES Huntington Beach L.L.C., MBC *Applied Environmental Sciences*, Tenera Environmental, California Energy Commission staff and consultants, Santa Ana Regional Water Quality Control Board, U.S. Fish and Wildlife Service, National Marine Fisheries Service, California Department of Fish and Game, and the California Coastal Commission. Members of the BRRT reviewed and commented on two drafts of the study plan, the first quarterly data report, and the Six-Month and Nine-Month Reports.

5.3.1 Field Sampling

MBC sampled fishes and macroinvertebrates impinged on traveling screens during normal operation of the HBGS on a weekly basis beginning in late-July 2003 and continuing through July 2004. Once per week, fish impingement samples were collected for one approximately 24-hr period in coordination with generating station operations personnel. Twenty-four hours prior to each survey, the screens were run and the accumulation container emptied. The following day, traveling screens were operated for approximately 10 minutes, enough time to complete one rotation and sufficient to bring up any impinged organisms from the forebay for identification. Accumulated fishes, invertebrates, algae, and debris from the 24-hr sample were sorted, and fishes and macroinvertebrates were identified to species (whenever possible), enumerated and batch-weighed. Standard length of up to 200 individual fishes of each species was measured, and sex of up to 50 individuals of selected species was determined by external morphology or inspection of gonads. Algae and shell debris were identified and batch-weighed by species. Station operation data (number of circulator pumps operating, intake temperature, and discharge temperature) and general weather conditions were recorded during sampling.

Circulating water flow through the plant during the 24-hr sample period was determined by consulting with plant personnel. Results from each weekly 24-hr impingement sample were extrapolated to a weekly impingement total using cooling water flow for the 7-day period (Saturday through Friday). The normal operation impingement total is the sum of the weekly extrapolations based on the cooling water flow of the HBGS.

MBC sampled fishes and macroinvertebrates impinged on traveling screens during all scheduled heat treatment operations at the HBGS. The results of all six heat treatments are presented in this analysis. Heat treatments are performed periodically (usually once every six to eight weeks) to control growth of fouling organisms in the cooling water system. During these procedures, a portion of the heated discharge water is circulated through the forebay and intake conduits, raising the water temperature to approximately 41°C (106°F), and marine life succumbs to the elevated temperature.

During each survey, traveling screens were run until no more organisms were impinged on the traveling screens. Fishes, invertebrates, algae, and debris were sorted, and fishes and invertebrates were identified to species (whenever possible), enumerated and batch-weighed. Standard length of up to 200 individual fishes of each species was measured, and sex of up to 50 individuals of selected species was determined by external morphology or inspection of gonads. Algae and shell debris were identified and batch-weighed by species. Station operation data (number of circulator pumps operating, intake temperature, and discharge temperature) and general weather conditions were recorded during sampling.

5.3.2 Data Analysis

Total impingement at the generating station was calculated by summing the extrapolated normal operations estimates with the sum of the heat treatment survey data. Common and scientific names of fishes are from Nelson et al. (2004), and invertebrate names were derived from several sources, including Turgeon et al. (1988) and Williams et al. (1988).

5.3.2.1 Impingement Impact Assessment

Comparison of impingement losses of juvenile and adult fishes and invertebrates with source water populations (as was done for larval fishes and target invertebrates) is not possible due to insufficient data on the source water populations for these species. However, to put impingement results in context, we compared them to: (1) commercial landings from commercial Catch Block 738, located offshore the HBGS, (2) southern California recreational landings as reported by the Pacific States Marine Fisheries Commission's (PSMFC) Recreational Fisheries Information Network database (RecFIN), and (3) recreational landings from Huntington, Newport, and Long Beach as reported by the NMFS Los Angeles Times Sportfish Database. The two recreational landing databases (RecFIN and NMFS L.A. Times) were compiled using different methods. The RecFIN database relied heavily on phone surveys, while the NMFS database was compiled using sportfish landing data from daily reports published in the Los Angeles Times. Data from the PSMFC RecFIN database were analyzed for southern California as a whole (analysis on a finer scale was not possible). The NMFS database was originally compiled by MBC, and includes sportfish catch by landing as reported daily in the Los Angeles Times from 1959 through 2003 (Mitchell 1999). Our analysis of this database was limited to recreational landings from Long Beach, Huntington Beach, and Newport Beach.

To compare impingement at the HBGS with local commercial landings, we multiplied the biomass of impinged (commercially-caught) species by the commercial value (price per pound) reported from Catch Block 738 (offshore the HBGS) in 2002 and 2003 (CDFG 2004). This analysis was limited to those fish and macroinvertebrate species that were both impinged and commercially caught offshore the HBGS during at least one of those two years. It also assumed that the fishes and macroinvertebrates impinged would otherwise be caught and sold commercially.

5.4 RESULTS

The following section presents results from the 2003-4 impingement study at the HBGS.

5.4.1 Impingement Summary

In total, an estimated 51,082 fishes representing 57 species were impinged during 52 normal operations and six heat treatment surveys (Table 5-2). Surveys were conducted from July 2003 through July 2004. Total impingement biomass was 1,292 kg (2,848 lbs). The most abundant fish species were queenfish (70%), white croaker (10%), shiner perch (8%), and northern anchovy (4%). Abundance during six heat treatment impingement surveys accounted for 75% of total impingement abundance. Data are presented by survey in Appendix C.

5.4.1.1 Normal Operations Results

An estimated 12,694 fish representing 36 species were impinged during 52 weeks of normal operations surveys (Table 5-2). Highest normal operations abundance occurred on 28 January 2004. Aside from this somewhat anomalous impingement total, there were slight seasonal peaks of abundance in Sept.-Oct. 2003 (mainly queenfish and northern anchovy) and in Apr.-May 2004 (primarily queenfish and white croaker). The most abundant species were queenfish (83%), northern anchovy (7%), white croaker (2%), and shiner perch (2%). Abundance during the 52 normal operations surveys accounted for 25% of total impingement abundance. Fish biomass for the survey year totaled 290 kg (639 lbs). Biomass was dominated by larger elasmobranchs, such as Pacific electric ray (*Torpedo californica*; 45%), thornback (*Platyrhinoidis triseriata*; 6%), and bat ray (*Myliobatis californica*; 4%), as well as some of the more abundant fish species, including queenfish (20%) and specklefin midshipman (*Porichthys myriaster*; 4%).

5.4.1.2 Heat Treatment Results

An estimated 38,388 fish representing 55 species were impinged during six heat treatment surveys (Table 5-2). The most abundant species were queenfish (66%), white croaker (12%), shiner perch (10%), and northern anchovy (4%). Abundance during the six heat treatment impingement surveys accounted for 75% of total impingement abundance. Highest heat treatment abundance was recorded in May 2004 (primarily queenfish and white croaker) and in September 2003 (primarily queenfish and shiner perch).

Fish biomass during the six heat treatment surveys totaled 1,001.8 kg (2,208.6 lbs). Biomass was dominated by the most abundant species, such as queenfish (59%), white croaker (9%), and shiner perch (5%), and larger fish such as kelp bass (*Paralabrax clathratus*; 5%) and jacksmelt (*Atherinopsis californiensis*; 3%).

Table 5-2. Fish impingement totals from 52 normal operation and 6 heat treatment surveys. (Continued on following page).

		Normal Operation Totals		Heat Treatment Totals		Impingement Totals		Percent of Total	
Species	**Common Name**	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt.
Seriphus politus	queenfish	10,468	58.015	25,379	590.141	35,847	648.156	70.2	50.2
Genyonemus lineatus	white croaker	274	3.374	4,629	92.047	4,903	95.421	9.6	7.4
Cymatogaster aggregata	shiner perch	215	2.014	3,830	49.813	4,045	51.827	7.9	4.0
Engraulis mordax	northern anchovy	824	5.513	1,369	9.343	2,193	14.856	4.3	1.2
Phanerodon furcatus	white seaperch	80	0.485	789	18.588	869	19.073	1.7	1.5
Peprilus simillimus	Pacific butterfish	131	2.096	470	13.826	601	15.922	1.2	1.2
Hyperprosopon argenteum	walleye surfperch	30	0.498	446	15.255	476	15.753	0.9	1.2
Atherinopsis californiensis	jacksmelt	23	2.370	309	27.298	332	29.668	0.7	2.3
Atherinops affinis	topsmelt	-	-	231	3.664	231	3.664	0.5	0.3
Leuresthes tenuis	California grunion	49	0.211	91	0.498	140	0.709	0.3	0.1
Paralabrax clathratus	kelp bass	-	-	138	46.965	138	46.965	0.3	3.6
Scorpaena guttata	California scorpionfish	35	5.528	75	21.066	110	26.594	0.2	2.1
Sardinops sagax	Pacific sardine	69	3.322	38	3.994	107	7.316	0.2	0.6
Urobatis halleri	round stingray	52	17.322	48	22.331	100	39.653	0.2	3.1
Porichthys myriaster	specklefin midshipman	99	10.249	1	0.006	100	10.255	0.2	0.8
Embiotoca jacksoni	black perch	12	1.873	54	5.288	66	7.161	0.1	0.6
Cheilotrema saturnum	black croaker	21	0.330	44	6.682	65	7.012	0.1	0.5
Paralabrax nebulifer	barred sand bass	7	0.364	55	9.301	62	9.665	0.1	0.7
Atractoscion nobilis	white seabass	11	0.135	49	4.793	60	4.928	0.1	0.4
Roncador stearnsii	spotfin croaker	-	-	49	1.766	49	1.766	0.1	0.1
Chromis punctipinnis	blacksmith	7	0.015	39	2.241	46	2.256	0.1	0.2
Xenistius californiensis	salema	11	0.101	35	0.345	46	0.446	0.1	<0.1
Pleuronichthys ritteri	spotted turbot	35	2.438	4	0.007	39	2.445	0.1	0.2
Menticirrhus undulatus	California corbina	-	-	33	3.104	33	3.104	0.1	0.2
Torpedo californica	Pacific electric ray	31	129.444	-	-	31	129.444	0.1	10.0
Heterostichus rostratus	giant kelpfish	21	1.045	9	0.708	30	1.753	0.1	0.1
Synodus lucioceps	California lizardfish	29	1.130	-	-	29	1.130	0.1	0.1
Pleuronichthys verticalis	hornyhead turbot	27	0.277	1	0.144	28	0.421	0.1	<0.1
Myliobatis californica	bat ray	19	10.659	5	7.267	24	17.926	<0.1	1.4
Citharichthys stigmaeus	speckled sanddab	14	0.043	9	0.054	23	0.097	<0.1	<0.1
Paralichthys californicus	California halibut	15	4.068	6	5.868	21	9.936	<0.1	0.8
Anchoa compressa	deepbody anchovy	6	0.032	14	0.144	20	0.176	<0.1	<0.1
Leptocottus armatus	Pacific staghorn sculpin	17	0.870	3	0.103	20	0.973	<0.1	0.1
Platyrhinoidis triseriata	thornback	18	15.812	2	1.242	20	17.054	<0.1	1.3
Girella nigricans	opaleye	7	4.274	12	8.378	19	12.652	<0.1	1.0
Rhacochilus vacca	pile perch	-	-	19	4.729	19	4.729	<0.1	0.4
Anisotremus davidsonii	sargo	-	-	17	1.434	17	1.434	<0.1	0.1
Rhacochilus toxotes	rubberlip seaperch	-	-	17	0.745	17	0.745	<0.1	0.1
Scomber japonicus	chub mackerel	-	-	17	0.336	17	0.336	<0.1	<0.1
Medialuna californiensis	halfmoon	-	-	13	3.545	13	3.545	<0.1	0.3
Porichthys notatus	plainfin midshipman	9	3.267	1	0.003	10	3.270	<0.1	0.3
Trachurus symmetricus	jack mackerel	7	0.030	2	0.253	9	0.283	<0.1	<0.1
Ophidion scrippsae	basketweave cusk-eel	7	0.378	1	0.011	8	0.389	<0.1	<0.1
Pleuronichthys guttulatus	diamond turbot	6	0.849	2	0.358	8	1.207	<0.1	0.1
Ophichthus zophochir	yellow snake eel	6	1.332	1	0.200	7	1.532	<0.1	0.1
Chilara taylori	spotted cusk eel	-	-	7	0.128	7	0.128	<0.1	<0.1
Umbrina roncador	yellowfin croaker	-	-	6	1.934	6	1.934	<0.1	0.1

Continued on next page.

Table 5-2. (Continued). Fish impingement totals from 52 normal operation and 6 heat treatment surveys.

		Normal Operation Totals		Heat Treatment Totals		Impingement Totals		Percent of Total	
Species	**Common Name**	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt.
Halichoeres semicinctus	rock wrasse	-	-	4	1.391	4	1.391	<0.1	0.1
Hypsoblennius gilberti	rockpool blenny	-	-	3	0.016	3	0.016	<0.1	<0.1
Rhinobatos productus	shovelnose guitarfish	-	-	2	11.174	2	11.174	<0.1	0.9
Sebastes auriculatus	brown rockfish	-	-	2	1.184	2	1.184	<0.1	0.1
Triakis semifasciata	leopard shark	-	-	2	0.812	2	0.812	<0.1	0.1
Syngnathus californiensis	kelp pipefish	-	-	2	0.007	2	0.007	<0.1	<0.1
Paralabrax maculatofasciatus	spotted sand bass	-	-	1	0.900	1	0.900	<0.1	0.1
Semicossyphus pulcher	California sheephead	-	-	1	0.359	1	0.359	<0.1	<0.1
Odontopyxis trispinosa	pygmy poacher	-	-	1	0.005	1	0.005	<0.1	<0.1
Sebastes miniatus	vermillion rockfish	-	-	1	0.002	1	0.002	<0.1	<0.1
	Totals:	**12,694**	**289.763**	**38,388**	**1,001.796**	**51,082**	**1,291.559**	**100.0**	**100.0**
	No. of Species:	**36**		**55**		**57**			

5.4.1.3 Seasonal Variation

Normal operation fish impingement abundance and biomass peaked in early spring, corresponding with the impingement of large numbers of queenfish (Figures 5-1 and 5-2). Secondary peaks in biomass occurred in late-March 2004 and mid-December 2003, and resulted from the impingement of relatively large Pacific electric rays (*Torpedo californica*). Heat treatment abundance was highest in May 2004 and September 2003, while biomass peaked in May 2004.

5.4.1.4 Diel Variation

Diel variation in impingement was not analyzed during the 2003-4 impingement study at the HBGS. However, diel variation in fish entrapment was analyzed in previous studies at the HBGS. In the 1970s, biologists noticed nocturnally active fishes were entrapped in higher numbers than diurnally active fishes. In 1978, higher rates of fish entrapment were observed to occur at the HBGS during the night (FES et al. 1980). Diel entrapment data were collected in 1979, which indicated that entrapment rates were approximately eight times higher from midnight to dawn than during the remaining hours of the day, and was 10 times higher for queenfish, 11 times higher for white croaker, 5 times higher for northern anchovy, and 4 times higher for silversides. In 1980, entrapment rates for all species were 90% higher at night than during the day. The likely explanation for this disparity in entrapment rates was the vertical distribution of the most abundant fish species (queenfish and white croaker). These two species in particular spent the nighttime hours higher in the water column, thus increasing their susceptibility to entrainment in the CWIS.

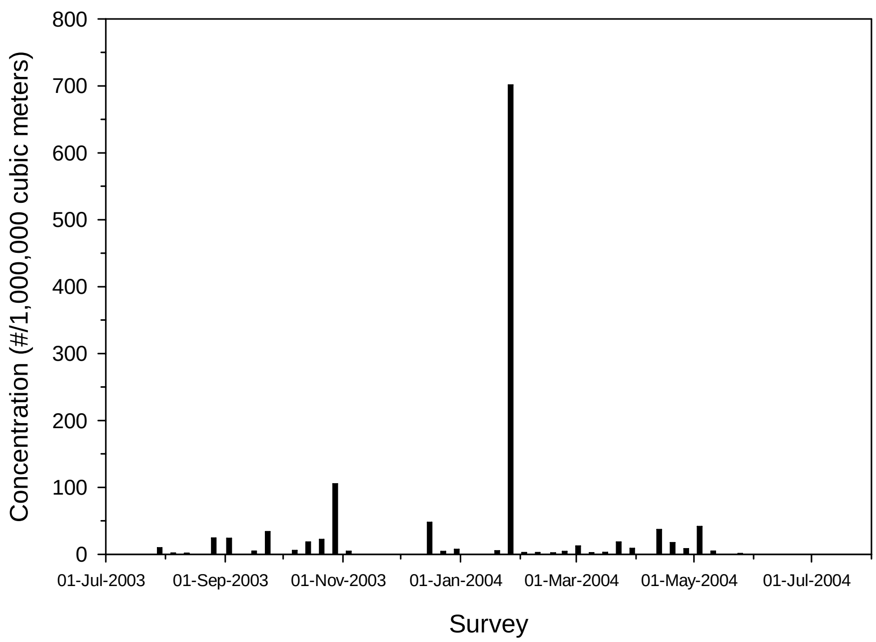


Figure 5-1. Abundance (#/1,000,000 m^3) of fishes collected in HBGS impingement samples during 2003-4.

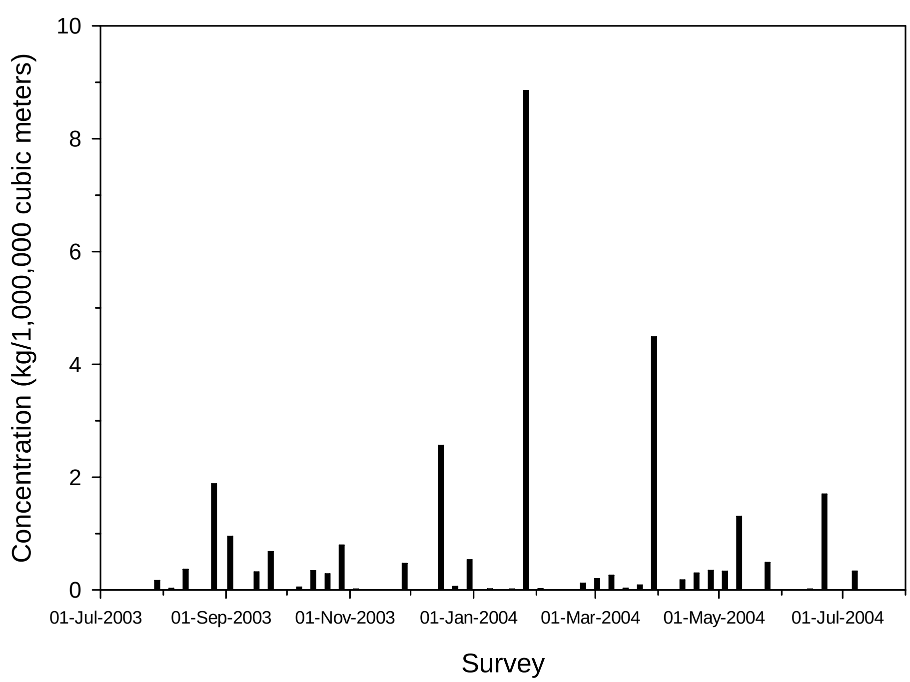


Figure 5-2. Biomass (kg/1,000,000 m^3) of fishes collected in HBGS impingement samples during 2003-4.

5.4.1.5 Comparison with Previous Studies

The annual fish impingement estimate from the 2003-4 study at the HBGS (51,082 fishes weighing 1,292 kg) was higher than in the previous eight years (Table 5-1). The results presented in Table 5-1 are from NPDES monitoring studies. From 1999 through 2002, impingement increased from 417 individuals to 23,248 individuals, corresponding to an increase in cooling water flow. Between 1995 and 1999, impingement decreased from 89,342 individuals to 417 individuals. During this time period, however, the most abundant species were the same collected in the 2003-4 impingement study. Since 1979, the top species impinged include queenfish (79%), white croaker (7%), northern anchovy (4%), walleye surfperch (2%), and white seaperch (1%). Recent results indicate an increase in impingement concurrent with an increase in average cooling water flow.

The annual macroinvertebrate impingement estimate from the 2003-4 study at the HBGS (70,638 invertebrates weighing 168 kg) was higher than previously recorded since 1994. Since that time, annual impingement has ranged from 4,885 individuals (1998) to the high measured during the current study. From 1994 through 2005, the most abundant species have been the yellow crab (18%), tuberculate pear crab (16%), and the nudibranchs *Hermissenda crassicornis* (13%) and *Dendronotus frondosus* (9%).

5.4.2 Impingement Results by Species

Species-specific analyses are limited to the four species that together comprised 92% of total impingement abundance and 63% of impingement biomass: queenfish, white croaker, shiner perch, and northern anchovy.

5.4.2.1 Queenfish (*Seriphus politus*)

Information on the life history, ecology, population trends, and fishery of queenfish (*Seriphus politus*) is summarized in Section 4.3.3.4.

From 1979 through 2002, annual impingement of queenfish at the HBGS ranged from 59 individuals (1999) to 798,174 individuals (1981).

5.4.2.1.1 Sampling Results

Queenfish was the most abundant species collected in both normal operations and heat treatment impingement samples (Table 4-31). Total impingement for the survey period was 35,847 individuals. It occurred in 31 of 52 normal operations surveys, and all six heat treatment surveys (Table 5-3). Highest normal operations abundance and biomass occurred in late January (Figures 5-3 and 5-4), and highest heat treatment abundance and biomass occurred in late May.

The queenfish measured in impingement surveys ranged from the 40 to 190 mm (1.6 to 7.5 in) in size (Figure 5-5). Distribution was bimodal with peaks at 60-70 mm (2.4-2.8 in) and 120 mm (4.7 in). Queenfish mature at about 127 mm (5 in), during their first spring or second summer (Love 1996). Maximum reported size is 305 mm (12 in) (Miller and Lea 1972). Therefore, most of the fish impinged were young-of-the-year (YOY) and Age-1 fish. Mean length of fish measured during the six heat treatments was greatest in August (mean of 132 mm [5.2 in] SL) and lowest in February (mean of 97 [3.8 in] mm SL). Of the 352 mature fish inspected for determination of sex during the study year, 253 (72%) were female, and 99 (28%) were male.

Table 5-3. Heat treatment impingement totals for queenfish.

Heat Treatment Date	Impingement Abundance	Impingement Biomass
16 August 2003	3,200	116.908
26 September 2003	3,548	104.300
7 November 2003	4,272	106.810
6 January 2004	4,529	88.728
22 February 2004	4,204	52.445
30 May 2004	5,626	120.950
Total	**25,379**	**590.141**

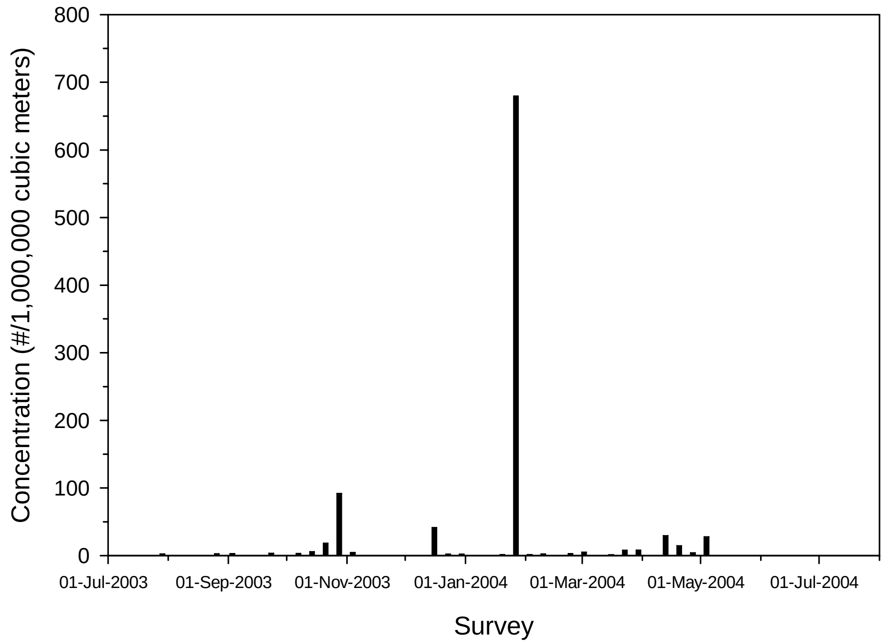


Figure 5-3. Abundance (#/1,000,000 m^3) of queenfish collected in HBGS impingement samples during 2003-4.

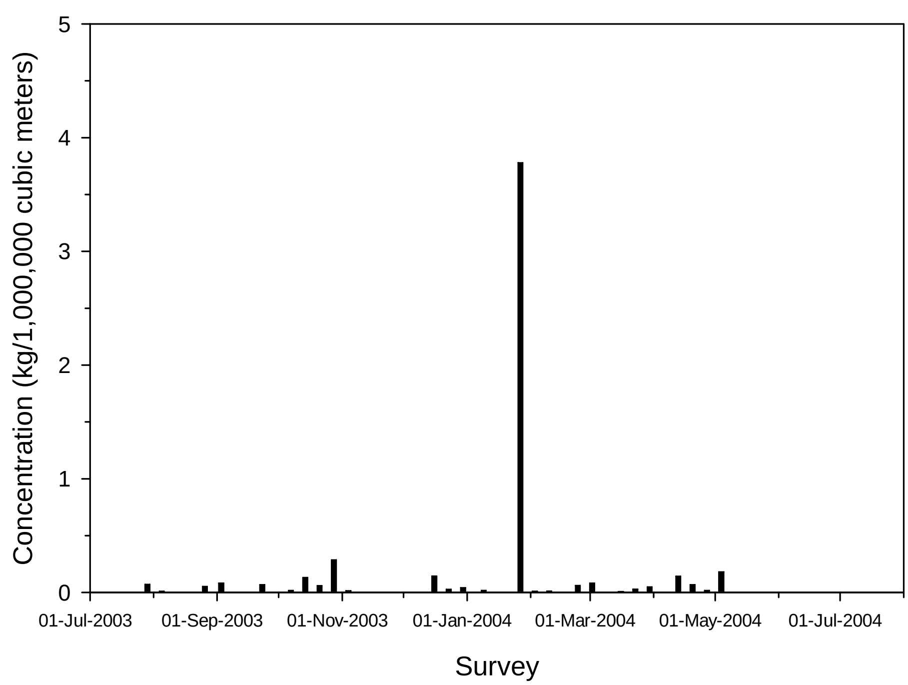


Figure 5-4. Biomass (kg/1,000,000 m^3) of queenfish collected in HBGS impingement samples during 2003-4.

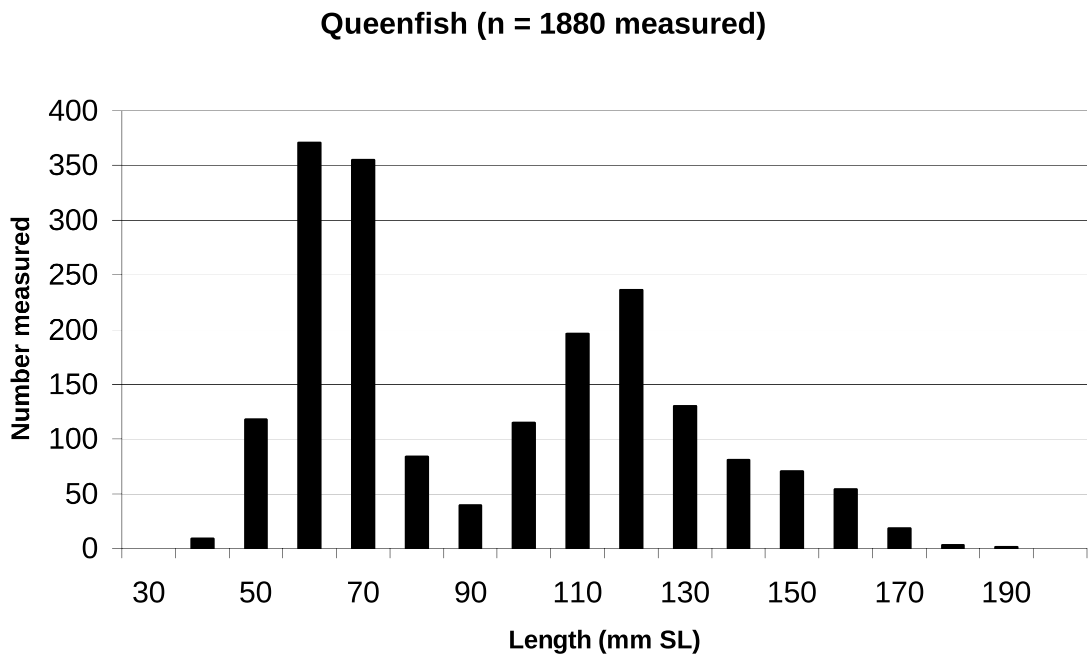


Figure 5-5. Length frequency distribution of queenfish (*Seriphus politus*) in impingement samples.

5.4.2.2 White Croaker (*Genyonemus lineatus*)

Information on the life history, ecology, population trends, and fishery of white croaker (*Genyonemus lineatus*) is summarized in Section 4.3.3.5.

From 1979 through 2002, annual impingement of white croaker at the HBGS ranged from 0 (1999) to 66,979 individuals (1980).

5.4.2.2.1 Sampling Results

White croaker was the third most abundant species in normal operations impingement samples, and the second most abundant species in heat treatment samples (Table 4-31). It was collected in only 8 of 52 normal operation samples, but in all six heat treatment samples (Table 5-4). Highest normal operations losses were recorded in August 2003 and April-May 2004 (Figures 5-6 and 5-7), and highest heat treatment abundance occurred in May 2004.

The white croaker measured in impingement surveys ranged from the 50 to 200 mm (1.97 to 7.87 in) in size, with most fish in the 80-90 mm (3.15-3.54 in) size classes (Figure 5-8). White croaker mature between about 130 and 190 mm (5.12 and 7.5 in), somewhere between their first to fourth year (Love et al. 1984, Love 1996). Therefore, most of the white croaker impinged were probably in their first year. Mean length of fish measured during the six heat treatments was greatest in February (mean of 133 mm [5.24 in] SL) and lowest in August 2003 and May 2004 (mean of 95 mm [3.7 in] SL). New recruits (50 to 60 mm [1.97 to 2.4 in]) were most common in late winter through spring (January through May 2004). Of the 108 mature individuals inspected for determination of sex during the study year, 61 (56%) were female and 47 (44%) were male.

Table 5-4. Heat treatment impingement totals for white croaker.

Heat Treatment Date	Impingement Abundance	Impingement Biomass
16 August 2003	1,192	21.196
26 September 2003	497	8.570
7 November 2003	17	0.846
6 January 2004	44	1.643
22 February 2004	10	0.252
30 May 2004	2,869	59.540
Total	**4,629**	**92.047**

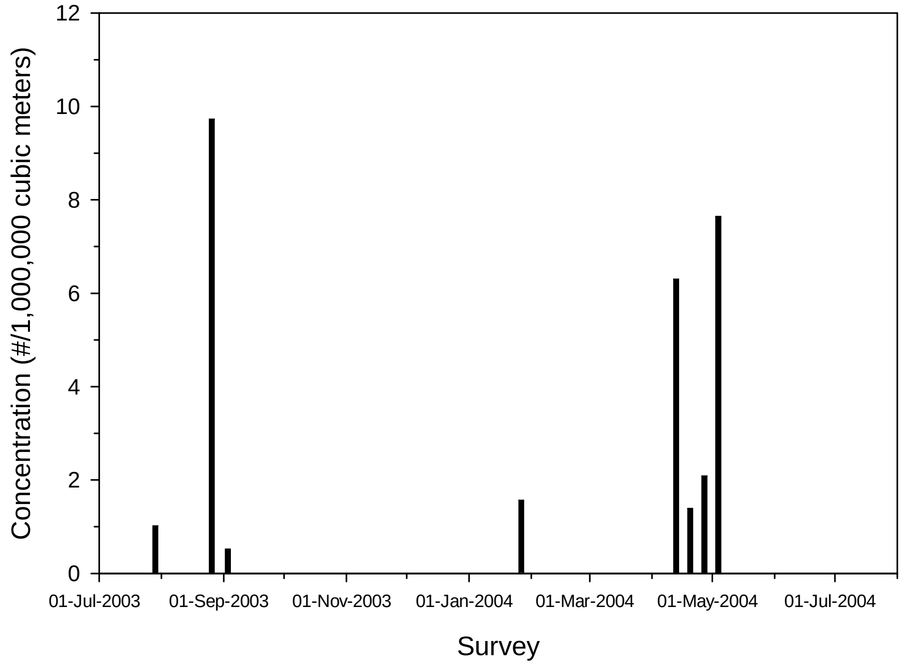


Figure 5-6. Abundance (#/1,000,000 m^3) of white croaker collected in HBGS impingement samples during 2003-4.

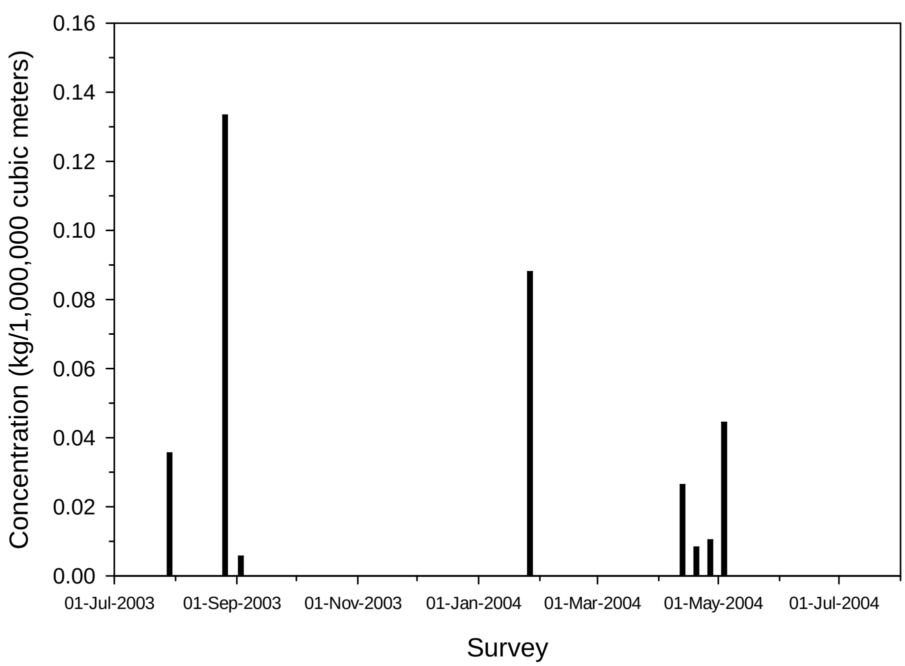


Figure 5-7. Biomass (kg/1,000,000 m^3) of white croaker collected in HBGS impingement samples during 2003-4.

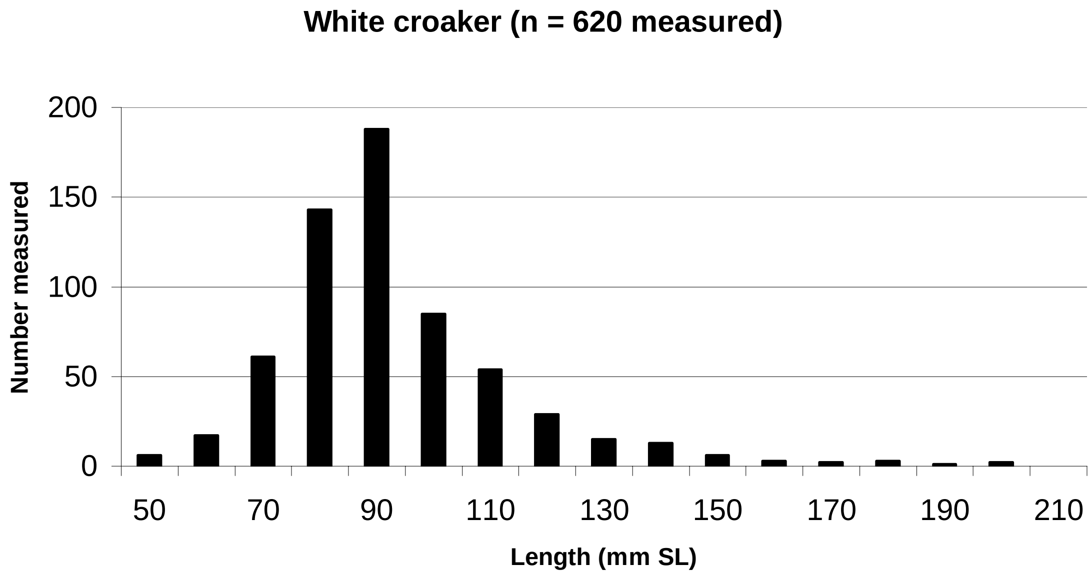


Figure 5-8. Length frequency distribution of white croaker (*Genyonemus lineatus*) in impingement samples.

5.4.2.3 Shiner Perch (*Cymatogaster aggregata*)

Shiner perch (*Cymatogaster aggregata*) ranges from San Quintin Bay, Baja California, to Port Wrangell, Alaska (Miller and Lea 1972). There are 19 species of Pacific nearshore surfperches (Family Embiotocidae) that occur off southern California (Miller and Lea 1972). Most inhabit nearshore waters, bays, and estuaries, though some are found further offshore. Of the 19 species of surfperches that occur in southern California, 10 species besides shiner perch have been collected either within or directly offshore the AES HBGS: shiner perch, walleye surfperch (*Hyperprosopon argenteum*), white seaperch (*Phanerodon furcatus*), black perch (*Embiotoca jacksoni*), kelp surfperch (*Brachyistius frenatus*), pile perch (*Rhacochilus vacca*), barred surfperch (*Amphistichus argenteus*), rubberlip surfperch (*Rhacochilus toxotes*), striped surfperch (*Embiotoca lateralis*), rainbow surfperch (*Hypsurus caryi*), and pink seaperch (*Zalembius rosaceous*).

5.4.2.3.1 Habitat Requirements

Shiner perch occurs primarily in shallow-water marine, bay, and estuarine habitats (Emmett et al. 1991), and is demersal on sandy and muddy bottoms. On the southern California shelf, shiner perch are found at depths to 90 m (295.3 ft), and Allen (1982) reported most occur at about 70 m (229.7 ft). It has been reported to depths of 146 m (479 ft) (Miller and Lea 1972). Juveniles and adults occur in oligohaline to eurohaline waters, and even occasionally in fresh water. This species forms schools or aggregations during the day (Fitch and Lavenberg 1975), but solitary individuals are found on the bottom at night. Important prey items for this species off southern California include calanoid copepods and chaetognaths (Allen 1982). It is a predominantly diurnal visual plankton feeder, but larger individuals may engage in nocturnal epibenthic searching (Allen 1982). Shiner perch, along with white croaker, formed Allen's (1982) "nearshore schoolers" recurrent group; the two species occur commonly off southern California even though shiner perch is considered a cold-temperate, outer-shelf species, while white croaker is a temperate, inner-shelf species.

5.4.2.3.2 Reproduction

Eggs of the shiner perch are fertilized internally, and females give birth to live young. Mating occurs primarily in the spring and summer in California (Bane and Robinson 1970). The reproductive capacity of this species is directly related to female size; smaller females produce as few as 5 young, while larger females can produce over 20 young (Wilson and Millemann 1969).

5.4.2.3.3 Age and Growth

Shiner perch have no larval stage. At birth, fully developed young are about 34 to 78 mm (1.3 to 3.1 in) in length (Wilson and Millemann 1969; Hart 1973). Shiner perch live for about eight years and reach about 180 mm (7.1 in) in length (Miller and Lea 1972; Hart 1973).

5.4.2.3.4 Population Trends and Fishery

This species is not commercially important, but some shiner perch are landed for bait and human consumption (Emmett et al. 1991). Shiner perch are fished recreationally, especially from piers and in bays and estuaries. Total statewide recreational landings of “surfperches” were 489,000 fish in 1999, with most of the catch in central and northern California (Fritzche and Collier 2001). Numbers of shiner perch in southern California waters declined after the mid-1970s, and this is likely related to warming ocean temperature, decreased zooplankton biomass, and reduced upwelling (Stull and Tang 1996; Beck and Herbinson 2003; Allen et al. 2003).

From 1979 through 2002, annual impingement of shiner perch at the HBGS ranged from 0 individuals (1999-2000) to 9,909 individuals (1979).

5.4.2.3.5 Sampling Results

Shiner perch ranked fourth in normal operations abundance, and third in heat treatment abundance, with 95% of the impingement occurring during heat treatments (Table 4-31). Total impingement for the study year was 4,045 individuals. This species occurred in only 6 of 41 normal operations surveys, but in all six heat treatment surveys (Table 5-5). Highest normal operation and heat treatment abundances were recorded in September 2003 (Figures 5-9 and 5-10).

The shiner perch measured in impingement surveys ranged from the 50 to 120 mm (1.97 to 4.7 in) in size, with most fish in the 70 mm (2.8 in) size class (Figure 5-11). Therefore, most of the impinged fish were YOY. The smallest shiner perch (40 and 50 mm [1.6 and 1.97 in] size classes) appeared in May 2004, corresponding to the known spawning season of shiner perch (Bane and Robinson 1970). Of the 170 mature fish inspected for determination of sex during the study year, 130 (76%) were female, and 40 (24%) were male.

Table 5-5. Heat treatment impingement totals for shiner perch.

Heat Treatment Date	Impingement Abundance	Impingement Biomass
16 August 2003	665	6.748
26 September 2003	2,428	31.570
7 November 2003	570	9.092
6 January 2004	46	1.207
22 February 2004	1	0.035
30 May 2004	120	1.161
Total	**3,830**	**49.813**

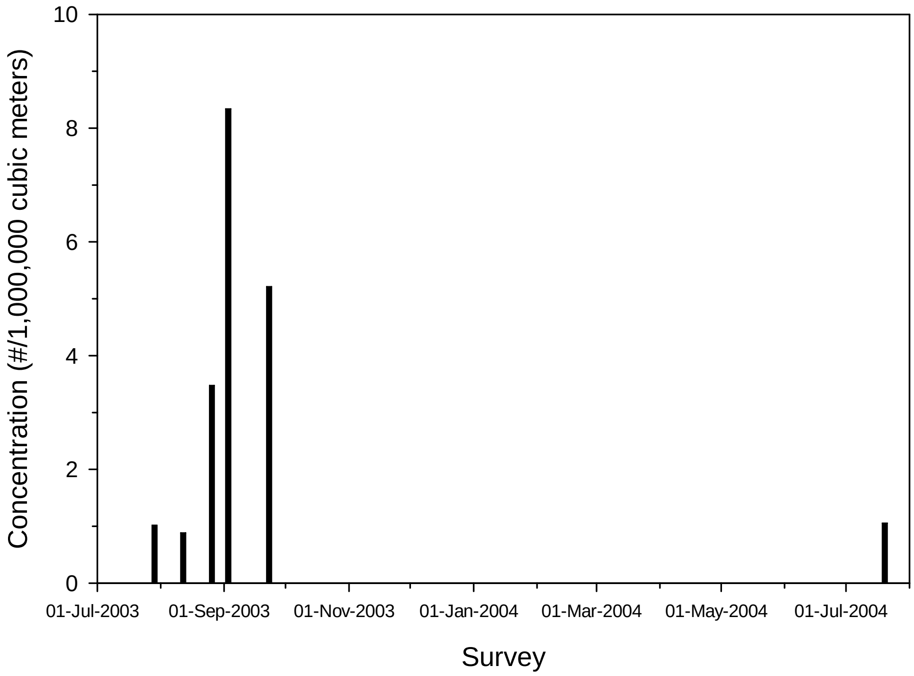


Figure 5-9. Abundance (#/1,000,000 m³) of shiner perch collected in HBGS impingement samples during 2003-4.

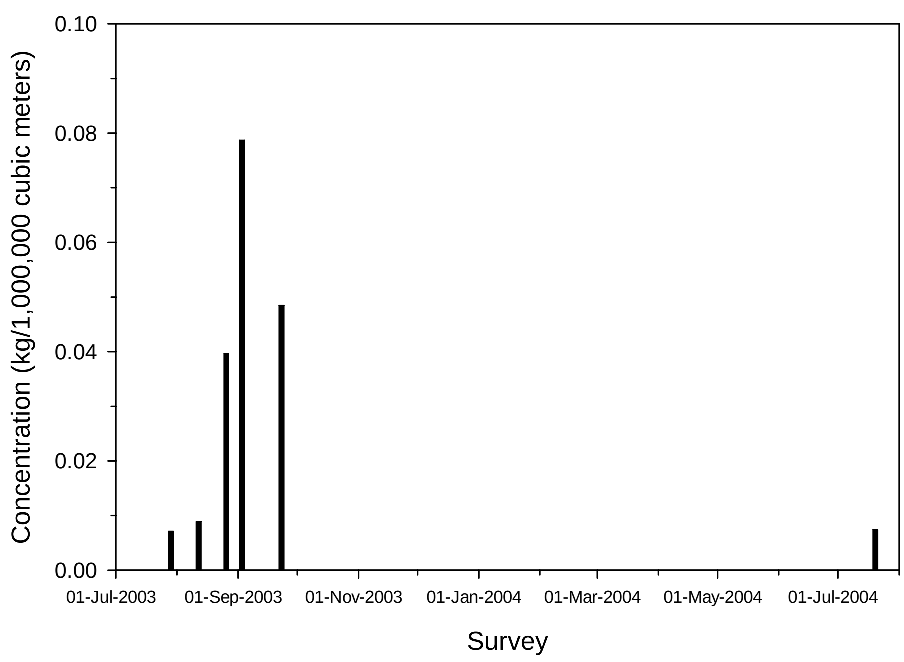


Figure 5-10. Biomass (kg/1,000,000 m³) of shiner perch collected in HBGS impingement samples during 2003-4.

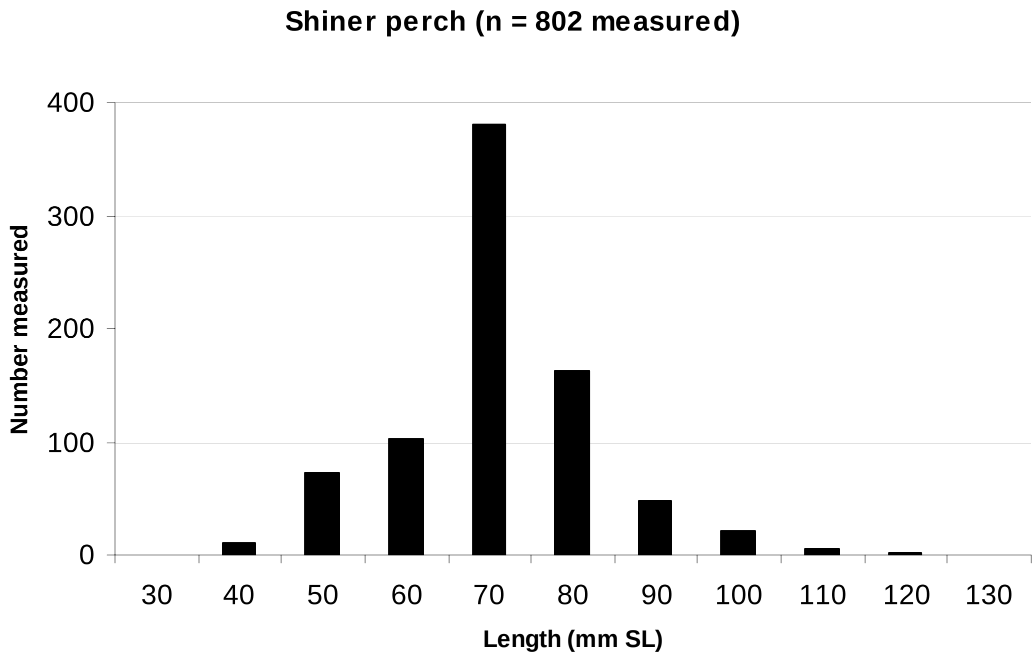


Figure 5-11. Length frequency distribution of shiner perch (*Cymatogaster aggregata*) in impingement samples.

5.4.2.4 Northern Anchovy (*Engraulis mordax*)

Information on the life history, ecology, population trends, and fishery of northern anchovy (*Engraulis mordax*) is summarized in Section 4.3.3.2.

From 1979 through 2002, annual impingement of northern anchovy at the HBGS ranged from 0 individuals (1993 and 1999) to 59,037 individuals (1980).

5.4.2.4.1 Sampling Results

Northern anchovy were the second most abundant species in normal operations impingement samples, and the fourth most abundant species in heat treatment samples (Table 4-31). It was collected in 16 of 52 normal operation samples, and during all six heat treatment surveys (Table 5-6). Highest normal operations abundance occurred in September-October (Figures 5-12 and 5-13), and highest heat treatment abundance was recorded in September.

The northern anchovy measured in impingement surveys ranged from the 20 to 130 mm (0.8 to 5.12 in) in size, with most fish in the 80-90 mm (3.15-3.54 in) size classes (Figure 5-14). Northern anchovy reach 102 mm (4 in) in their first year, and 119 (4.7 in) in their second (Sakagawa and Kimura 1976). Therefore, most of the impinged fish were Age-0 and Age-1 fish. Of the 86 mature individuals inspected for determination of sex during the study year, 74 (86%) were female and 12 (14%) were male.

Table 5-6. Heat treatment impingement totals for northern anchovy.

Heat Treatment Date	Impingement Abundance	Impingement Biomass
16 August 2003	70	1.806
26 September 2003	643	3.317
7 November 2003	167	1.100
6 January 2004	482	3.084
22 February 2004	4	0.021
30 May 2004	3	0.015
Total	**1,369**	**9.343**

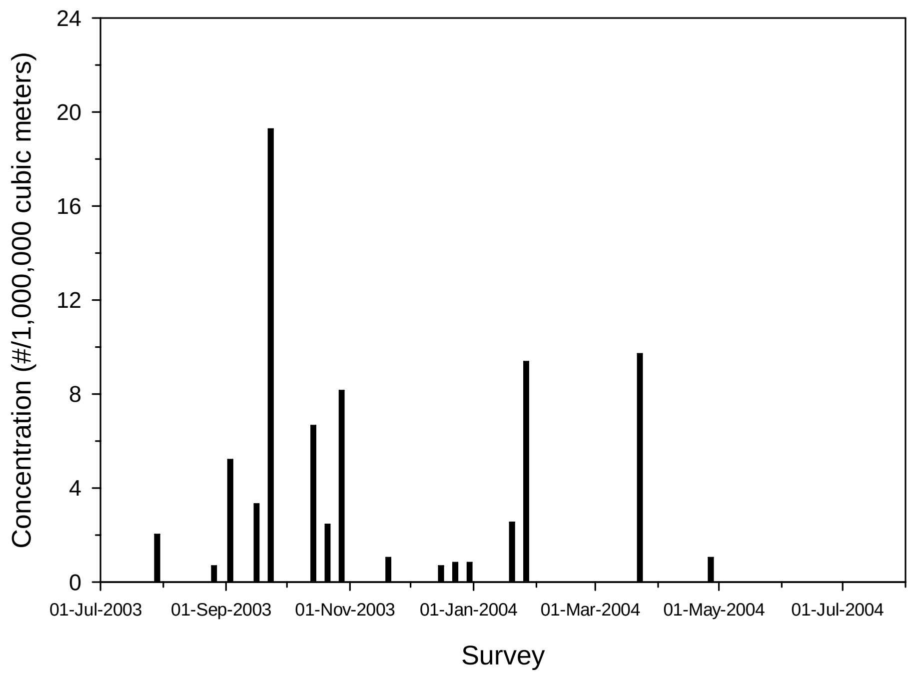


Figure 5-12. Abundance (#/1,000,000 m^3) of northern anchovy collected in HBGS impingement samples during 2003-4.

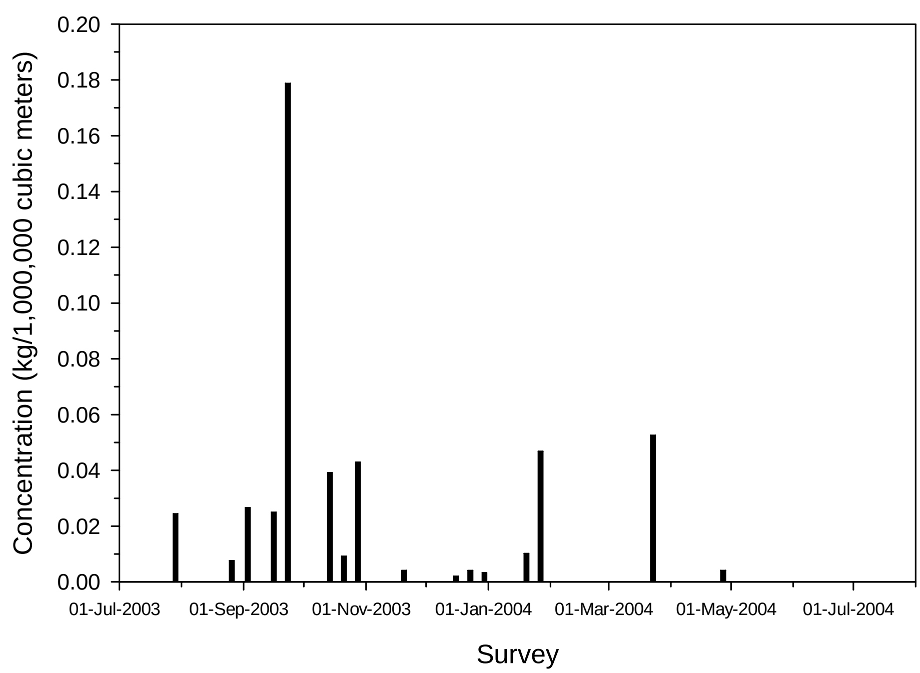


Figure 5-13. Biomass (kg/1,000,000 m^3) of northern anchovy collected in HBGS impingement samples during 2003-4.

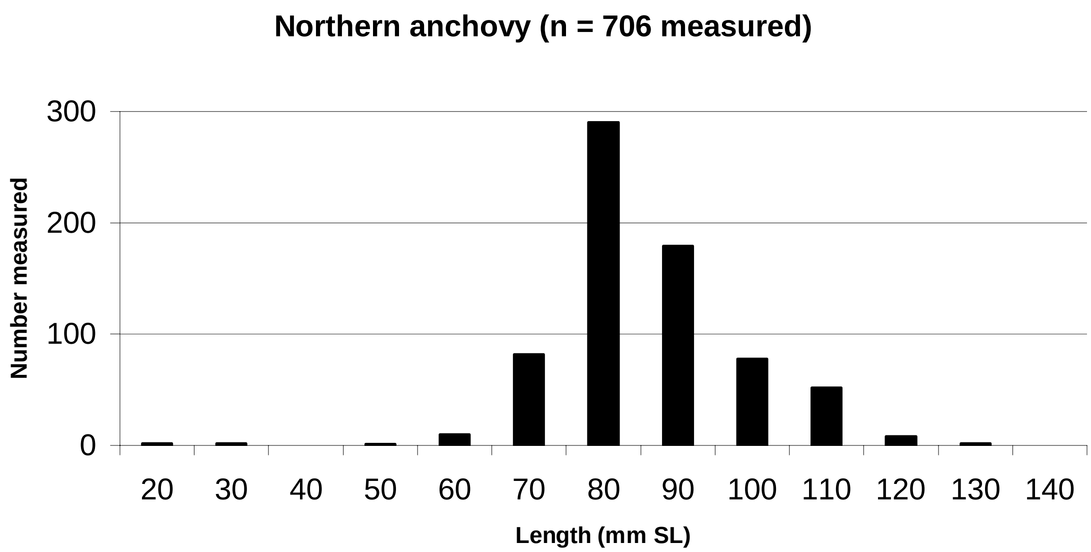


Figure 5-14. Length frequency distribution of northern anchovy (*Engraulis mordax*) in impingement samples.

5.4.3 Macroinvertebrate Impingement

In total, an estimated 70,638 invertebrates representing 37 species were impinged during the study year (Table 5-7). Total biomass was 168 kg (369 lbs). The most abundant macroinvertebrate species were the nudibranch *Dendronotus frondosus* (88%), yellow rock crab (*Cancer anthonyi*; 4%), graceful rock crab (*Cancer gracilis*; 2%), and Pacific rock crab (*Cancer antennarius*; 2%). Abundance during six heat treatment impingement surveys accounted for less than 2% of total impingement abundance. Data are presented by survey in an appendix to this report.

5.4.3.1 Normal Operations Results

An estimated 69,432 macroinvertebrates representing 31 species were impinged during 52 normal operations surveys (Table 5-7). Impingement was highest in late-March 2004 (primarily *Dendronotus*) and early-December 2003 (mainly *Dendronotus*). The most abundant species were the nudibranch *Dendronotus frondosus* (90%), yellow rock crab (4%), and graceful rock crab (2%). Abundance during 52 normal operations surveys accounted for more than 98% of total impingement abundance. Macroinvertebrate biomass during all 52 normal operations surveys totaled 150 kg (332 lbs). Biomass was dominated by two-spotted octopus (*Octopus bimaculatus/bimaculoides*; 15%), shell debris of the Pacific littleneck (*Protothaca staminea*; 15%), yellow rock crab (14%), purple-striped jelly (*Chrysaora colorata*; 14%) and the nudibranch *Dendronotus frondosus* (10%). No whole Pacific littleneck were impinged; instead, bits of shell debris were collected in 11 of 41 surveys, and in larger amounts (> five kilograms per week) during two of those nine surveys in July and September 2003. It is likely that individuals colonized the surfaces of the CWIS along with barnacles, mussels, and turf.

Table 5-7. Macroinvertebrate impingement totals from 52 normal operation and 6 heat treatment surveys.

		Normal Operation Totals		Heat Treatment Totals		Impingement Totals		Percent of Total	
Species	**Common Name**	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt.
Dendronotus frondosus	nudibranch	62,150	14.963	-	-	62,150	14.963	88.0	8.9
Cancer anthonyi	yellow rock crab	2,706	21.754	151	1.342	2,857	23.096	4.0	13.8
Cancer gracilis	graceful rock crab	1,484	2.905	11	0.079	1,495	2.984	2.1	1.8
Cancer antennarius	Pacific rock crab	958	8.588	68	1.179	1026	9.767	1.5	5.8
Pyromaia tuberculata	tuberculate pear crab	597	0.955	386	0.382	983	1.337	1.4	0.8
Cancer productus	red rock crab	417	6.101	25	0.165	442	6.266	0.6	3.7
Crangon nigromaculata	blackspotted bay shrimp	336	0.511	2	0.004	338	0.515	0.5	0.3
Polyorchis penicillatus	jellyfish	326	4.207	-	-	326	4.207	0.5	2.5
Pachygrapsus crassipes	striped shore crab	27	0.088	149	0.401	176	0.489	0.2	0.3
Hermissenda crassicornis	nudibranch	50	0.031	111	0.114	161	0.145	0.2	0.1
Lysmata californica	red rock shrimp	20	0.026	140	0.194	160	0.220	0.2	0.1
Portunus xantusii	Xantus swimming crab	47	0.292	16	0.055	63	0.347	0.1	0.2
Octopus bimaculatus/bimaculoides	two-spotted octopus	27	22.919	34	2.474	61	25.393	0.1	15.2
Heptacarpus palpator	intertidal coastal shrimp	27	0.068	31	0.018	58	0.086	0.1	0.1
Chrysaora colorata	purple-striped jelly	53	21.674	-	-	53	21.674	0.1	12.9
Pisaster sp.	sea star (decomposed)	48	9.872	-	-	48	9.872	0.1	5.9
Ophiothrix spiculata	spiny brittlestar	26	0.082	14	0.007	40	0.089	0.1	0.1
Pugettia producta	shield-backed kelp crab	26	0.114	11	0.199	37	0.313	0.1	0.2
Panulirus interruptus	California spiny lobster	12	10.998	20	8.637	32	19.635	<0.1	11.7
Salpidae	salp, unid.	18	0.108	-	-	18	0.108	<0.1	0.1
Cerebratulus californiensis	ribbon worm	17	0.186	-	-	17	0.186	<0.1	0.1
Navanax inermis	California aglaja	-	-	15	0.038	15	0.038	<0.1	<0.1
Dendronotus subramosus	stubby dendronotus	-	-	14	0.028	14	0.028	<0.1	<0.1
Neotrypaea californiensis	bay ghost shrimp	13	0.060	-	-	13	0.060	<0.1	<0.1
Urechis caupo	innkeeper worm	6	0.577	2	0.025	8	0.602	<0.1	0.4
Flabellina iodinea	Spanish shawl	7	0.007	-	-	7	0.007	<0.1	<0.1
Loligo opalescens	market squid	7	0.442	-	-	7	0.442	<0.1	0.3
Parastichopus parvimensis	warty sea cucumber	7	0.459	-	-	7	0.459	<0.1	0.3
Loxorhynchus crispatus	masking crab	7	0.212	-	-	7	0.212	<0.1	0.1
Hemigrapsus oregonensis	yellow shore crab	6	0.006	-	-	6	0.006	<0.1	<0.1
Penaeus californiensis	yellowleg shrimp	5	0.185	-	-	5	0.185	<0.1	0.1
Pisaster ochraceous	ochre starfish	-	-	3	1.103	3	1.103	<0.1	0.7
Loxorhynchus grandis	sheep crab	-	-	1	0.657	1	0.657	<0.1	0.4
Pachycheles pubescens	pubescent porcelain crab	-	-	1	0.001	1	0.001	<0.1	<0.1
Pachycheles rudis	thick-clawed porcelain crab	-	-	1	0.001	1	0.001	<0.1	<0.1
Protothaca staminea	Pacific littleneck (debris)	-	22.012	-	-	-	22.012	<0.1	13.1
Petricola californiensis	California petricolid (debris)	-	0.058	-	-	-	0.058	<0.1	<0.1
	Totals:	**69,432**	**150.462**	**1,206**	**17.103**	**70,638**	**167.565**	**100.0**	**100.0**
	No. of Species:	**31**		**22**		**37**			

5.4.3.2 Heat Treatment Results

An estimated 1,206 macroinvertebrates representing 22 species were impinged during six heat treatment surveys (Table 5-7). The most abundant species were the tuberculate pear crab (32%), yellow rock crab (13%), striped shore crab (*Pachygrapsus crassipes*; 12%), and red rock shrimp (*Lysmata californica*; 12%). Abundance during the heat treatment impingement surveys accounted for only 2% of total impingement abundance. Heat treatment abundance was highest in late-May 2004, and the sample was comprised primarily of small crustaceans, including tuberculate pear crab, red rock shrimp, yellow rock crab, and striped shore crab.

5.4.4 Macroinvertebrate Results by Species

Species-specific analyses are limited to the five species that together comprised 92% of total impingement abundance and 63% of impingement biomass: the nudibranch *Dendronotus frondosus*, yellow rock crab, two-spotted octopus, purple-striped jelly, and California spiny lobster.

5.4.4.1 Nudibranch (*Dendronotus frondosus*)

The nudibranch (*Dendronotus frondosus*) is a cosmopolitan nudibranch that lives intertidally and subtidally in the northern hemisphere (Morris et al. 1980, Behrens 1991). It lives on, and feeds on, a wide variety of hydroids, including species of *Tubularia*, *Hydractinia*, *Sarsia*, *Obelia*, *Sertularia*, *Abietinaria*, *Aglaophenia*, and others (Morris et al. 1980). This species was only impinged during 5 of 41 normal operations surveys, and was absent in heat treatment surveys. An estimated total of 62,150 individuals were impinged during the study year, but only weighed 15.0 kg (33.1 lbs), equal to an average of over 4,150 individuals per kg (Table 5-7). It was the most abundant macroinvertebrate impinged, comprising 88% of impingement abundance. Highest impingement occurred coincident with, or immediately following, impingement of large amounts of turf (*Syncoryne eximia*, formerly *Sarsia*). It is likely individuals settled within the CWIS, and were inhabiting and grazing on the turf growing in the CWIS. From 1994 through 2002, annual impingement of *D. frondosus* at the HBGS ranged from 0 individuals (1994-2001) to 2,201 individuals (2002).

5.4.4.2 Yellow Rock Crab (*Cancer anthonyi*)

Information on the life history, ecology, population trends, and fishery of rock crabs (*Cancer* spp.) is summarized in Section 4.3.3.15. An estimated total of 2,857 individuals weighing 23.1 kg (60 lbs) were impinged during the study year (Table 5-7). This species was impinged in 19 of 52 normal operations surveys, and only three of the six heat treatment surveys. Highest normal operations abundance occurred in January and May–June 2004, and highest heat treatment abundance was recorded in May 2004. Carapace lengths were not measured, so estimated size classes cannot be estimated. However, the individuals impinged at the HBGS during the study year were small, averaging 8 g (0.3 oz) per crab. From 1994 through 2002, annual impingement of yellow rock crab at the HBGS ranged from 202 individuals (1998) to 5,538 individuals (2002).

5.4.4.3 Two-Spotted Octopus (*Octopus bimaculatus/bimaculoides*)

There are two similar octopus species that occur in southern California: *Octopus bimaculatus* and *O. bimaculoides*. Both are referred to as the two-spotted octopus since they are difficult to distinguish, and for more than 60 years were thought to represent a single species (Morris et al. 1980). *O. bimaculoides* ranges from San Simeon, California, to Bahia San Quintin, Baja California, and is found in a variety of habitats to depths of 20 m (65.6 ft) (Lang and Hochberg 1997). The sibling species *O. bimaculatus* has a similar geographic distribution, occurring from Santa Barbara, California, south to Punta Eugenia, Baja California, and in some locations within the Gulf of California. It also occurs in slightly deeper depths (to 50 m [164 ft]) (Morris et al. 1980; Lang and Hochberg 1997). They both occur in a variety of habitats, including mudflats, intertidal zones, reefs, crevices, and kelp beds.

O. bimaculoides females lay their eggs under rocks from late winter to early summer, and brood them continuously for two to four months (Morris et al. 1980). Females lay between 200 and 800 eggs, depending on female size and condition (Lang and Hochberg 1997). The young remain on the bottom after hatching, and often move toward the intertidal. Adults feed on mollusks, crustaceans, and fishes. In the rocky intertidal zone, *O. bimaculoides* drills and feeds principally on limpets (*Collisella* and *Notoacmea*), snails (*Tegula* spp.), Pacific littleneck, and hermit crabs (*Pagurus* spp.) (Morris et al. 1980). They also feed on mussels (*Mytilus* spp.) and the Pacific calico scallop (*Argopecten ventricosus*) (Lang and Hochberg 1997).

O. bimaculatus spawns throughout most of the year, though there is a distinct seasonal peak from April through July (Lang and Hochberg 1997). Hatching takes place over a relatively short time period since there is an inverse relationship between development time and water temperature (Ambrose 1981). Ambrose (1981) also reported an average clutch size of about 20,000 eggs for a female weighing about 260 g (9.2 oz). After hatching, young octopuses are planktonic for several months, and then settle to the bottom (Lang and Hochberg 1997). Juvenile *O. bimaculatus* feed on small crustaceans, while adults consume a wide variety of motile benthic invertebrates.

An estimated total of 61 individuals weighing 25.4 kg (56 lbs) were impinged during the study year (Table 5-7). This species was impinged in 4 of 52 normal operations surveys, and five of the six heat treatment surveys. Highest normal operations abundance occurred in May and June 2004, and highest heat treatment abundance was recorded in August and September 2003. Mantle lengths were not measured, so estimated size classes cannot be estimated. However, the individuals impinged during normal operations (average of 0.85 kg [1.9 lbs] each) were about 12 times the size of those impinged during heat treatments (average of 0.07 kg [0.15 lbs] each). From 1994 through 2002, annual impingement of two-spot octopus at the HBGS ranged from 9 individuals (1996) to 61 individuals (1998).

5.4.4.4 Purple-Striped Jelly (*Chrysaora colorata*)

Purple-striped jelly (*Chrysaora colorata*, formerly *Pelagia colorata*) is found along the coast of California in oceanic and slope waters (Morris et al. 1980; Wrobel and Mills 1998). The purple-striped jelly feeds on ctenophores, pelagic tunicates, fish eggs and larvae, planktonic crustaceans, and other Scyphomedusae. Unlike most jellyfishes, the fertilized egg of the purple-striped jelly develops to a planula larva, which then develops directly into a free-swimming ephyra stage without intervention of a sessile, asexually reproducing polyp stage. *Chrysaor*a is fed upon by ocean sunfish (*Mola mola*) and blue rockfish (*Sebastes mystinus*). An estimated 53 purple-striped jellies weighing 21.7 kg (47.8 lbs) were impinged during 5 of 52 normal operations surveys, though none were impinged during heat treatments (Table 5-7). They were most abundant in June and July 2004. From 1994 through 2002, annual impingement of purple-striped jelly at the HBGS ranged from 0 individuals (five years) to 63 individuals (2000).

5.4.4.5 California Spiny Lobster (*Panulirus interruptus*)

Information on the life history, ecology, population trends, and fishery of California spiny lobster (*Panulirus interruptus*) is summarized in Section 4.3.3.12. A total of 32 spiny lobsters weighing 19.7 kg (43.4 lbs) was impinged during the study year; an estimated 12 during two weeks of normal operations and 20 during four heat treatment surveys (Table 5-7). This species was most abundant in August and September 2003, which coincides with their inshore distribution during mating season. Of the 19 spiny lobsters measured, carapace lengths averaged 63 mm (2.5 in), ranging from 9 to 98 mm (0.35 to 3.8 in). The average length (63 mm [2.5 in]) is the reported size at maturity and indicates an age of five to six years (Barsky 2001). Of the 14 lobsters examined, 10 (71%) were female, and 4 (29%) were male. Sex was not determined for 5 of the 19 lobsters measured. From 1994 through 2002, annual impingement of spiny lobster at the HBGS ranged from 1 individual (1995 and 2001) to 297 individuals (1999).

5.4.5 Factors Affecting Impingement

Weekly flow during the one-year survey period ranged from 6,233,895 m^3 (1,647 mgd) to 12,950,150 m^3 (3,421 mgd) and averaged 9,280,820 m^3 (2,452 mgd). The highest normal operation fish impingement abundance was recorded during the 27th week (27 January 2004), when 1,346 fishes (mostly juvenile queenfish) representing 12 species were collected during a 24-hr sample period, for an extrapolated weekly impingement of 7,571 individuals weighing 95.6 kg (210.8 lbs) (Figure 5-15). This represents 60% of the total annual normal operations impingement abundance. This was not the week with the highest weekly flow volume; however, all eight circulator pumps were in operation during this impingement sampling period. The highest normal operation macroinvertebrate impingement was recorded during the 30 March 2004 survey (Figure 5-16).

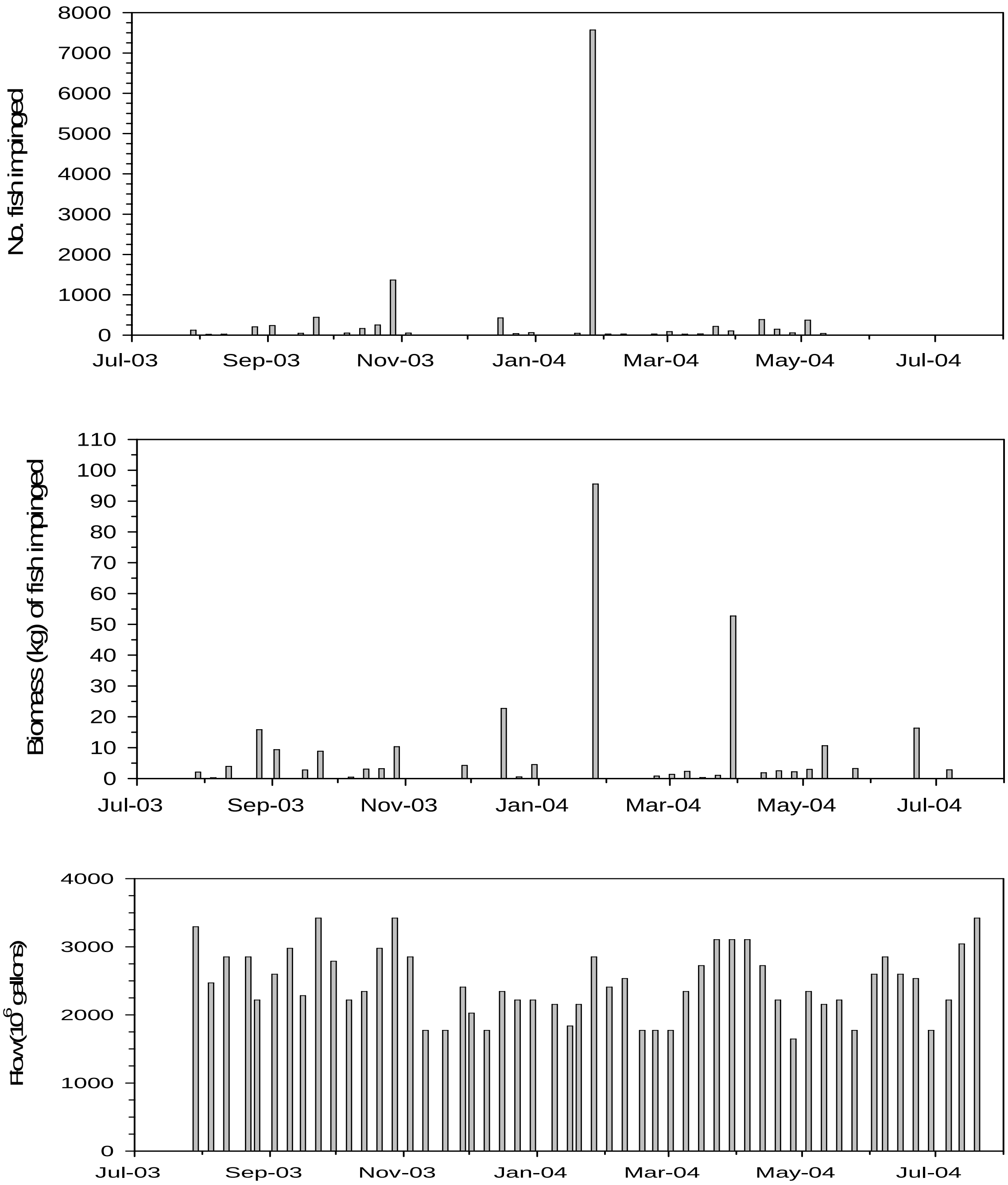


Figure 5-15. Weekly normal operation fish impingement abundance, normal operation fish impingement biomass, and cooling water flow volume, July 2003 – July 2004.

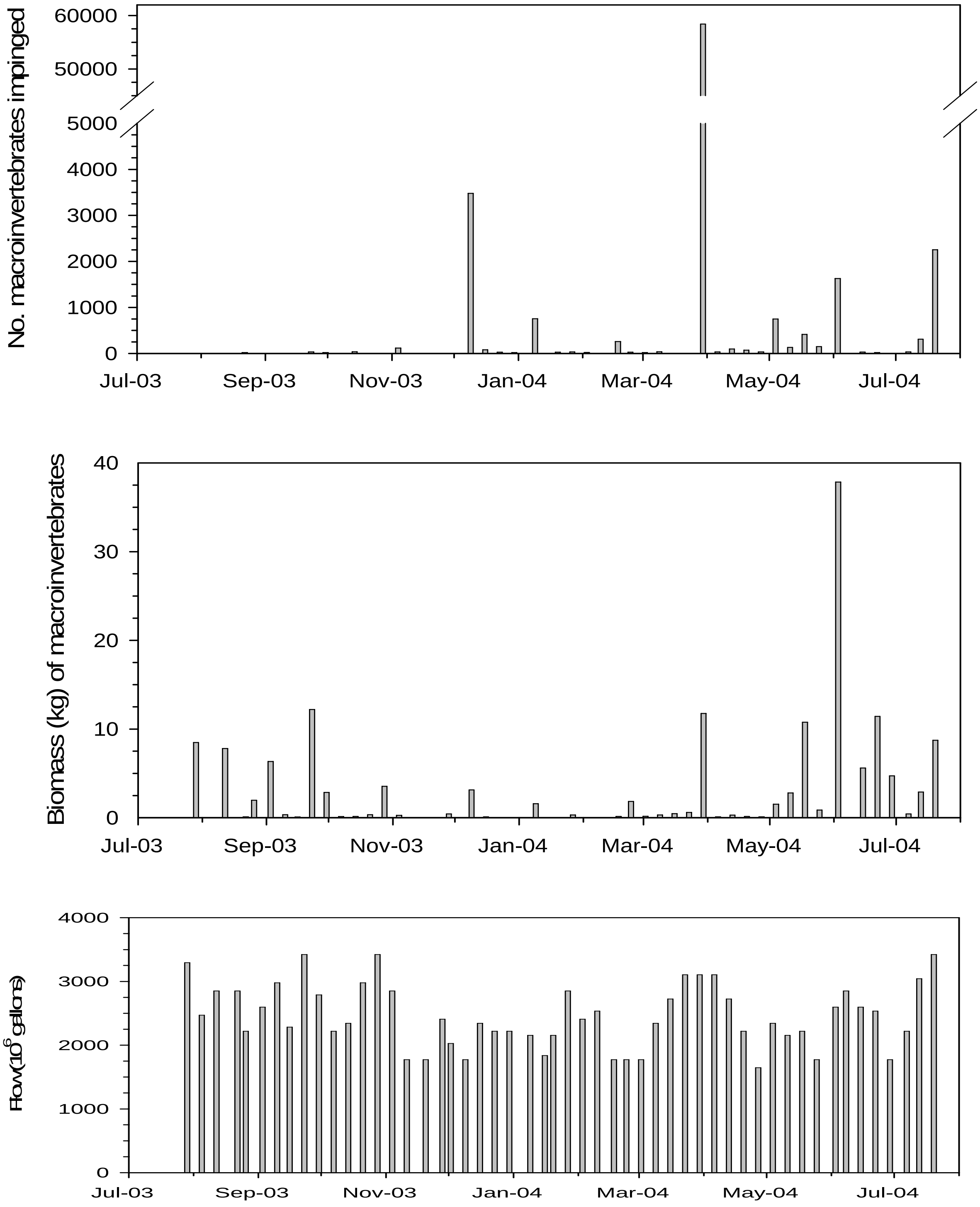


Figure 5-16. Weekly normal operation invertebrate impingement abundance, normal operation fish impingement biomass, and cooling water flow volume, July 2003 – July 2004.

Impingement rates at coastal generating stations are dependent on intake flow and the abundance and distribution of source populations. Intake flow can vary daily, seasonally, and annually. The abundance and distribution of fish and invertebrate populations is affected by oceanographic conditions (such as water temperature and upwelling), biological processes (such as spawning, recruitment, and predation), and human influences (such as fishing and anthropogenic impacts).

The relation between intake flow volume and fish impingement has been examined before at coastal generating stations. In the present study, normal operations impingement parameters for both fishes and macroinvertebrates exhibited no correlation with flow volume (Figure 5-17). Though not required for the present study, water clarity (as measured by Secchi disk) of the HBGS intake forebay was recorded during all normal operation surveys. From October 2003 – September 2004, the 2004 HBGS NPDES monitoring period, normal operation fish impingement CPUE was positively correlated with Secchi depth (r^2 = 0.44, p = 0.02). However, it should be noted that Secchi visibility may have been affected by turbulence during periods of higher flow volumes and not necessarily turbidity. The lack of strong correlations between flow and impingement rates likely results from (1) fluctuations in densities of fishes and invertebrates in the zone of influence of the intake structure, and (2) the presence of relatively low flow areas within the forebays of some generating stations that allow entrapped organisms to survive and not immediately become impinged after they are entrained.

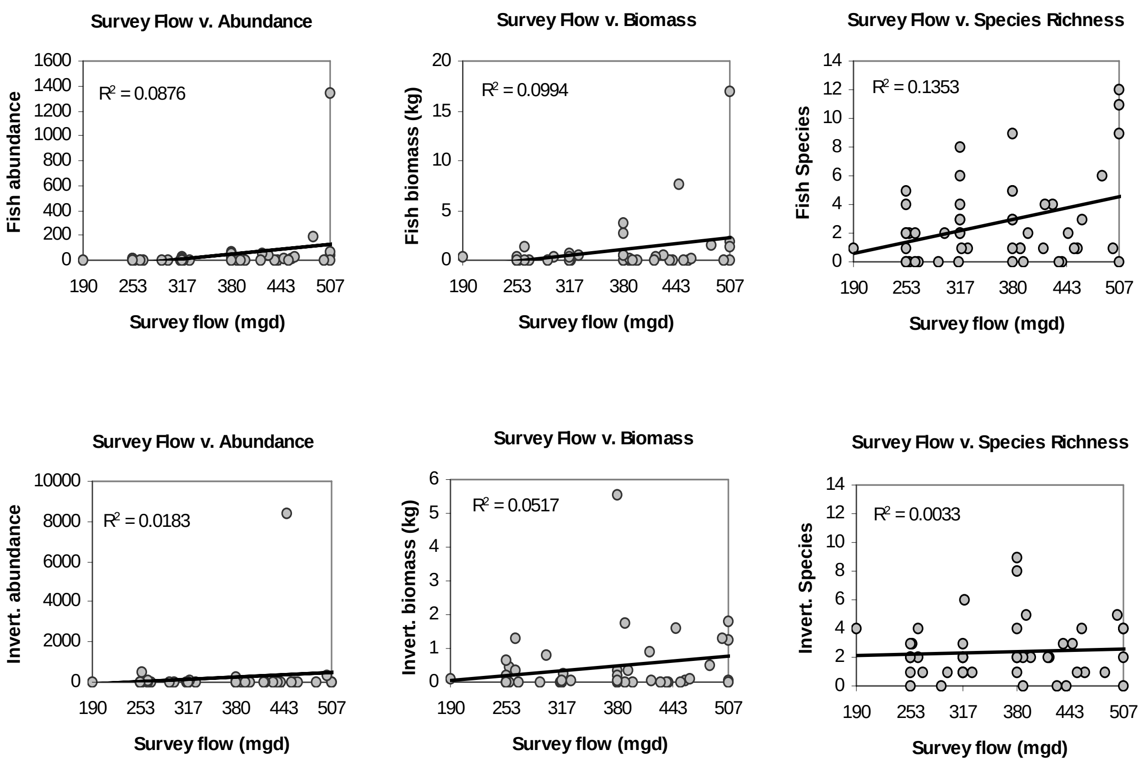


Figure 5-17. Normal operation fish (top) and macroinvertebrate (bottom) impingement parameters and their relations to survey flow volumes.

6.0 IMPACT ASSESSMENT

6.1 IMPACT ASSESSMENT OVERVIEW

The purpose of the AES HBGS Entrainment and Impingement Study is to assess the effects on populations of marine fishes and invertebrates from operation of the AES HBGS cooling water intake system. The results presented in this report were collected during a one-year entrainment study (Sept. 2003 – Aug. 2004) and a one-year impingement study (July 2003 – July 2004). Entrainment was measured by collecting samples near the HBGS intake structure, while impingement was estimated by direct measurements of fishes and macroinvertebrates impinged at the HBGS during normal operations and heat treatment surveys.

The analysis of effects due to operation of the CWIS at the HBGS was limited to the most abundant fishes and a list of target invertebrates collected during the course of the study. This approach was taken primarily because of the uncertainty associated with the assessments of organisms that are in low abundance in the samples. The most abundant organisms may also have higher risk for population-level impacts, but their high entrainment levels also reflect their high overall abundance in the source water. Therefore all of the estimates need to be placed in context, either through the estimates of the source water areas affected or through independent estimates of the adult populations. At the other extreme, although no State- or Federally-listed threatened or endangered species were entrained or impinged during the study, even very low levels of impacts to these species would need to be assessed. The limits of our analyses also resulted from the uncertainty associated with assessments based on few direct observations. By focusing our analyses on the most abundant species in entrainment and impingement surveys, more accurate assessments could be made on those species. The entrainment estimates were based on a set of conservative assumptions resulting in estimates that represented ‘worst-case losses’ for the year. These assumptions included: (1) the estimation of entrainment losses based on maximum permitted flow at the HBGS, even though actual flow for the study year was much less, and (2) an assumed entrainment survival rate of zero.

The life history of species in the community must be considered when discussing potential effect to fish and shellfish populations due to operation of the CWIS at the HBGS. Although the study focused on species potentially affected by entrainment and impingement, it is important to note that several fish fishes have early life stages that are not susceptible to these processes. Live-bearers, such as surfperches, some sharks, and some rays, produce young that are fully developed and too large to be affected by entrainment. From the standpoint of impingement effects, one of the most abundant groups of species in the entrainment samples, gobies, were not susceptible to impingement at HBGS since the larvae entrained resulted from transport out of nearby protected bays and harbors. Even in these environments, gobies would not be subject to impingement because they are bottom-dwelling species that typically do not move up into the water column. Even fishes that swim in the water column are generally not susceptible to impingement effects as they mature because they are able to swim against the slow approach velocity of the cooling water inflow.

The larval fishes entrained by the HBGS CWIS differed somewhat from the juvenile and adult fishes that were impinged. The most abundant fish larvae in entrainment samples (CIQ gobies) comprised 37% of the total fishes collected during entrainment sampling, but as discussed above no gobies were collected in impingement samples. Two of the other abundant larval fish species, white croaker and northern anchovy, were well represented in impingement samples. Conversely, the most abundant fish species collected in impingement samples (queenfish) was not as abundant in the entrainment samples, comprising <5% of total entrainment.

6.2 Summary of Entrainment Results

Entrainment impacts were assessed using two demographic models, Adult Equivalent Loss (*AEL*) and Fecundity Hindcasting (*FH*), which translate larval entrainment estimates into adult losses. The third modeling approach, the Empirical Transport Model (*ETM*), compared the numbers of larvae entrained with the numbers of larvae at risk of entrainment in the source waters to obtain an estimate of the proportional mortality caused by entrainment. Results from these modeling estimates are presented in Table 6-1.

Table 6-1. Summary of entrainment modeling estimates on target taxa based on the three modeling techniques (*FH, AEL,* and *ETM* [P_M]). The *FH* model estimates breeding adult females, therefore this estimate is multiplied by two for comparison with the AEL model that estimates numbers of adults irrespective of sex. The comparison assumes a 50:50 ratio of males:females in the population. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the estimate.

Taxon	Estimated Annual Entrainment	2·*FH*	*AEL*	P_M Alongshore Extrapolation	P_M Offshore +Alongshore Extrapolation
CIQ goby complex	113,166,834	202,538	147,493	1.0% (60.9 km)	1.0%
northern anchovy	54,349,017	53,490	304,125	1.2% (72.0 km)	0.7%
spotfin croaker	69,701,589	NA	NA	0.3% (16.9 km)	0.3%
queenfish	17,809,864	NA	NA	0.6% (84.9 km)	0.5%
white croaker	17,625,263	NA	NA	0.7% (47.8 km)	0.4%
black croaker	7,128,127	NA	NA	0.1% (19.4 km)	0.05%
salema	11,696,960	NA	NA	NA	NA
blennies	7,165,513	6,466	NA	0.8% (12.8 km)	0.3%
diamond turbot	5,443,118	NA	NA	0.6% (16.9 km)	0.3%
California halibut	5,021,168	NA	NA	0.3% (30.9 km)	0.08%
sand crab megalops	69,793	NA	NA	NA	NA
California spiny lobster	0	NA	NA	NA	NA
ridgeback rock shrimp	0	NA	NA	NA	NA
market squid	0	NA	NA	NA	NA
rock crab megalops	6,411,171	NA	NA	1.1% (26.5 km)	0.8%

NA – Estimate not available due to either insufficient life history information or low abundance in entrainment samples.

An estimated 345 million larval fishes were entrained during the one-year study period, an average of about 945,000 per day. The CIQ goby complex was the most abundant fish taxon in both the entrainment and source water samples and comprised 37% of the total larvae collected at the entrainment station (Table 4-1). The CIQ goby complex is comprised of up to three species that are common in southern California bays and estuaries (arrow, shadow, and/or cheekspot gobies) and, as early larvae, cannot be reliably identified to the species level. Northern anchovy was the second most abundant fish taxon collected in both entrainment and source water, comprising 18% of the total in both sets of samples. Four species of croakers were also included in the assessment. White croaker larvae were relatively abundant throughout the sampling period, while queenfish, spotfin croaker, and black croaker were not abundant until the latter part of the study in July and August 2004.

The fish taxa that were the focus of our analysis have different distributions and life histories. They include fishes that are primarily distributed in estuarine and enclosed bay habitats, in coastal nearshore habitats, and in coastal open ocean habitats. The CIQ goby adults are generally not found along the open coast where the HBGS intake structure is located—only 25 gobies have been impinged at the HBGS since 1979 (3 cheekspot and 22 arrow gobies), and none have been collected in annual trawls off the HBGS since 1976. Although adult gobies are relatively small, bottom-dwelling fishes and may not have been adequately sampled by the mesh of the traveling screen or otter trawls, the coastal habitat off the generating station is not well suited for any of these three species of gobies, and it is unlikely there are large numbers of adult gobies off the coast of Huntington Beach. More likely, the adult populations are concentrated in nearby coastal embayments and harbors, such as Alamitos Bay, Anaheim Bay, and Talbert Marsh, and their larvae are dispersed in these environs and transported out into coastal waters by tidal flushing and prevailing currents (Horn and Allen 1976). The arrow goby is an abundant constituent of the fish community at the Golden Shore Marine Reserve, a created wetland at the mouth of the Los Angeles River approximately 22 km (13 mi) upcoast from the HBGS (MBC 2003b). During the final year of a five-year mitigation monitoring project, densities of arrow goby ranged from 0.7 individuals/m^2 in winter to 4.5 individuals/m^2 in summer, but may have been even higher due to some escapement through the 6-mm seine mesh used for sampling. MacDonald (1975) found densities of 4 to 5 individuals/m^2 in Anaheim Bay in winter, although concentrations of up to 20 individuals/m^2 were found in some individual burrows. Combtooth blennies and diamond turbot are two other target taxa that are primarily distributed in estuarine and bay habitats (Love 1996).

The *ETM* results showed that the additional mortality to the source population resulting from entrainment was very low for gobies, blennies and diamond turbot. The estimates of the additional mortality due to entrainment (P_M) were 1.0% or less for all three taxa (Table 6-1). Demographic modeling (*AEL* and *FH*) of CIQ gobies larval entrainment estimates showed potential losses of approximately 150,000 to 200,000 adults. The *ETM* and demographic modeling results overestimate the effects of entrainment on the adult populations of these taxa, which are primarily distributed in bay and estuarine areas. Adult populations of CIQ gobies, in particular, are almost entirely restricted to estuarine areas and the larvae of these species are probably capable of swimming behavior that reduces their transport into coastal waters by tidal currents (Barlow 1963, Pearcy and Myers 1973, Brothers 1975). Although the larvae that are transported into coastal waters provide for genetic exchange between estuarine areas along the coast (Dawson et al. 2002), they also experience much higher rates of mortality than larvae that are retained in estuarine areas. As a result, the survival rates from an estuarine area (Brothers 1975) used in the demographic models were probably much lower than the actual survival in the open coastal waters resulting in overestimates of the actual effects at the adult population level. Similarly, the magnitude of any effects at the adult population level would be much less than the P_M estimate of 1.0%, because this is an estimate of the mortality on the larvae population in open coastal waters and would not apply to the larvae retained in estuarine areas that would be contributing to adult recruitment.

Entrainment effects on fishes primarily distributed along outer coastal habitats, including California halibut, queenfish, white croaker, spotfin croaker, and black croaker were also low, with the estimated additional mortality due to HBGS entrainment of approximately 1% or less (Table 6-1). Estimated effects from the *ETM* were even less when the potential source population was increased to include offshore areas. Another open coastal taxon, salema, was not assessed using any of the models because it was only present during two surveys at the source water and entrainment stations, but not during the same surveys. Therefore, we were unable to calculate estimates of *PE* for salema necessary for the *ETM* calculations. In addition, there is very little life history information available for salema necessary for demographic modeling approaches. Surprisingly, critical life history information such as larval survival rates necessary for calculating the demographic models was also not available for common coastal species such as white croaker, which is found over soft-bottom habitat off the entire southern California coast, and was the second most abundant fish collected in annual trawl surveys. It also ranked second in historical impingement abundance. Despite its nearshore distribution and abundance in the areas offshore the HBGS, the estimated additional mortality from entrainment based on the *ETM* modeling was less than 1%.

Two of these species, California halibut and white croaker, are part of the local commercial fishery. The projected ex-vessel value of California halibut and white croaker lost as a result of larval entrainment was calculated for CDFG Catch Block 738 (10 km x 10 km directly off the HBGS) by multiplying the annual fishery value of reported landings for each species in that catch block by the modeled P_M alongshore extrapolations. For halibut, the fishery value from Block 738 was $18,245 in 2003 and $5,483 in 2002. The alongshore P_M estimate of 0.003 (Table 6-1) translates to values of $55 and $16 in 2003 and 2002, respectively. For white croaker, the fishery value was $9,783 in 2003 and $11,755 in 2002. The alongshore P_M estimate of 0.007 (Table 6-1) translates to values of $68 and $82 in 2003 and 2002, respectively.

Northern anchovy is a pelagic species found out to 480 km (298.3 mile) from shore, and is one of the most abundant fish species off the southern California coast. Juvenile northern anchovy, which were abundant in HBGS impingement samples, are usually found closer to shore, including in embayments and estuaries. Northern anchovy is the numerically dominant fish collected in annual trawl surveys off the HBGS, and ranks third in historical impingement abundance. Live-bait boats commonly fish the nearshore areas between the HBGS and Newport Harbor for this species. The estimated entrainment mortality based on both offshore and alongshore extrapolation of the source population is probably the most appropriate estimate to use for this wide-ranging species and this estimate from *ETM* indicates that the additional mortality resulting from entrainment is approximately 1% over a coastal distance of 72 km (Table 6-1). Although the two demographic model estimates for northern anchovy provide a wide range of estimates, the estimated numbers of adults lost due to entrainment are also low given the large adult populations of northern anchovy in the Southern California Bight. These adult losses can be compared to recent stock estimates of 388,000 MT of northern anchovy in the region from San Francisco to Punta Baja, Mexico (Jacobson et al. 1994).

Northern anchovy are fished commercially off of Huntington Beach. The projected ex-vessel value of northern anchovy lost as a result of larval entrainment was calculated for CDFG Catch Block 738 (directly off the HBGS) by multiplying the annual fishery value reported for anchovy landings in that catch block by the modeled P_M alongshore and offshore extrapolations. The fishery value was $15,094 in 2003 and $12,784 in 2002. The alongshore P_M estimate of 0.012 (Table 6-1) translates to values of $181 and $153 in 2003 and 2002, respectively.

Rock crabs (genus *Cancer*) were the only target invertebrate taxa collected in sufficient abundance for analysis. Although large numbers of sand crab larvae were collected, only two of the larvae were in the later megalops stage chosen as target organisms for assessment. The other invertebrate target taxa were not collected in any of the entrainment samples. Similar to the results for the fishes, the estimated increased mortality due to entrainment for rock crab megalops larvae was low—0.8 to 1.1% (Table 6-1). The projected ex-vessel value of rock crab lost as a result of larval entrainment was calculated for Catch Block 738 (directly off the HBGS) by multiplying the annual fishery value for reported rock crab landings in that catch block by the modeled P_M alongshore extrapolations. The fishery value was $730 in 2003 and $5,121 in 2002. The alongshore P_M estimate of 0.011 (Table 6-1) translates to values of $8 and $56 in 2003 and 2002, respectively.

The estimated levels of P_M for the HBGS are less than estimated results from recent 316(b) entrainment studies at other California power plants. One of the potential reasons for the differences is the habitat where the intake structures for these power plants are located. Some of these studies were conducted in estuarine areas that have very limited source water bodies relative to the open coastal source water for the HBGS. The decreased source water bodies for these studies result in higher P_M estimates relative to the HBGS. The results from the HBGS are also lower than a similar study conducted at the Diablo Canyon Power Plant (DCPP) located on the open coast in San Luis Obispo County in central California. Unlike the HBGS, the nearshore areas around the DCPP CWIS are heterogeneous with rocky reefs, kelp beds and sandy areas. In addition, the CWIS at the DCPP is protected by a rock jetty that provides additional habitat for fishes. In contrast to the DCPP and other similar CWIS intakes, the habitat around the HBGS intake is homogeneous sand flats that extend for several kilometers north, south and offshore of the intake. This homogeneous environment probably results in a more uniform distribution of larvae throughout the sampling area resulting in average estimates of *PE* that closely approximated the volumetric ratio of the cooling water to the sampled source water volume of 0.002% for several of the more abundant target taxa and for the average across all of the fishes. As a result, the P_M estimates for the HBGS are more dependent on the estimated larval durations and currents used to calculate the source water body. This result helps support the approach taken in the cumulative impact assessment that relies solely on the volumetric withdrawal of cooling water in estimating proportional entrainment for the model.

The P_M estimates based on alongshore current displacement ranged from 0.1% to 1.2% (Table 6-1). The length of coastline (km) used in extrapolating the estimates of P_M ranged from 12.8 to 84.9 km (7.9 to 52.7 mile) (Table 6-1). An estimate of the area of larval production lost due to entrainment (area of production foregone) can be estimated by multiplying the P_M estimates by the alongshore source water length and the width of the source water area sampled (5 km [3.1 mile]). Estimates of the area of production foregone ranged from 0.12 to 4.47 km^2, and averaged 1.50 km^2 (Table 6-2).

Table 6-2. Summary of entrainment modeling estimates for target taxa and estimation of area of production foregone. The shoreline distance (km) used in the alongshore extrapolation of P_M is presented in parentheses next to the shoreline distance estimate.

Taxon	Estimated Annual Entrainment	P_m Alongshore Extrapolation	Shoreline Distance (km) of Production Foregone	Area of Production Foregone (km^2)
CIQ gobies	113,166,834	1.0% (60.9 km)	0.604	3.024
northern anchovy	54,349,017	1.2% (72.0 km)	0.894	4.471
spotfin croaker	69,701,589	0.3% (16.9 km)	0.050	0.248
queenfish	17,809,864	0.6% (84.9 km)	0.531	2.657
white croaker	17,625,263	0.7% (47.8 km)	0.340	1.699
black croaker	7,128,127	0.1% (19.4 km)	0.023	0.115
salema	11,696,960	NA	NA	NA
blennies	7,165,513	0.8% (12.8 km)	0.098	0.492
diamond turbot	5,443,118	0.6% (16.9 km)	0.098	0.488
California halibut	5,021,168	0.3% (30.9 km)	0.077	0.386
rock crab	6,411,171	1.1% (26.5 km)	0.284	1.418

The conversion of the estimates of P_M into an alternative currency such as area of production foregone is useful for species that do not have commercial or recreational landings and for these species can be used to provide some context for the estimated effects of entrainment. It is especially useful when applied to fishes such as gobies or rockfishes that occupy a habitat as adults and can be quantified into numbers of adults per unit area. This allows the larval mortality to be equated with the loss of the production from a percentage of that habitat. For these fishes there is an understanding in using this approach that there is some limitation on the population due to availability of habitat. Therefore it is not as applicable to open coastal fishes such as croakers, anchovies, and salema since there is no indication that there are limitations on their habitat. In many cases these fishes are widely distributed across large coastal areas with no physical limitation on habitat availability. The limitations on these species occur due to a wide range of other factors including food availability, water quality, and ocean conditions.

6.3 SUMMARY OF IMPINGEMENT RESULTS

An estimated 51,082 fishes representing 57 species and weighing 1,292 kg were impinged during the one-year study period, an average daily impingement of about 140 individuals weighing 3.5 kg (7.8 lbs) (Table 6-3). Heat treatments accounted for 75% of fish impingement abundance and 78% of biomass. The most abundant species were queenfish (70%), white croaker (10%), shiner perch (8%), and northern anchovy (4%), and all species impinged during the one-year study were present in previous impingement studies at the generating station. Queenfish, white croaker, and northern anchovy are the overall long-term dominants in annual HBGS impingement sampling since 1979. Shiner perch was abundant at the HBGS in 1979, but abundance declined dramatically though 1984, and remained low thereafter. The decreasing numbers of shiner perch (as well as white seaperch and walleye surfperch) were not limited to the waters off the HBGS; similar declines were noted at several locations in southern California. This decline coincided with increasing water temperatures, decreased zooplankton biomass, and reduced upwelling in the SCB (Roemmich and McGowan 1995; Allen et al. 2003). The increasing numbers of shiner perch in impingement samples the last few years could have resulted from the increased flow volume at the HBGS, increasing standing stock in the source waters, or both.

Table 6-3. Summary of annual impingement estimates for the fish (top) and macroinvertebrate (bottom) species with the highest impingement abundance and biomass.

	Normal Operations		Heat Treatments		Annual Impingement[1]	
	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt. (kg)
Fishes						
queenfish	10,468	58.02	25,379	590.14	35,847	648.16
white croaker	274	3.37	4,629	92.05	4,903	95.42
shiner perch	215	2.01	3,830	49.81	4,045	51.82
northern anchovy	824	5.51	1,369	9.34	2,193	14.86
Percent of total					**92%**	**63%**
Macroinvertebrates						
D. frondosus	62,150	14.96	-	-	62,150	14.96
yellow rock crab	2,706	21.75	151	1.34	2,857	23.10
graceful rock crab	1,484	2.90	11	0.08	1,495	2.98
Pacific rock crab	958	8.59	68	1.18	1,026	9.77
two-spotted octopus	27	22.92	34	2.47	61	25.39
purple-striped jelly	53	21.67	-	-	53	21.67
California spiny lobster	12	11.00	20	8.64	32	19.64
Percent of total					**96%**	**70%**

[1]Annual impingement is the sum of Normal Operations and Heat Treatments. Annual values may differ slightly from actual due to rounding.

All fish species impinged during the present study have been collected previously at the HBGS. The only species impinged in the present study that is classified as 'rare' was yellow snake eel (*Ophichthus zophochir*). The classification comes from Miller and Lea (1972), indicating 20 or less were taken prior to 1972. The scarcity of this species likely results from its burrowing behavior. Lea and Rosenblatt (2000) speculated that tropical ophichthids are transported to higher latitude waters during warm-water years, settle out, and live an expatriated existence. This species was taken in impingement samples at HBGS in seven survey years since 1979, and has also been collected at other generating stations in southern California (SCE 2000). Of the 60 white seabass impinged at the HBGS during this study, 49 were returned to MBC's laboratory and scanned for coded wire tags to determine if they were hatchery-reared or part of the natural population (Vojkovich and Crooke 2001). Of the 49 white seabass scanned, only 4 (8%) were hatchery-reared fish with tags. Coincidentally, a survey of 2–3-year-old white seabass caught by sportfishers in 2000 indicated that 7% were hatchery-reared fish with tags (Dotson and Charter 2003). All of the hatchery fish collected in impingement samples were returned to the Hubbs Sea-World Research Institute Hatchery for further analysis.

An estimated 70,638 macroinvertebrates representing 37 species and weighing 168 kg (370.4 lbs) were impinged during the one-year study, an average daily impingement of about 196 macroinvertebrates weighing 0.5 kg (1.0 lbs). Unlike fish impingement, most macroinvertebrates (98%) were impinged during normal operations. The most abundant species were the nudibranch *Dendronotus frondosus* (88%), yellow rock crab (4%), graceful rock crab (2%), and Pacific rock crab (2%).

The average annual macroinvertebrate impingement over the last ten years exceeded 16,000 individuals weighing about 146 kg (321.9 lbs). Abundances of the nudibranchs *Hermissenda crassicornis* and *Dendronotus frondosus* were higher in 2002 and 2003 than in any other survey year since 1994 (for which long-term macroinvertebrate data are compiled). Cause(s) for the increase in impingement of these species are unknown, but the highest abundances of these individuals coincided with surveys where large amounts of turf (*Syncoryne eximia*) were collected. It is possible that the small nudibranchs settle among the fouling invertebrates, including turf, within the CWIS. The individuals collected at the HBGS were very small (4,154 individuals per 1.0 kg for *Dendronotus*).

Comparison of impingement losses of juvenile and adult fishes and invertebrates with source water populations (as was done for larval fishes and target invertebrates) is not possible due to insufficient data on the source water populations for these species. However, to put impingement results in context, we compared them to: (1) commercial landings from commercial Catch Block 738, located offshore the HBGS, (2) southern California recreational landings as reported by the Pacific States Marine Fisheries Commission's (PSMFC) Recreational Fisheries Information Network database (RecFIN), and (3) recreational landings from Huntington, Newport, and Long Beach as reported by the NOAA Fisheries Los Angeles Times Sportfish Database.

To compare impingement at the HBGS with local commercial landings, we multiplied the biomass of impinged (commercially-caught) species by the commercial value (price per pound) reported from Catch Block 738 (offshore the HBGS) in 2002 and 2003 (CDFG 2004). This analysis was limited to those fish and macroinvertebrate species that were both impinged and commercially caught offshore the

HBGS during at least one of those two years. It also assumed that the fishes and macroinvertebrates impinged would otherwise be caught and sold commercially. Combined annual fish and macroinvertebrate impingement at the HBGS amounted to $823 using 2002 Catch Block values and $1,072 using 2003 Catch Block values (Table 6-4). The top-valued species were California spiny lobster, white croaker, surfperches, and California scorpionfish (*Scorpaena guttata*).

Table 6-4. Commercial value of impinged fish and macroinvertebrates at the HBGS, July 2003 – July 2004 (ranked by 2003 commercial value).

Category	2003 price per pound	2002 price per pound	Annual impingement biomass		2003 value	2002 value
			kg	lbs		
California spiny lobster	$6.92	$6.62	19.64	43.30	$299.77	$286.66
white croaker	$1.27	$1.08	95.42	210.40	$267.40	$226.62
surfperch - unspec.	$1.00	–	99.29	218.93	$218.93	–
California scorpionfish	$1.93	$1.94	26.59	58.64	$113.30	$113.56
California halibut	$3.46	$3.30	9.94	21.91	$75.88	$72.24
rock crab - unspec.	$0.54	$0.92	42.11	92.86	$50.59	$85.38
shovelnose guitarfish	$0.66	$0.83	11.17	24.64	$16.23	$20.51
white seabass	$1.45	–	4.93	10.87	$15.76	–
rockfish - unspec.	$2.00	$2.20	1.19	2.62	$5.23	$5.74
California sheephead	$3.53	$3.75	0.36	0.79	$2.79	$2.97
jacksmelt	$0.03	–	29.67	65.42	$1.96	–
northern anchovy	$0.05	$0.03	14.86	32.76	$1.51	$1.09
leopard shark	$0.77	–	0.81	1.79	$1.37	–
Pacific sardine	$0.04	$0.04	7.32	16.13	$0.61	$0.72
sanddab - unspec.	$2.66	$2.66	0.10	0.21	$0.57	$0.57
market squid	$0.20	$0.09	0.44	0.97	$0.19	$0.09
jack mackerel	$0.10	$1.69	0.28	0.62	$0.06	$1.05
Pacific mackerel	$0.07	$0.23	0.34	0.74	$0.05	$0.17
octopus	–	$0.10	25.39	55.99	–	$5.60
				Totals:	$1,072.21	$822.97

Note: It is unknown if queenfish were included in the white croaker landing totals, since there were no reported queenfish landings. Using the price per pound of white croaker, impingement of queenfish would equal $1,815 (2003) and $1,544 (2002), raising the annual totals to $2,887 (2003) and $2,367 (2002).

Impingement at the HBGS was also compared with local recreational landings. This analysis was limited to those fish and macroinvertebrate species that were both impinged in the current study and caught recreationally in southern California in 2003 and reported in at least one of the sportfishing databases: PSMFC's RecFIN database (PSMFC 2004) and/or the NOAA Fisheries Southern California

Recreational Sport Fisheries Database (NOAA Fisheries 2004). The two databases were compiled using different methods. The RecFIN database relied heavily on phone surveys, while the NOAA Fisheries database was compiled using sportfish landing data from daily reports published in the Los Angeles Times. Data from the PSMFC RecFIN database were analyzed for southern California as a whole (analysis on a finer scale was not possible). For most species, the numbers impinged at the HBGS represented less than one percent of recreational landings in southern California (Table 6-5). Exceptions to this included giant kelpfish (2%), white croaker (3%), queenfish (4%), white seaperch (14%), and shiner perch (16%). There are no known recreational fisheries for queenfish or giant kelpfish in southern California. White seaperch and shiner perch are likely targeted by fishermen from piers and breakwaters. White croaker are targeted primarily by fishermen from piers, breakwaters, and private boats (Moore and Wild 2001).

Impingement at the HBGS was also compared with recreational landings reported in the NOAA Fisheries Recreational Sport Fisheries Database for Southern California (NOAA Fisheries 2004). This database was originally compiled for NOAA Fisheries by MBC, and includes sportfish catch by landing as reported daily in the Los Angeles Times from 1959 through 2003 (Mitchell 1999). Our analysis of the NOAA database was limited to recreational landings from Long Beach, Huntington Beach, and Newport Beach (Table 6-6).

Table 6-5. Annual fish impingement abundance and projected annual losses from larval entrainment at the HBGS compared to 2003 recreational fishing landings in southern California as reported in the RecFIN database (ranked by RecFIN landings, top 29 species) (PSFMC 2004).

Common Name	2003 Southern California Recreational Landings	HBGS Impingement	Proportion of Impingement to Recreational Capture	P_M Alongshore	P_M Offshore + Alongshore	Estimated Losses using P_M Alongshore	Estimated Losses using P_M Offshore + Alongshore
queenfish	974,312	35,847	3.7%	0.006	0.005	5,846	4,872
pacific mackerel	828,490	17	<0.1%	NA	NA	NA	NA
barred sand bass	802,096	62	<0.1%	NA	NA	NA	NA
kelp bass	595,291	138	<0.1%	NA	NA	NA	NA
white croaker	180,002	4,903	2.7%	0.007	0.004	1,260	720
vermillion rockfish	160,170	1	<0.1%	NA	NA	NA	NA
walleye surfperch	143,524	476	0.3%	0	0	0	0
California halibut	142,075	21	<0.1%	0.003	0.0008	426	114
California scorpionfish	130,126	110	0.1%	NA	NA	NA	NA
jacksmelt	118,464	332	0.3%	NA	NA	NA	NA
halfmoon	110,425	13	<0.1%	NA	NA	NA	NA
topsmelt	93,605	231	0.2%	NA	NA	NA	NA
yellowfin croaker	71,932	6	<0.1%	NA	NA	NA	NA
California sheephead	69,843	1	<0.1%	NA	NA	NA	NA
blacksmith	66,822	46	0.1%	NA	NA	NA	NA
opaleye	51,956	19	<0.1%	NA	NA	NA	NA
white seabass	50,521	60	0.1%	NA	NA	NA	NA
black perch	42,120	66	0.2%	0	0	0	0
brown rockfish	36,193	2	<0.1%	NA	NA	NA	NA
shiner perch	25,114	4,045	16.1%	0	0	0	0
California corbina	19,680	33	0.2%	NA	NA	NA	NA
sargo	17,159	17	0.1%	NA	NA	NA	NA
spotfin croaker	16,977	49	0.3%	0.003	0.003	51	51
pile perch	8,926	19	0.2%	0	0	0	0
rock wrasse	6,728	4	0.1%	NA	NA	NA	NA
rubberlip seaperch	6,520	17	0.3%	0	0	0	0
white seaperch	6,110	869	14.2%	0	0	0	0
spotted sand bass	3,538	1	<0.1%	NA	NA	NA	NA
giant kelpfish	1,281	30	2.3%	NA	NA	NA	NA
	4,780,002	**47,435**	**1.0%**				

Table 6-6. Comparison of fish impingement abundance at the HBGS from 2003–2004 and recreational fishing landings from Huntington, Newport, and Long Beach as reported in the NOAA Fisheries Los Angeles Times Sportfish Database (NOAA Fisheries 2004).

Common Name	HBGS Annual Impingement	2003 Landings	1999-2003 Average Annual Landings	1959-2003 Average Annual Landings
California barracuda	0	50,094	95,620	90,694
"sea bass"		21	14	57,440
white seabass	60	3,404	3,407	1,022
brown rockfish	2	0	19	7
bocaccio	0	0	1,495	219
black croaker	65	77	37	24
white croaker	4,903	296	645	1,756
queenfish	35,847	0	0	1,020
spotfin croaker	49	0	1	18
yellowfin croaker	6	1,120	573	111
California corbina	33	0	0	1
"croakers"		54	27	9
black surfperch	66	30	13	10
rubberlip perch	17	2	1	1
"perch"	5,492	21,793	14,110	5,296
blacksmith	46	2,732	1,901	375
kelp bass	138	77,004	66,783	79,203
barred sand bass	62	219,721	242,771	86,648
halfmoon	13	110	66	202
California sheephead	1	7,490	10,061	3,193
California halibut	21	2,350	2,726	8,561
jack mackerel	9	415	1,268	658
chub mackerel	17	3,974	15,338	98,519
jacksmelt	332	2	2	502
leopard shark	2	14	8	2
olive rockfish	0	0	43	136
opaleye	19	374	428	133
“sanddab”	23	32,680	43,680	7,220
sargo	17	1,020	728	210
California scorpionfish	110	32,390	35,981	12,559
round stingray	100	0	0	1
“turbot”	75	0	0	1
Totals:	**47,479**	**457,167**	**537,746**	**455,751**

Catches of species generally fluctuate over time because species not only vary in their availability and abundance, but also in their desirability to anglers. Table 5-6 presents total catch numbers, and does not take into account variability in fishing effort over time. Catch from three different time periods (2003, 1999-2003, and 1959-2003) are presented to show trends through time. The annual number of sport anglers in southern California has varied little over the last 40 years, remaining at about 620,000 angler trips per year, though the total number of fish landed has steadily decreased (Dotson and Charter 2003). Between San Pedro and San Clemente, the total catch per angler peaked in 1980, and then steadily decreased by about 50% to 1999. The authors noted that fishing regulations, including size limits, take limits, and closures, have affected catch rates in southern California (Dotson and Charter 2003).

There are no known stock estimates of fishes or macroinvertebrates in southern California for species other than those managed by NOAA fisheries (e.g., Pacific groundfish and coastal pelagics), and those stock estimates are generally for population units in areas much larger than the SCB. The Bight ’98 Study, performed in 1998, is the latest of the regional monitoring efforts for which fish and invertebrate data are available (Allen et al. 2002). The purposes of the Bight ’98 study were to describe patterns in fish and invertebrate population attributes in the SCB, to describe fish and invertebrate assemblages, and to assess the condition and extent of anthropogenic impact on fish and invertebrate populations based on the extent and distribution of tissue contamination in flatfishes, anomalies and sublethal effects, the status of population attributes in affected areas compared with reference areas, assemblage biointegrity and organization, and debris. The Regional Monitoring Surveys coordinated by the Southern California Coastal Water Research Project (SCCWRP), which were performed in 1994, 1998, and 2003 are useful in describing the fish and invertebrate communities of the SCB, but these surveys were not designed to provide stock estimates.

The Bight ’98 study included sampling in bays and harbors, and extended the sampling area inshore of the 20-m (65.6 ft) isobath (the inshore limit of the 1994 Pilot Project) to the 5-m (16.4 ft) isobath. White croaker, queenfish, northern anchovy, and shiner perch accounted for 28%, 6%, 5%, and 1% of survey fish abundance, respectively, with white croaker being the most abundant species in the SCB. The authors compared fish population attributes (such as abundance, biomass, and diversity) in the SCB from three different time periods: 1957-1975, 1994, and 1998. Though there were slight differences among the time periods, Allen et al. (2002) note “*Fish population attribute mean values for the SCB were very similar between the three time periods: fish abundance was 156-173 individuals/haul; biomass was 4.9-7.1 kg/haul; species richness was 10.1-11.7 species/haul; and diversity was 1.28-1.59 bits/individual/haul*”. Herbinson et al. (2001) reported a long-term decline in white croaker abundance in the SCB from 1976 through 1998. In spite of this, white croaker still appear (as of 1998) to be the most abundant fish species on the southern California shelf.

The macroinvertebrate species most affected by the generating station were not well-represented in the 1998 trawl survey. Tuberculate pear crab comprised 1% of the survey abundance, with all other commonly impinged invertebrates comprising <0.2% of survey abundance or less in trawl samples (Allen et al. 2002). Ridgeback prawn (one of the entrainment target species in the present study) was the second most abundant invertebrate in the Bight-wide trawl survey, comprising 16% of total abundance. Unlike fish population attributes (such as abundance, biomass, and diversity), Allen et al. (2002) noted that invertebrate population attributes in 1998 were generally lower than in 1994 or 1957-1975, with highest abundance and biomass per haul occurring in 1994, and highest species richness in 1957-1975. Diversity was not measured in 1957-1975, but dropped from 1.09 to 0.99 per haul between 1994 and 1998.

Results of annual trawl surveys offshore the HBGS from 1976-2004 were analyzed for trends. The trawl surveys were conducted annually each August off the HBGS between the Santa Ana River mouth and the Huntington Beach Pier. From 1976-1993, a total of twelve trawls was performed, including six performed perpendicular to shore. Beginning in 1994, sampling effort was reduced to six trawls per year, with all performed parallel to shore on the discharge isobath.

Fish abundance offshore the generating station in summer declined after 1994, when the trawl program was halved. This could be due to reduced numbers of fishes in the study area, reduced sampling effort, and/or the elimination of trawls that extended further offshore. The trawl locations were limited to the discharge isobath, and cannot account for cross-shelf shifts in fish populations. However, when the relationship between fish abundance and flow rate is considered, it is likely there has been a decrease in fish abundance offshore Huntington Beach through time.

The long-term dataset for impinged macroinvertebrates is not as complete as that for fishes; annual macroinvertebrate impingement totals are available only from 1994 to present. During that time period, the impingement rate has increased slightly with respect to abundance, but biomass has remained stable.

Trend analysis may provide insight to population trends; however, it would be extremely difficult to determine the reasons for the annual variations and patterns. Numerous factors, such as regional oceanographic conditions, availability of food resources, and anthropogenic impacts (including I&E), probably affect the composition and abundance of nearshore fishes and invertebrates. Most of our the long-term impingement data set was collected under a warm oceanic regime in the SCB, and further influenced by a series of El Niño/Southern Oscillation events within this time period (Moser et al. 2001) (Figure 6-1). These included El Niño events in 1982–1983, 1993, and 1997–1998, and La Niña events in 1988–1989 and 1999.

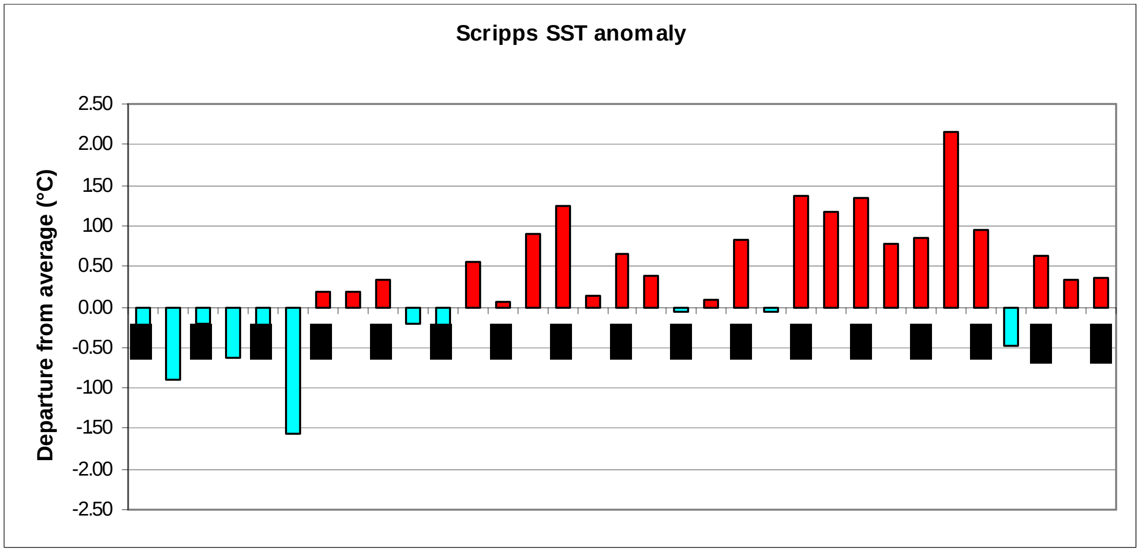


Figure 6-1. Annual sea surface temperature anomaly (departure from 82-year average) from 1970-2002 at Scripps Pier, La Jolla, CA.

In addition to periodic El Niño and La Niña events, the lower frequency Pacific Decadal Oscillation (PDO) describes multidecadal cycles of warm and cold oceanic regimes off California (Horn and Stephens 2006). The PDO affects ocean climate (water temperature, upwelling, productivity, precipitation, and runoff) along the Pacific Coast. When the Aleutian Low atmospheric pressure cell is strong, there is a warm temperature regime off California. During this time, the California Current is weak, upwelling is reduced, and productivity is low. However, precipitation and runoff are high. When the Aleutian Low is weak, the California Current is strong, upwelling is greater, and precipitation and runoff are low. These regime shifts have caused shifts in fish populations in the Pacific Ocean (Allen et al. 2004).

From 1951 through the mid-1990s, macrozooplankton biomass in waters off southern California decreased by 80%, coinciding with a temperature increase in the oceanic surface layer (Roemmich and McGowan 1995). All of the fish species most commonly impinged examined feed on zooplankton with the decrease possibly affecting overall fish abundance. Holbrook et al. (1997) estimated a 69% decrease in populations of 75 fish species at King Harbor and off Palos Verdes, California, between 1975 and 1993. Brooks et al. (2002) examined impingement data from four coastal generating stations, including the HBGS, and determined that the abundance of 37 fish species declined an average of 41% from 1978 to 1992. The authors attributed this to a regional decline in productivity.

6.4 IMPACT SUMMARY

The operation of the cooling water intake system at present results in an annual estimated impingement of 51,082 fishes weighing 1,292 kg (2,848 lbs), and an estimated 70,368 macroinvertebrates weighing 168 kg (369 lbs). These estimates are equal to approximately 140 fish weighing 3.5 kg (8 lbs) per day, and 194 macroinvertebrates weighing 0.5 kg (1 lbs) per day. There are no source population estimates for impinged species with which to determine if the losses are "substantial" on a population level.

Impacts to SCB fish and invertebrate populations caused by the entrainment of planktonic larvae through the HBGS CWIS can only be assessed indirectly through modeling (Section 4.1). These impacts are additive with the direct impingement losses. Of the ten abundant fish species entrained at HBGS, seven have some commercial or recreational fishery value. The *ETM* procedure estimates the annual probability of mortality due to entrainment (P_M). It puts the entrainment estimate into context by comparing it with a known source population at risk of entrainment. The P_M estimates for all of the target taxa were approximately one percent or less (Table 6-1). The alongshore estimates indicate that these impacts occur over an estimated 13 to 85 km (8 to 52.8 mile) of coastline. The distance of shoreline potentially affected is directly proportional to the estimate of time that the larvae are exposed to entrainment. Nearly half of the 53 different fish taxa entrained belonged to species with some direct fishery value (e.g., sand basses, white seabass, California barracuda) even though most of those were very infrequent in the samples. Because of their low abundance in the samples, most of these taxa were not modeled for potential impacts. The single invertebrate taxon modeled for entrainment impacts, *Cancer* crabs, had projected impacts of 1.1% of a source water population extrapolated along a shoreline distance of 27 km (16.8 mile). Even in a heavily exploited commercial species these levels of additional mortality would be considered very low, especially when the populations of these species extend over a much larger geographic range than the extrapolated source water bodies.

There were a few fishes where the combined effects of entrainment and impingement could be assessed. This was done using the RecFIN data presented in Table 6-4. Estimates of entrainment effects based on P_M estimates when added to impingement resulted in losses to the recreational catch for southern California totaling 4.2% for queenfish, 3.4% for white croaker, 0.3% for California halibut, and 0.6% for spotfin croaker. The entrainment estimates were determined by multiplying the P_M estimates by the total southern California landing estimates.

Key findings of the entrainment study are as follows:

- No State- or Federally-listed threatened or endangered species were entrained in the year-long study;
- Annual entrainment losses of equivalent adults could only be projected for CIQ gobies (101,269 using *FH* and 147,493 using *AEL*) and northern anchovy (26,745 using *FH* and 304,125 using *AEL*);
- Fish entrainment losses were equivalent to 0.1% to 1.2% of the source water populations of those species modeled. Approximately one-half of the taxa entrained through HBGS had some direct value to sport or commercial fishers, although most were entrained in very low abundance.
- The five most abundantly entrained fish species (CIQ gobies, anchovies, spotfin croaker, white croaker and queenfish) represented fishes from a variety of habitats including bay/wetland (gobies), benthic nearshore (croakers), and pelagic nearshore/offshore (anchovies). Of these

species spotfin croaker is probably the least abundant in the SCB. The most abundantly impinged macroinvertebrate larvae (sand or mole crabs) are widely distributed along shorelines in the SCB.

- Cost estimates for entrainment losses based on using the P_M estimate as a proportion of the dollar value of the catch landed from Catch Block 738 totaled $307 and $312 based on 2002 and 2003 data, respectively. These estimates underestimate the potential value of the losses because they are based on P_M estimates for only four of the target taxa, and the size of the block is much smaller than the potential source water for the species analyzed.

The following is a summary of impingement impacts:

- No State- or Federally-listed threatened or endangered species were impinged in the year-long study;
- Impingement losses (fishes and macroinvertebrates) were equivalent to $823–$2,367 using 2002 commercial catch data, and $1,072–$2,887 using 2003 data;
- Fish impingement losses were equivalent to 1% of southern California recreational landings as reported by PSFMC (2004), and about 10% of recreational landings from Huntington, Newport, and Long Beach as reported by NOAA Fisheries (2004). However, many of the species most commonly impinged are those which are not highly prized by sport fishers;
- The four most abundantly impinged fish species are fairly abundant in the SCB, together comprising 40% of fish abundance from the 1998 Regional Monitoring Study in the SCB. The most abundantly impinged macroinvertebrates were not nearly as abundant in the Bight-wide study, however.

Based on results of long-term impingement and trawl studies at the HBGS, numbers of fishes at intake depth off the HBGS have declined since the 1970s and 1980s. It is unclear whether this resulted from coastwise or cross-shelf population shifts, or a reduction in stocks through time, and what led to these changes (e.g., oceanographic conditions, anthropogenic impacts, etc.).

7.0 CALCULATION BASELINE

7.1 INTRODUCTION

The data collected as part of the impingement and entrainment study were used in developing a characterization of baseline levels of IM&E for the HBGS. The calculation baseline was an important feature of EPA's Phase II regulations. Calculation baseline was defined as follows:

> *"Calculation baseline means an estimate of impingement mortality and entrainment that would occur at your site assuming that: the cooling water system has been designed as a once-through system; the opening of the cooling water intake structure is located at, and the face of the standard 3/8-inch mesh traveling screen is oriented parallel to, the shoreline near the surface of the source waterbody; and the baseline practices, procedures, and structural configuration are those that your facility would maintain in the absence of any structural or operational controls, including flow or velocity reductions, implemented in whole or in part for the purposes of reducing impingement mortality and entrainment. You may also choose to use the current level of impingement mortality and entrainment as the calculation baseline. The calculation baseline may be estimated using: historical impingement mortality and entrainment data from your facility or another facility with comparable design, operational, and environmental conditions; current biological data collected in the waterbody in the vicinity of your cooling water intake structure; or current impingement mortality and entrainment data collected at your facility. You may request that the calculation baseline be modified to be based on a location of the opening of the cooling water intake structure at a depth other than at or near the surface if you can demonstrate to the Director that the other depth would correspond to a higher baseline level of impingement mortality and/or entrainment."*

As presented in the PIC, the HBGS CWIS does not conform to the calculation baseline. Significant deviations from the calculation baseline are:

- The intake is submerged rather than at, or near, the surface;
- The traveling screens are located more than 1,000 ft from the shoreline rather than at the shoreline; and
- The intake design includes a velocity cap.

The new regulations allowed facilities to take credit for deviations from the calculation baseline if it could demonstrate that these deviations provided reduced levels of IM&E. EPA did not indicate if actual cooling water flows or design (maximum) cooling water flows were to be used in determination of the calculation baseline.

7.2 METHODS

The following sections describe methodologies used to estimate the calculation baseline at the HBGS. As required by the HBGS NPDES permit (Section VI.C.2.e) the proposed methodology for determination of the calculation baseline was submitted to the SARWQCB in August 2006.

7.2.1 Entrainment Calculation Baseline

To determine the calculation baseline for entrainment, annual entrainment estimates were recalculated using two different cooling water flow scenarios: (1) design (maximum) flow at the HBGS, and (2) actual average flows during the calendar years 2004-5. The years 2004-5 were selected to represent the period following the retooling of Units 3&4, and considered representative of current conditions. Entrainment data collection methods are detailed in Section 4.2.1. The average concentration of each taxonomic group from the samples from each of the 45 entrainment surveys was used with the HBGS daily cooling water flow (both actual [average from 2004-5] and design flow) for the corresponding survey period to estimate total annual entrainment. The number of days within each survey period varied depending upon the sampling frequency and the days the samples were collected.

7.2.2 Impingement Calculation Baseline

To determine the calculation baseline for impingement mortality, annual impingement estimates were recalculated using two different cooling water flow scenarios: (1) design (maximum) flow at the HBGS, and (2) actual average flows during the calendar years 2004-5. Impingement data collection methods are detailed in Section 5.3.1. The average concentration of each taxonomic group from the samples from each of the 52 normal operation impingement surveys was used with the HBGS daily cooling water flow (both actual [average from 2004-5] and design flow) for the corresponding survey period to estimate total annual impingement. Heat treatment abundance and biomass were adjusted to account for differences in cooling water flow during the study year (2003-4) and both the actual flow during 2004-5 and design flow. For example, the average annual cooling water flow during 2004-5 was 92% of the flow volume recorded during the 2003-4 impingement study. Therefore, total heat treatment abundance and biomass for each fish and invertebrate taxa were multiplied by 0.92 to approximate conditions in 2004-5.

All fish recorded during the 2003-4 were included in the calculation baseline estimate for both normal operation and heat treatment surveys. During that study, all impinged macroinvertebrates were identified and analyzed during sampling. For the current analysis, the determination of calculation baseline was performed for ‘shellfish’, defined as all crustaceans and cephalopod mollusks.

7.3 CREDITS TOWARD PERFORMANCE STANDARDS

As indicated in Section 7.1, the HBGS cooling water intake does not conform to EPA’s definition of calculation baseline. In the preamble to the Phase II regulations, EPA indicated: “*In many cases, existing technologies at the site show some reduction in impingement and entrainment when compared to the baseline. In such cases, impingement mortality and entrainment reductions (relative to the calculated baseline) achieved by these existing technologies should be counted toward the performance standards. In addition, operational measures such as operation of traveling screens, employment of more efficient return systems, and even locational choices should be credited for any corresponding reduction in impingement mortality and entrainment.*” EPA chose not to incorporate operating capacity into the calculation baseline, as the definition is not dependent upon intake flow volumes.

7.3.1 Entrainment

The determination of calculation baseline for entrainment did not assume any credits for the existing HBGS cooling water intake structure.

7.3.2 Impingement Mortality

The determination of calculation baseline for fish impingement mortality assumed a credit for the velocity cap. Velocity caps work on the premise that fish will avoid rapid changes in horizontal flow but are less able to detect and avoid vertical velocity vectors. Velocity caps are installed at many offshore intakes nationwide, and have been documented to reduce impingement by more than 90% (EPA 2001).

The Huntington Beach Generating Station (HBGS) Velocity Cap Effectiveness Study was carried out by a team of researchers from the University of Washington College of Fisheries (Thomas et al. 1979; Thomas et al. 1980a-d). This study may be the most comprehensive evaluation of velocity cap effectiveness ever conducted. This study collected impingement and source water data on individual species and the results were reported in several University of Washington technical reports. The results were also published in an IEEE journal (Thomas and Johnson 1980). The hydroacoustic methods used as one of the approaches for sampling the source water fish populations were presented at a Scientific Committee on Oceanic Research (SCOR) meeting in 1980 (Thorne 1980).

The study consisted of a series of field trials at four different power plants over one year, with the majority of the trials at HBGS. The seven trials at HBGS resulted in 123 hourly estimates of impingement and source water fish abundances with 70 observations at full flow with the velocity cap in place. This was the control condition and was used to compare impingement and source water abundances under several other plant operating conditions. Source water abundances of fishes were estimated using hydroacoustic sampling that was supplemented with net sampling to verify the composition of the acoustic targets. Gill nets were also positioned at different depths in the water column to determine the vertical distribution of the different species. Data were collected with the plant under full operation in reverse flow (without velocity cap).

The study had several unique features that improved the ability to measure the effectiveness of the velocity cap. First, test conditions were evaluated for a few hours or days and then changed to evaluate another set of test conditions. This insured that fish composition and source water abundances didn’t change dramatically between tests. Secondly, the intake tunnels were cleared of fishes between observations by injecting chlorine at the upstream end of the screenwell in concentrations that forced the fishes towards the traveling screens. This insured a complete count of fish entrapment during each trial. In addition, several trials of each test condition were conducted over the course of the study to ensure that seasonal differences in ocean conditions and fish composition were taken into account. Finally, the entrapment data were combined with estimates of source water fish populations in the vicinity of the intakes to calculate estimates of entrapment vulnerability. The source water population estimates were made using net and hydroacoustic sampling. This enabled the effects of the velocity cap to be evaluated independently of offshore population abundances. The statistical technique for adjusting the entrapment rates was to calculate the ratio of entrapment to fish densities in the source water in the vicinity of the intake (*E/B*). This ratio was used to estimate the relative vulnerability of fishes to entrapment by the intake.

The use of the vulnerability ratio (*E/B*) in assessing differences among treatments had additional benefits that increased the statistical power to determine if there was a significant decrease in the vulnerability of fishes to impingement in the control condition with the velocity cap. The ratio of vulnerability resulted in a measure that adjusted the impingement data for the abundances of fishes in the source water during each observation to insure that any differences in impingement were the results of the presence or absence of the velocity cap and not source water abundances. This decreased the variation among observations within a treatment, which contributed to the ability to detect differences among treatments. The use of the *E/B* ratio and the large number of replicates of each treatment increased the statistical power of the study to detect any differences due to the velocity cap.

The final report presents results both for total impingement of all fish species combined (Table 7-1) and three individual fishes: queenfish, white croaker, and northern anchovy. There were also large numbers of silversides collected, but they were mostly collected in the source water sampling, and were only collected from impingement sampling during reverse operations in the absence of the velocity cap. Although not analyzed in the report due to the absence of normal operations data for comparison, the results for silversides are a good example of the effectiveness of the velocity cap. Results showed that silversides were primarily distributed in the surface layers where they were less likely to be pulled into the system during normal operations with the velocity cap. In the absence of the velocity cap the intake draws water vertically from surface layers resulting in greater impingement of silversides.

Table 7-1. Entrapment Densities for Total Fishes at the HBGS.

Year	Velocity Cap Present	Time	Entrapment Density (kg/hr)	Effectiveness
1979	No	Day/Night 18-hr	20.45	
1979	Yes	Day/Night 18-hr	1.97	90%
1979	No	Night	32.93	
1979	Yes	Night	15.53	53%
			Average:	**72%**
1980	No	Day	47.2	
1980	Yes	Day	0.65	99%
1980	No	Night	52.99	
1980	Yes	Night	6.78	87%
			Average:	**93%**
			Overall:	**82%**

*Data from 1979 and 1980 Velocity Cap Studies (from Thomas et al. 1980, Table 3, p. 18).

The vulnerability ratios from the study present a more accurate measure of the true effectiveness of the velocity cap. The difference in vulnerability for Treatment 2 (full flow without the velocity cap) and

Treatment 3 (full flow without the velocity cap) was highly significant which was verified by analyzing the data with a one-tailed Mann-Whitney U-Test ($p < 0.0001$). Although these results clearly demonstrate the effectiveness of the velocity cap, the estimated efficiency is conservative since data from silversides were not included in the analysis. Silversides are usually found in the upper water column, and are more susceptible to an intake without a velocity cap than one with a velocity cap.

Based on these studies at the HBGS, the velocity cap at the HBGS resulted in a credit of 82% towards meeting the performance standard for reducing impingement mortality. As noted previously, this is likely a conservative estimate since the analysis omitted species (such as silversides) that are more likely to benefit from the velocity cap than demersal species such as croakers. To account for the reduction in impingement due to the velocity cap, the mean percent reduction (82%) was applied to the annual fish impingement abundance and biomass using both actual and design flows. Species-specific fish impingement abundance and biomass were multiplied by 0.18 to calculate the reduction in total impingement. No adjustments were made for shellfish.

7.4 RESULTS

The following section presents estimates of the calculation baseline for entrainment and impingement mortality.

7.4.1 Entrainment

The calculation baseline estimates for annual entrainment based on actual (2004-5) cooling water flows are presented in Table 7-2. The estimates based on design flows are presented in Table 7-3.

7.4.2 Impingement Mortality

The calculation baseline estimates for annual impingement mortality based on actual (2004-5) cooling water flows are presented in Tables 7-4 through 7-7. The annual estimates based on design flows are presented in Tables 7-8 through 7-11.

Table 7-2. Annual entrainment estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Total Count	Total Estimated Entrainment	Percent of Total	Cumul. Percent	Std. Error Entrainment Estimate
FISHES						
Gobiidae unid.	gobies	2,484	82,909,028	30.15	30.15	4,997,566
Roncador stearnsi	spotfin croaker	912	61,063,631	22.21	52.36	7,659,603
Engraulidae	anchovies	1,209	39,580,026	14.39	66.75	3,134,829
Seriphus politus	queenfish	306	15,770,277	5.74	72.49	2,196,195
Genyonemus lineatus	white croaker	446	10,958,915	3.99	76.47	944,319
Xenistius califoriensis	salema	153	10,393,637	3.78	80.25	4,640,088
Sciaenidae unid.	croaker	244	8,234,675	2.99	83.25	787,118
Cheilotrema saturnum	black croaker	96	6,120,533	2.23	85.47	1,321,487
Hypsoblennius spp.	blennies	166	5,227,431	1.90	87.38	419,391
Hypsopsetta guttulata	diamond turbot	87	4,311,897	1.57	88.94	406,099
Paralichthys californicus	California halibut	98	3,922,779	1.43	90.37	361,252
Menticirrhus undulatus	California corbina	43	2,397,713	0.87	91.24	718,360
Paralabrax spp.	sand bass	48	2,330,599	0.85	92.09	435,277
Atherinopsidae	silverside	97	2,233,320	0.81	92.90	353,434
Citharichthys spp.	sanddabs	31	1,401,729	0.51	93.41	246,695
Hypsypops rubicundus	garibaldi	43	1,148,121	0.42	93.83	509,477
Sphyraena argentea	California barracuda	14	988,916	0.36	94.19	228,390
Oxyjulis californica	senorita	27	829,048	0.30	94.49	209,101
Pleuronectidae unid.	flounders	17	775,541	0.28	94.77	104,994
Umbrina roncador	yellowfin croaker	24	772,153	0.28	95.05	218,477
Gillichthys mirabilis	longjaw mudsucker	20	522,819	0.19	95.24	95,897
Pleuronichthys ritteri	spotted turbot	12	460,530	0.17	95.41	72,415
Triphoturus mexicanus	Mexican lampfish	8	438,259	0.16	95.57	75,935
Diaphus theta	California headlight fish	11	395,677	0.14	95.71	89,180
Lepidogobius lepidus	bay goby	18	391,580	0.14	95.86	90,313
Syngnathidae unid.	pipefishes	17	381,945	0.14	96.00	213,897
Myctophidae unid.	lanternfishes	6	358,746	0.13	96.13	80,606
Leptocottus armatus	Pacific staghorn sculpin	16	332,239	0.12	96.25	67,529
Haemulidae	grunts	5	326,926	0.12	96.37	108,146
Acanthogobius flavimanus	yellowfin goby	15	301,378	0.11	96.48	111,599
Atractoscion nobilis	white seabass	5	300,887	0.11	96.59	99,800
Gibbonsia spp.	clinid kelpfishes	10	189,461	0.07	96.65	47,829
Pleuronichthys verticalis	hornyhead turbot	3	177,561	0.06	96.72	47,851
Sardinops sagax	Pacific sardine	4	152,360	0.06	96.77	107,982
Peprilus simillimus	Pacific butterfish	2	117,605	0.04	96.82	48,126
Semicossyphus pulcher	California sheephead	2	103,088	0.04	96.85	41,502
Halichoeres semicinctus	rock wrasse	1	85,156	0.03	96.89	40,290
Labrisomidae unid.	labrisomid kelpfishes	3	81,333	0.03	96.91	42,724
Stenobrachius leucopsarus	northern lampfish	3	74,045	0.03	96.94	31,806
Paralichthyidae unid.	lefteye flounders & sanddabs	2	67,272	0.02	96.97	33,237
Medialuna californiensis	halfmoon	2	50,005	0.02	96.98	38,293
Scorpaenidae	scorpionfishes	1	40,995	0.01	97.00	31,406
Scomber japonicus	Pacific mackerel	2	39,754	0.01	97.01	21,648
Symphurus atricauda	California tonguefish	1	34,396	0.01	97.03	26,350
Typhlogobius californiensis	blind goby	1	30,036	0.01	97.04	23,010
Strongylura exilis	California needlefish	1	26,118	0.01	97.05	19,869
Oxylebius pictus	painted greenling	1	24,096	0.01	97.06	18,239

(continued)

Table 7-2. (Continued). Annual entrainment estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Total Count	Total Estimated Entrainment	Percent of Total	Cumul. Percent	Std. Error Entrainment Estimate
FISHES *(continued)*						
Merluccius productus	Pacific hake	1	22,125	0.01	97.06	16,766
Coryphopterus nicholsii	blackeye goby	1	21,339	0.01	97.07	16,233
Ruscarius creaseri	rouchcheek sculpin	1	19,804	0.01	97.08	15,065
Agonidae unid.	poachers	1	18,431	0.01	97.09	13,973
Pleuronectiformes unid.	flatfishes	1	16,979	0.01	97.09	12,970
Cottidae unid.	sculpins	1	16,820	0.01	97.10	12,814
	Total Identified Fishes:	**6,723**	**266,989,734**			
larvae, unidentified yolksac	unidentified yolksac larvae	136	4,668,434	1.70	98.80	921,905
larval fish fragment	unidentified larval fishes	51	2,001,380	0.73	99.52	330,997
larval/post-larval fish unid.	larval fishes	39	1,272,894	0.46	99.99	192,847
larval fish - damaged	unidentified larval fishes	1	38,090	0.01	100.00	26,996
	Total Unidentified Fishes:	**227**	**7,980,797**			
	Total Fishes:	**6,950**	**274,970,531**			
INVERTEBRATES						
Cancer anthonyi (megalops)	yellow crab	77	4,548,723	68.69	68.69	1,180,257
Cancer gracilis (megalops)	slender crab	31	982,598	14.84	83.52	217,296
Cancer antennarius (megalops)	brown rock crab	18	851,934	12.86	96.39	179,954
Cancer productus (megalops)	red rock crab	3	124,857	1.89	98.27	42,996
Emerita analoga (megalops)	mole crabs - larva	2	48,843	0.74	99.01	37,858
Cancer spp. (megalops)	cancer crabs	2	33,556	0.51	99.52	18,735
Cancer spp.	cancer crabs	1	32,032	0.48	100.00	24,361
	Total Target Invertebrate Larvae:	**134**	**6,622,544**			
Emerita analoga (zoea)	mole crabs - larva	10,399	363,033,148			73,186,329
	Total Invertebrate Larvae:	**10,533**	**369,655,692**			

Table 7-3. Annual entrainment estimates at the HBGS based on design cooling water flow.

Taxon	Common Name	Total Count	Total Estimated Entrainment	Percent of Total	Cumul. Percent	Std. Error Entrainment Estimate
FISHES						
Gobiidae unid.	gobies	2,484	113,166,834	31.89	31.89	6,568,091
Roncador stearnsi	spotfin croaker	912	69,701,589	19.64	51.53	8,636,383
Engraulidae	anchovies	1,209	54,349,017	15.31	66.84	4,355,775
Seriphus politus	queenfish	306	17,809,864	5.02	71.86	2,415,487
Genyonemus lineatus	white croaker	446	17,625,263	4.97	76.83	1,491,336
Xenistius califoriensis	salema	153	11,696,960	3.30	80.13	5,186,479
Sciaenidae unid.	croaker	244	10,534,802	2.97	83.09	1,004,033
Hypsoblennius spp.	blennies	166	7,165,513	2.02	85.11	580,175
Cheilotrema saturnum	black croaker	96	7,128,127	2.01	87.12	1,481,158
Hypsopsetta guttulata	diamond turbot	87	5,443,118	1.53	88.66	476,544
Paralichthys californicus	California halibut	98	5,021,168	1.41	90.07	447,516
Atherinopsidae	silverside	97	3,654,229	1.03	91.10	577,117
Menticirrhus undulatus	California corbina	43	2,809,417	0.79	91.89	807,329
Paralabrax spp.	sand bass	48	2,793,730	0.79	92.68	518,724
Citharichthys spp.	sanddabs	31	1,913,607	0.54	93.22	314,973
Hypsypops rubicundus	garibaldi	43	1,622,966	0.46	93.68	776,711
Oxyjulis californica	senorita	27	1,190,449	0.34	94.01	311,376
Sphyraena argentea	California barracuda	14	1,133,103	0.32	94.33	258,040
Pleuronectidae unid.	flounders	17	982,419	0.28	94.61	131,877
Umbrina roncador	yellowfin croaker	24	962,905	0.27	94.88	266,187
Gillichthys mirabilis	longjaw mudsucker	20	834,682	0.24	95.11	155,798
Lepidogobius lepidus	bay goby	18	683,887	0.19	95.31	161,835
Syngnathidae unid.	pipefishes	17	591,496	0.17	95.47	353,236
Leptocottus armatus	Pacific staghorn sculpin	16	584,664	0.16	95.64	115,109
Pleuronichthys ritteri	spotted turbot	12	561,958	0.16	95.80	87,434
Triphoturus mexicanus	Mexican lampfish	8	536,324	0.15	95.95	95,606
Acanthogobius flavimanus	yellowfin goby	15	522,589	0.15	96.10	176,940
Diaphus theta	California headlight fish	11	486,274	0.14	96.23	110,942
Myctophidae unid.	lanternfishes	6	423,578	0.12	96.35	94,314
Haemulidae	grunts	5	368,219	0.10	96.46	121,028
Atractoscion nobilis	white seabass	5	347,306	0.10	96.55	114,685
Gibbonsia spp.	clinid kelpfishes	10	341,921	0.10	96.65	87,691
Pleuronichthys verticalis	hornyhead turbot	3	198,470	0.06	96.71	52,984
Sardinops sagax	Pacific sardine	4	166,724	0.05	96.75	117,891
Peprilus simillimus	Pacific butterfish	2	138,138	0.04	96.79	56,479
Semicossyphus pulcher	California sheephead	2	129,222	0.04	96.83	52,033
Stenobrachius leucopsarus	northern lampfish	3	111,109	0.03	96.86	46,395
Labrisomidae unid.	labrisomid kelpfishes	3	108,964	0.03	96.89	58,784
Halichoeres semicinctus	rock wrasse	1	97,344	0.03	96.92	45,888
Paralichthyidae unid.	lefteye flounders & sanddabs	2	95,195	0.03	96.94	45,031
Medialuna californiensis	halfmoon	2	77,804	0.02	96.97	58,815
Scomber japonicus	Pacific mackerel	2	61,004	0.02	96.98	32,608
Scorpaenidae	scorpionfishes	1	50,467	0.01	97.00	38,150
Symphurus atricauda	California tonguefish	1	42,344	0.01	97.01	32,009
Strongylura exilis	California needlefish	1	40,637	0.01	97.02	30,719
Oxylebius pictus	painted greenling	1	40,289	0.01	97.03	30,456
Typhlogobius californiensis	blind goby	1	36,976	0.01	97.04	27,951

(continued)

Table 7-3. (Continued). Annual entrainment estimates at the HBGS based on design cooling water flow.

Taxon	Common Name	Total Count	Total Estimated Entrainment	Percent of Total	Cumul. Percent	Std. Error Entrainment Estimate
FISHES *(continued)*						
Merluccius productus	Pacific hake	1	33,954	0.01	97.05	25,667
Coryphopterus nicholsii	blackeye goby	1	33,202	0.01	97.06	25,099
Agonidae unid.	poachers	1	30,817	0.01	97.07	23,295
Ruscarius creaseri	rouchcheek sculpin	1	30,813	0.01	97.08	23,293
Pleuronectiformes unid.	flatfishes	1	30,192	0.01	97.09	22,823
Cottidae unid.	sculpins	1	28,990	0.01	97.10	21,914
	Total Identified Fishes:	**6,723**	**344,570,635**			
larvae, unidentified yolksac	unidentified yolksac larvae	136	6,100,663	1.72	98.81	1,148,559
larval fish fragment	unidentified larval fishes	51	2,508,742	0.71	99.52	386,659
larval/post-larval fish unid.	larval fishes	39	1,655,508	0.47	99.99	246,622
larval fish - damaged	unidentified larval fishes	1	41,681	0.01	100.00	29,473
	Total Unidentified Fishes:	**227**	**10,306,594**			
	Total Fishes:	**6,950**	**354,877,229**			
INVERTEBRATES						
Emerita analoga (zoea)	mole crabs - larva	10,399	465,806,877	98.35	98.35	91,912,298
Cancer anthonyi (megalops)	yellow crab	77	5,207,996	1.10	99.45	1,320,180
Cancer gracilis (megalops)	slender crab	31	1,304,771	0.28	99.72	311,450
Cancer antennarius (megalops)	brown rock crab	18	973,538	0.21	99.93	202,088
Cancer productus (megalops)	red rock crab	3	164,478	0.03	99.96	53,672
Emerita analoga (megalops)	mole crabs - larva	2	69,793	0.01	99.98	54,061
Cancer spp. (megalops)	cancer crabs	2	65,159	0.01	99.99	34,834
Cancer spp.	cancer crabs	1	35,885	0.01	100.00	27,126
	Total Target Invertebrate Larvae:	**10,533**	**473,628,497**			

Table 7-4. Annual fish impingement mortality abundance estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Est. Normal Operation Abundance	Heat Treatment Abundance	Total Annual Abundance	Percent of Total	Calc. Baseline Abundance
Seriphus politus	queenfish	8,540	23,349	31,889	69.32	177,161
Genyonemus lineatus	white croaker	303	4,259	4,562	9.92	25,344
Cymatogaster aggregata	shiner perch	238	3,524	3,762	8.18	20,900
Engraulis mordax	northern anchovy	693	1,259	1,952	4.24	10,844
Phanerodon furcatus	white seaperch	95	726	821	1.78	4,561
Peprilus simillimus	Pacific pompano	129	432	561	1.22	3,117
Hyperprosopon argenteum	walleye surfperch	31	410	441	0.96	2,450
Atherinopsis californiensis	jacksmelt	21	284	305	0.66	1,694
Atherinops affinis	topsmelt	-	213	213	0.46	1,183
Paralabrax clathratus	kelp bass	-	127	127	0.28	706
Leuresthes tenuis	California grunion	32	84	116	0.25	644
Sardinops sagax	Pacific sardine	80	35	115	0.25	639
Porichthys myriaster	specklefin midshipman	103	1	104	0.23	578
Scorpaena guttata	California scorpionfish	33	69	102	0.22	567
Urobatis halleri	round stingray	55	44	99	0.22	550
Paralabrax nebulifer	barred sand bass	9	51	60	0.13	333
Embiotoca jacksoni	black perch	5	50	55	0.12	306
Atractoscion nobilis	white seabass	9	45	54	0.12	300
Cheilotrema saturnum	black croaker	13	40	53	0.12	294
Roncador stearnsii	spotfin croaker	-	45	45	0.10	250
Chromis punctipinnis	blacksmith	7	36	43	0.09	239
Xenistius californiensis	salema	9	32	41	0.09	228
Pleuronichthys ritteri	spotted turbot	32	4	36	0.08	200
Heterostichus rostratus	giant kelpfish	24	8	32	0.07	178
Menticirrhus undulatus	California corbina	-	30	30	0.07	167
Synodus lucioceps	California lizardfish	29	-	29	0.06	161
Pleuronichthys verticalis	hornyhead turbot	26	1	27	0.06	150
Myliobatis californica	bat ray	21	5	26	0.06	144
Torpedo californica	Pacific electric ray	26	-	26	0.06	144
Paralichthys californicus	California halibut	19	6	25	0.05	139
Leptocottus armatus	Pacific staghorn sculpin	20	3	23	0.05	128
Citharichthys stigmaeus	speckled sanddab	14	8	22	0.05	122
Anchoa compressa	deepbody anchovy	6	13	19	0.04	106
Platyrhinoidis triseriata	thornback	16	2	18	0.04	100
Girella nigricans	opaleye	6	11	17	0.04	94
Rhacochilus vacca	pile perch	-	17	17	0.04	94
Anisotremus davidsonii	sargo	-	16	16	0.03	89
Rhacochilus toxotes	rubberlip seaperch	-	16	16	0.03	89
Scomber japonicus	Pacific chub mackerel	-	16	16	0.03	89
Medialuna californiensis	halfmoon	-	12	12	0.03	67
Porichthys notatus	plainfin midshipman	11	1	12	0.03	67
Trachurus symmetricus	jack mackerel	7	2	9	0.02	50
Ophidion scrippsae	basketweave cusk-eel	7	1	8	0.02	44
Ophichthus zophochir	yellow snake eel	6	1	7	0.02	39
Pleuronichthys guttulatus	diamond turbot	5	2	7	0.02	39
Chilara taylori	spotted cusk-eel	-	6	6	0.01	33
Umbrina roncador	yellowfin croaker	-	6	6	0.01	33
Halichoeres semicinctus	rock wrasse	-	4	4	0.01	22
Hypsoblennius gilberti	rockpool blenny	-	3	3	0.01	17
Sebastes auriculatus	brown rockfish	-	3	3	0.01	17
Rhinobatos productus	shovelnose guitarfish	-	2	2	0.00	11
Syngnathus californiensis	kelp pipefish	-	2	2	0.00	11

(Continued)

Table 7-4. (Continued). Annual fish impingement mortality abundance estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Est. Normal Operation Abundance	Heat Treatment Abundance	Total Annual Abundance	Percent of Total	Calc. Baseline Abundance
Triakis semifasciata	leopard shark	-	2	2	0.00	11
Odontopyxis trispinosa	pygmy poacher	-	1	1	0.00	6
Paralabrax maculatofasciatus	spotted sand bass	-	1	1	0.00	6
Sebastes miniatus	vermillion rockfish	-	1	1	0.00	6
Semicossyphus pulcher	California sheephead	-	1	1	0.00	6
Total Abundance		**10,680**	**35,322**	**46,002**	**100.00**	**255,567**
Number of Species		**36**	**55**	**57**		

Table 7-5. Annual fish impingement mortality biomass (kg) estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Est. Normal Operation Biomass	Heat Treatment Biomass	Total Annual Biomass	Percent of Total	Calc. Baseline Biomass
Seriphus politus	queenfish	49.060	542.930	591.990	50.04	3,288.833
Torpedo californica	Pacific electric ray	107.373	-	107.373	9.08	596.517
Genyonemus lineatus	white croaker	3.637	84.683	88.320	7.46	490.667
Cymatogaster aggregata	shiner perch	2.259	45.828	48.087	4.06	267.150
Paralabrax clathratus	kelp bass	-	43.208	43.208	3.65	240.044
Urobatis halleri	round stingray	18.612	20.545	39.157	3.31	217.539
Atherinopsis californiensis	jacksmelt	2.205	25.114	27.319	2.31	151.772
Scorpaena guttata	California scorpionfish	5.416	19.381	24.797	2.10	137.761
Myliobatis californica	bat ray	13.922	6.686	20.608	1.74	114.489
Phanerodon furcatus	white seaperch	0.540	17.101	17.641	1.49	98.006
Platyrhinoidis triseriata	thornback	14.489	1.143	15.632	1.32	86.844
Peprilus simillimus	Pacific pompano	2.005	12.720	14.725	1.24	81.806
Hyperprosopon argenteum	walleye surfperch	0.486	14.035	14.521	1.23	80.672
Engraulis mordax	northern anchovy	4.654	8.596	13.250	1.12	73.611
Girella nigricans	opaleye	3.712	7.708	11.420	0.97	63.444
Paralichthys californicus	California halibut	4.986	5.399	10.385	0.88	57.694
Porichthys myriaster	specklefin midshipman	10.373	0.006	10.379	0.88	57.661
Rhinobatos productus	shovelnose guitarfish	-	10.280	10.280	0.87	57.111
Paralabrax nebulifer	barred sand bass	0.468	8.557	9.025	0.76	50.139
Sardinops sagax	Pacific sardine	4.342	3.674	8.016	0.68	44.533
Cheilotrema saturnum	black croaker	0.226	6.147	6.373	0.54	35.406
Embiotoca jacksoni	black perch	0.882	4.865	5.747	0.49	31.928
Atractoscion nobilis	white seabass	0.113	4.410	4.523	0.38	25.128
Rhacochilus vacca	pile perch	-	4.351	4.351	0.37	24.172
Porichthys notatus	plainfin midshipman	3.791	0.003	3.794	0.32	21.078
Atherinops affinis	topsmelt	-	3.371	3.371	0.28	18.728
Medialuna californiensis	halfmoon	-	3.261	3.261	0.28	18.117
Menticirrhus undulatus	California corbina	-	2.856	2.856	0.24	15.867
Pleuronichthys ritteri	spotted turbot	2.096	0.006	2.102	0.18	11.678
Chromis punctipinnis	blacksmith	0.014	2.062	2.076	0.18	11.533
Umbrina roncador	yellowfin croaker	-	1.779	1.779	0.15	9.883
Heterostichus rostratus	giant kelpfish	1.066	0.651	1.717	0.15	9.539
Roncador stearnsii	spotfin croaker	-	1.625	1.625	0.14	9.028
Ophichthus zophochir	yellow snake eel	1.188	0.184	1.372	0.12	7.622
Anisotremus davidsonii	sargo	-	1.319	1.319	0.11	7.328
Halichoeres semicinctus	rock wrasse	-	1.280	1.280	0.11	7.111
Sebastes auriculatus	brown rockfish	-	1.089	1.089	0.09	6.050
Pleuronichthys guttulatus	diamond turbot	0.708	0.329	1.037	0.09	5.761
Synodus lucioceps	California lizardfish	1.016	-	1.016	0.09	5.644
Leptocottus armatus	Pacific staghorn sculpin	0.870	0.095	0.965	0.08	5.361
Paralabrax maculatofasciatus	spotted sand bass	-	0.828	0.828	0.07	4.600
Triakis semifasciata	leopard shark	-	0.747	0.747	0.06	4.150
Rhacochilus toxotes	rubberlip seaperch	-	0.685	0.685	0.06	3.806
Leuresthes tenuis	California grunion	0.141	0.458	0.599	0.05	3.328
Xenistius californiensis	salema	0.084	0.317	0.401	0.03	2.228
Ophidion scrippsae	basketweave cusk-eel	0.388	0.010	0.398	0.03	2.211
Pleuronichthys verticalis	hornyhead turbot	0.258	0.132	0.390	0.03	2.167
Semicossyphus pulcher	California sheephead	-	0.330	0.330	0.03	1.833
Scomber japonicus	Pacific chub mackerel	-	0.309	0.309	0.03	1.717
Trachurus symmetricus	jack mackerel	0.028	0.233	0.261	0.02	1.450
Anchoa compressa	deepbody anchovy	0.028	0.132	0.160	0.01	0.889
Chilara taylori	spotted cusk-eel	-	0.118	0.118	0.01	0.656

(Continued)

Table 7-5. (Continued). Annual fish impingement mortality biomass (kg) estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Est. Normal Operation Biomass	Heat Treatment Biomass	Total Annual Biomass	Percent of Total	Calc. Baseline Biomass
Citharichthys stigmaeus	speckled sanddab	0.041	0.050	0.091	0.01	0.506
Hypsoblennius gilberti	rockpool blenny	-	0.015	0.015	0.00	0.083
Syngnathus californiensis	kelp pipefish	-	0.006	0.006	0.00	0.033
Odontopyxis trispinosa	pygmy poacher	-	0.005	0.005	0.00	0.028
Sebastes miniatus	vermillion rockfish	-	0.002	0.002	0.00	0.011
Total Biomass (kg)		**261.477**	**921.654**	**1,183.131**	**100.00**	**6,572.951**
Number of Species		**36**	**55**	**57**		

Table 7-6. Annual shellfish impingement mortality abundance estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Est. Normal Operation Abundance	Heat Treatment Abundance	Total Annual Abundance	Percent of Total	Calc. Baseline Abundance
Cancer anthonyi	yellow crab	2,651	139	2,790	35.00	2,790
Cancer gracilis	graceful crab	1,459	10	1,469	18.43	1,469
Cancer antennarius	Pacific rock crab	907	63	970	12.17	970
Pyromaia tuberculata	tuberculate pear crab	611	355	966	12.12	966
Cancer productus	red rock crab	382	23	405	5.08	405
Crangon nigromaculata	blackspotted bay shrimp	383	2	385	4.83	385
Pachygrapsus crassipes	striped shore crab	180	137	317	3.98	317
Lysmata californica	red rock shrimp	48	129	177	2.22	177
Octopus bimaculatus/bimaculoides	two-spot octopus	137	31	168	2.11	168
Panulirus interruptus	California spiny lobster	111	18	129	1.62	129
Portunus xantusii	Xantus swimming crab	51	15	66	0.83	66
Heptacarpus palpator	intertidal coastal shrimp	26	29	55	0.69	55
Pugettia producta	northern kelp crab	25	10	35	0.44	35
Neotrypaea californiensis	bay ghost shrimp	10	-	10	0.13	10
Farfantepenaeus californiensis	yellowleg shrimp	7	-	7	0.09	7
Hemigrapsus oregonensis	yellow shore crab	7	-	7	0.09	7
Loligo opalescens	market squid	6	-	6	0.08	6
Loxorhynchus crispatus	moss crab	6	-	6	0.08	6
Loxorhynchus grandis	sheep crab	-	1	1	0.01	1
Pachycheles pubescens	pubescent porcelain crab	-	1	1	0.01	1
Pachycheles rudis	thick-clawed porcelain crab	-	1	1	0.01	1
Total Abundance		**7,007**	**964**	**7,971**	**100.00**	**7,971**
Number of Species		**18**	**16**	**21**		

Table 7-7. Annual shellfish impingement mortality biomass (kg) estimates at the HBGS based on 2004-5 cooling water flows.

Taxon	Common Name	Est. Normal Operation Biomass	Heat Treatment Biomass	Total Annual Biomass	Percent of Total	Calc. Baseline Biomass
Panulirus interruptus	California spiny lobster	56.065	7.946	64.011	46.91	64.011
Octopus bimaculatus/bimaculoides	two-spot octopus	25.292	2.276	27.568	20.20	27.568
Cancer anthonyi	yellow crab	19.740	1.235	20.975	15.37	20.975
Cancer antennarius	Pacific rock crab	9.253	1.085	10.338	7.58	10.338
Cancer productus	red rock crab	5.433	0.152	5.585	4.09	5.585
Cancer gracilis	graceful crab	2.733	0.073	2.806	2.06	2.806
Pyromaia tuberculata	tuberculate pear crab	1.012	0.351	1.363	1.00	1.363
Pachygrapsus crassipes	striped shore crab	0.345	0.369	0.714	0.52	0.714
Loxorhynchus grandis	sheep crab	-	0.604	0.604	0.44	0.604
Crangon nigromaculata	blackspotted bay shrimp	0.593	0.004	0.597	0.44	0.597
Loligo opalescens	market squid	0.384	-	0.384	0.28	0.384
Portunus xantusii	Xantus swimming crab	0.331	0.051	0.382	0.28	0.382
Pugettia producta	northern kelp crab	0.101	0.183	0.284	0.21	0.284
Lysmata californica	red rock shrimp	0.100	0.178	0.278	0.20	0.278
Farfantepenaeus californiensis	yellowleg shrimp	0.236	-	0.236	0.17	0.236
Loxorhynchus crispatus	moss crab	0.186	-	0.186	0.14	0.186
Heptacarpus palpator	intertidal coastal shrimp	0.063	0.017	0.080	0.06	0.080
Neotrypaea californiensis	bay ghost shrimp	0.045	-	0.045	0.03	0.045
Hemigrapsus oregonensis	yellow shore crab	0.007	-	0.007	0.01	0.007
Pachycheles pubescens	pubescent porcelain crab	-	0.001	0.001	0.00	0.001
Pachycheles rudis	thick-clawed porcelain crab	-	0.001	0.001	0.00	0.001
Total Biomass (kg)		**121.919**	**14.526**	**136.445**	**100.00**	**136.445**
Number of Species		**18**	**16**	**21**		

Table 7-8. Annual fish impingement mortality abundance estimates at the HBGS based on design (maximum) cooling water flow.

Taxon	Common Name	Est. Normal Operation Abundance	Heat Treatment Abundance	Total Annual Abundance	Percent of Total	Calc. Baseline Abundance
Seriphus politus	queenfish	13,111	33,786	46,897	69.80	260,539
Genyonemus lineatus	white croaker	408	6,163	6,571	9.78	36,506
Cymatogaster aggregata	shiner perch	269	5,099	5,368	7.99	29,822
Engraulis mordax	northern anchovy	987	1,822	2,809	4.18	15,606
Phanerodon furcatus	white seaperch	120	1,051	1,171	1.74	6,506
Peprilus simillimus	Pacific pompano	173	625	798	1.19	4,433
Hyperprosopon argenteum	walleye surfperch	39	593	632	0.94	3,511
Atherinopsis californiensis	jacksmelt	30	411	441	0.66	2,450
Atherinops affinis	topsmelt	-	308	308	0.46	1,711
Paralabrax clathratus	kelp bass	-	184	184	0.27	1,022
Leuresthes tenuis	California grunion	58	122	180	0.27	1,000
Porichthys myriaster	specklefin midshipman	161	1	162	0.24	900
Sardinops sagax	Pacific sardine	102	51	153	0.23	850
Urobatis halleri	round stingray	88	64	152	0.23	844
Scorpaena guttata	California scorpionfish	44	100	144	0.21	800
Embiotoca jacksoni	black perch	19	72	91	0.14	506
Paralabrax nebulifer	barred sand bass	14	74	88	0.13	489
Cheilotrema saturnum	black croaker	26	58	84	0.13	467
Atractoscion nobilis	white seabass	14	65	79	0.12	439
Roncador stearnsii	spotfin croaker	-	65	65	0.10	361
Chromis punctipinnis	blacksmith	11	52	63	0.09	350
Xenistius californiensis	salema	14	46	60	0.09	333
Pleuronichthys ritteri	spotted turbot	47	6	53	0.08	294
Heterostichus rostratus	giant kelpfish	36	12	48	0.07	267
Menticirrhus undulatus	California corbina	-	43	43	0.06	239
Torpedo californica	Pacific electric ray	40	-	40	0.06	222
Synodus lucioceps	California lizardfish	37	-	37	0.06	206
Pleuronichthys verticalis	hornyhead turbot	34	1	35	0.05	194
Myliobatis californica	bat ray	27	7	34	0.05	189
Citharichthys stigmaeus	speckled sanddab	22	12	34	0.05	189
Leptocottus armatus	Pacific staghorn sculpin	25	4	29	0.04	161
Paralichthys californicus	California halibut	19	9	28	0.04	156
Anchoa compressa	deepbody anchovy	8	19	27	0.04	150
Girella nigricans	opaleye	11	16	27	0.04	150
Rhacochilus vacca	pile perch	-	25	25	0.04	139
Platyrhinoidis triseriata	thornback	21	3	24	0.04	133
Scomber japonicus	Pacific chub mackerel	-	23	23	0.03	128
Rhacochilus toxotes	rubberlip seaperch	-	23	23	0.03	128
Anisotremus davidsonii	sargo	-	23	23	0.03	128
Porichthys notatus	plainfin midshipman	19	1	20	0.03	111
Medialuna californiensis	halfmoon	-	17	17	0.03	94
Ophidion scrippsae	basketweave cusk-eel	14	1	15	0.02	83
Trachurus symmetricus	jack mackerel	11	3	14	0.02	78
Pleuronichthys guttulatus	diamond turbot	7	3	10	0.01	56
Ophichthus zophochir	yellow snake eel	9	1	10	0.01	56
Chilara taylori	spotted cusk-eel	-	9	9	0.01	50
Umbrina roncador	yellowfin croaker	-	9	9	0.01	50
Halichoeres semicinctus	rock wrasse	-	6	6	0.01	33
Sebastes auriculatus	brown rockfish	-	4	4	0.01	22
Hypsoblennius gilberti	rockpool blenny	-	4	4	0.01	22
Syngnathus californiensis	kelp pipefish	-	3	3	0.00	17
Triakis semifasciata	leopard shark	-	3	3	0.00	17

(Continued)

Table 7-8. (Continued). Annual fish impingement mortality abundance estimates at the HBGS based on design (maximum) cooling water flow.

Taxon	Common Name	Est. Normal Operation Abundance	Heat Treatment Abundance	Total Annual Abundance	Percent of Total	Calc. Baseline Abundance
Rhinobatos productus	shovelnose guitarfish	-	3	3	0.00	17
Semicossyphus pulcher	California sheephead	-	1	1	0.00	6
Odontopyxis trispinosa	pygmy poacher	-	1	1	0.00	6
Paralabrax maculatofasciatus	spotted sand bass	-	1	1	0.00	6
Sebastes miniatus	vermillion rockfish	-	1	1	0.00	6
Total Abundance		**16,075**	**51,109**	**67,184**	**100.00**	**373,248**
Number of Species		**36**	**55**	**57**		

Table 7-9. Annual fish impingement mortality biomass (kg) estimates at the HBGS based on design (maximum) cooling water flow.

Taxon	Common Name	Est. Normal Operation Biomass	Heat Treatment Biomass	Total Annual Biomass	Percent of Total	Calc. Baseline Biomass
Seriphus politus	queenfish	73.916	785.619	859.535	50.02	4,775.194
Torpedo californica	Pacific electric ray	162.476	-	162.476	9.46	902.644
Genyonemus lineatus	white croaker	4.734	122.537	127.271	7.41	707.061
Cymatogaster aggregata	shiner perch	2.554	66.313	68.867	4.01	382.594
Paralabrax clathratus	kelp bass	3.145	62.522	65.667	3.82	364.817
Urobatis halleri	round stingray	29.118	29.728	58.846	3.42	326.922
Atherinopsis californiensis	jacksmelt	0.045	36.340	36.385	2.12	202.139
Scorpaena guttata	California scorpionfish	7.216	28.044	35.260	2.05	195.889
Myliobatis californica	bat ray	16.485	9.674	26.159	1.52	145.328
Phanerodon furcatus	white seaperch	0.653	24.745	25.398	1.48	141.100
Peprilus simillimus	Pacific pompano	2.801	18.406	21.207	1.23	117.817
Hyperprosopon argenteum	walleye surfperch	0.638	20.308	20.946	1.22	116.367
Platyrhinoidis triseriata	thornback	19.232	1.653	20.885	1.22	116.028
Girella nigricans	opaleye	6.440	11.153	17.593	1.02	97.739
Porichthys myriaster	specklefin midshipman	16.066	0.008	16.074	0.94	89.300
Rhinobatos productus	shovelnose guitarfish	-	14.875	14.875	0.87	82.639
Paralabrax nebulifer	barred sand bass	0.728	12.382	13.110	0.76	72.833
Paralichthys californicus	California halibut	5.091	7.812	12.903	0.75	71.683
Engraulis mordax	northern anchovy	-	12.438	12.438	0.72	69.100
Sardinops sagax	Pacific sardine	5.126	5.317	10.443	0.61	58.017
Embiotoca jacksoni	black perch	2.996	7.040	10.036	0.58	55.756
Cheilotrema saturnum	black croaker	0.476	8.895	9.371	0.55	52.061
Scomber japonicus	Pacific chub mackerel	6.299	0.447	6.746	0.39	37.478
Atractoscion nobilis	white seabass	0.168	6.381	6.549	0.38	36.383
Porichthys notatus	plainfin midshipman	6.533	0.004	6.537	0.38	36.317
Medialuna californiensis	halfmoon	1.649	4.719	6.368	0.37	35.378
Rhacochilus vacca	pile perch	-	6.295	6.295	0.37	34.972
Atherinops affinis	topsmelt	-	4.878	4.878	0.28	27.100
Menticirrhus undulatus	California corbina	-	4.132	4.132	0.24	22.956
Chromis punctipinnis	blacksmith	0.022	2.983	3.005	0.17	16.694
Pleuronichthys ritteri	spotted turbot	2.841	0.009	2.850	0.17	15.833
Umbrina roncador	yellowfin croaker	-	2.575	2.575	0.15	14.306
Roncador stearnsii	spotfin croaker	-	2.351	2.351	0.14	13.061
Ophichthus zophochir	yellow snake eel	2.016	0.266	2.282	0.13	12.678
Heterostichus rostratus	giant kelpfish	1.057	0.943	2.000	0.12	11.111
Anisotremus davidsonii	sargo	-	1.909	1.909	0.11	10.606
Halichoeres semicinctus	rock wrasse	-	1.852	1.852	0.11	10.289
Sebastes auriculatus	brown rockfish	-	1.576	1.576	0.09	8.756
Leptocottus armatus	Pacific staghorn sculpin	1.357	0.137	1.494	0.09	8.300
Synodus lucioceps	California lizardfish	1.288	-	1.288	0.07	7.156
Paralabrax maculatofasciatus	spotted sand bass	-	1.198	1.198	0.07	6.656
Triakis semifasciata	leopard shark	-	1.081	1.081	0.06	6.006
Rhacochilus toxotes	rubberlip seaperch	-	0.992	0.992	0.06	5.511
Leuresthes tenuis	California grunion	0.259	0.663	0.922	0.05	5.122
Ophidion scrippsae	basketweave cusk-eel	0.756	0.015	0.771	0.04	4.283
Trachurus symmetricus	jack mackerel	0.339	0.337	0.676	0.04	3.756
Xenistius californiensis	salema	0.126	0.459	0.585	0.03	3.250
Pleuronichthys guttulatus	diamond turbot	0.042	0.477	0.519	0.03	2.883
Semicossyphus pulcher	California sheephead	-	0.478	0.478	0.03	2.656
Anchoa compressa	deepbody anchovy	-	0.192	0.192	0.01	1.067
Pleuronichthys verticalis	hornyhead turbot	-	0.192	0.192	0.01	1.067
Chilara taylori	spotted cusk-eel	-	0.170	0.170	0.01	0.944

(Continued)

Table 7-9. (Continued). Annual fish impingement mortality biomass (kg) estimates at the HBGS based on design (maximum) cooling water flow.

Taxon	Common Name	Est. Normal Operation Biomass	Heat Treatment Biomass	Total Annual Biomass	Percent of Total	Calc. Baseline Biomass
Citharichthys stigmaeus	speckled sanddab	0.068	0.072	0.140	0.01	0.778
Hypsoblennius gilberti	rockpool blenny	-	0.021	0.021	0.00	0.117
Syngnathus californiensis	kelp pipefish	-	0.009	0.009	0.00	0.050
Odontopyxis trispinosa	pygmy poacher	-	0.007	0.007	0.00	0.039
Sebastes miniatus	vermillion rockfish	-	0.003	0.003	0.00	0.017
Total Biomass (kg)		**384.756**	**1,333.632**	**1,718.388**	**100.00**	**9,546.604**
Number of Species		**36**	**55**	**57**		

Table 7-10. Annual shellfish impingement mortality abundance estimates at the HBGS based on design (maximum) cooling water flow.

Taxon	Common Name	Est. Normal Operation Abundance	Heat Treatment Abundance	Total Annual Abundance	Percent of Total	Calc. Baseline Abundance
Cancer anthonyi	yellow crab	4,026	201	4,227	38.83	4,227
Cancer gracilis	graceful crab	1,622	14	1,636	15.03	1,636
Pyromaia tuberculata	tuberculate pear crab	758	514	1,272	11.68	1,272
Cancer antennarius	Pacific rock crab	1,137	91	1,228	11.28	1,228
Cancer productus	red rock crab	586	33	619	5.69	619
Crangon nigromaculata	blackspotted bay shrimp	548	3	551	5.06	551
Pachygrapsus crassipes	striped shore crab	238	198	436	4.01	436
Lysmata californica	red rock shrimp	61	187	248	2.28	248
Octopus bimaculatus/bimaculoides	two-spot octopus	175	45	220	2.02	220
Panulirus interruptus	California spiny lobster	138	26	164	1.51	164
Portunus xantusii	Xantus swimming crab	75	22	97	0.89	97
Heptacarpus palpator	intertidal coastal shrimp	40	42	82	0.75	82
Pugettia producta	northern kelp crab	40	14	54	0.50	54
Neotrypaea californiensis	bay ghost shrimp	14	-	14	0.13	14
Loligo opalescens	market squid	11	-	11	0.10	11
Loxorhynchus crispatus	moss crab	9	-	9	0.08	9
Hemigrapsus oregonensis	yellow shore crab	8	-	8	0.07	8
Farfantepenaeus californiensis	yellowleg shrimp	7	-	7	0.06	7
Loxorhynchus grandis	sheep crab	-	1	1	0.01	1
Pachycheles pubescens	pubescent porcelain crab	-	1	1	0.01	1
Pachycheles rudis	thick-clawed porcelain crab	-	1	1	0.01	1
Total Abundance		**9,493**	**1,393**	**10,886**	**100.00**	**10,886**
Number of Species		**18**	**16**	**21**		

Table 7-11. Annual shellfish impingement mortality biomass (kg) estimates at the HBGS based on design (maximum) cooling water flow.

Taxon	Common Name	Est. Normal Operation Biomass	Heat Treatment Biomass	Total Annual Biomass	Percent of Total	Calc. Baseline Biomass
Panulirus interruptus	California spiny lobster	69.285	11.498	80.783	43.71	80.783
Octopus bimaculatus/bimaculoides	two-spot octopus	34.623	3.293	37.916	20.52	37.916
Cancer anthonyi	yellow crab	29.765	1.787	31.552	17.07	31.552
Cancer antennarius	Pacific rock crab	13.347	1.570	14.917	8.07	14.917
Cancer productus	red rock crab	8.470	0.220	8.690	4.70	8.690
Cancer gracilis	graceful crab	3.466	0.105	3.571	1.93	3.571
Pyromaia tuberculata	tuberculate pear crab	1.390	0.509	1.899	1.03	1.899
Pachygrapsus crassipes	striped shore crab	0.474	0.534	1.008	0.55	1.008
Loxorhynchus grandis	sheep crab	-	0.875	0.875	0.47	0.875
Crangon nigromaculata	blackspotted bay shrimp	0.839	0.005	0.844	0.46	0.844
Loligo opalescens	market squid	0.652	-	0.652	0.35	0.652
Portunus xantusii	Xantus swimming crab	0.480	0.073	0.553	0.30	0.553
Pugettia producta	northern kelp crab	0.160	0.265	0.425	0.23	0.425
Lysmata californica	red rock shrimp	0.126	0.258	0.384	0.21	0.384
Loxorhynchus crispatus	moss crab	0.289	-	0.289	0.16	0.289
Farfantepenaeus californiensis	yellowleg shrimp	0.252	-	0.252	0.14	0.252
Heptacarpus palpator	intertidal coastal shrimp	0.101	0.024	0.125	0.07	0.125
Neotrypaea californiensis	bay ghost shrimp	0.063	-	0.063	0.03	0.063
Hemigrapsus oregonensis	yellow shore crab	0.008	-	0.008	0.00	0.008
Pachycheles pubescens	pubescent porcelain crab	-	0.001	0.001	0.00	0.001
Pachycheles rudis	thick-clawed porcelain crab	-	0.001	0.001	0.00	0.001
Total Biomass (kg)		**163.790**	**21.018**	**184.808**	**100.00**	**184.808**
Number of Species		**18**	**16**	**21**		

8.0 LITERATURE CITED

AES Huntington Beach L.L.C. and URS. 2000. Application for Certification: AES Huntington Beach Generating Station Retool Project. Prepared for the California Energy Commission. Dec. 2000.

AES. See AES Huntington Beach L.L.C.

Ahlstrom, E.H. and H.G. Moser.1975. Distributional atlas of fish larvae in the California Current region: flatfishes, 1955 through 1960. CalCOFI Atlas No. 23. 207 p.

Ahlstrom, E.H., K. Amaoka, D.A. Hensley, H.G. Moser, and B.Y. Sumida. 1984. Pleuronectiformes: development. Pages 640–670 *in* H.G. Moser, W.J. Richards, D.M. Cohen, M.P. Fahay, A.W. Kendall, Jr., and S.L. Richardson, eds. Ontogeny and systematics of fishes. Amer. Soc. Ichthyol. and Herpetol., Spec. Publ. No. 1. 760 p.

Allen, L.G. 1985. A habitat analysis of the nearshore marine fishes from southern California. Bull. So. Calif. Acad. Sci 84:133-155.

Allen, L.G. and E.E. DeMartini. 1983. Temporal and spatial patterns of nearshore distribution and abundance of the pelagic fishes off San Onofre-Oceanside, CA. Fish. Bull. U.S. 81(3):569-586.

Allen, M.J. 1982. Functional structure of soft-bottom fish communities of the southern California shelf. Ph.D. dissertation, Univ. Calif., San Diego, La Jolla, CA. 577 p.

Allen, M.J., A.K. Groce, D. Diener, J. Brown, A. Steinert, G. Deets, J.A. Noblet, S.L. Moore, D. Diehl, E.T. Jarvis, V. Raco-Rands, C. Thomas, Y. Ralph, R. Gartman, D. Cadien, S.B. Weisberg, and T. Mikel. 2002. Southern California Bight 1998 Regional Monitoring Program: V. Demersal fishes and megabenthic invertebrates. So. Calif. Coast. Wat. Res. Proj., Westminster, CA. 272 p. plus appendices.

Allen, M.J., R.W. Smith, E.T. Jarvis, V. Raco-Rands, B. Bernstein, and K. Herbinson. 2003. Temporal trends in southern California nearshore fish populations relative to environmental influences. Paper presented at the So. Calif. Acad. Sci., California State University Northridge, 9 May 2003.

Allen, M.J., S.L. Moore, K.C. Schiff, S.B. Weisberg, D. Diener, J.K. Stull, A. Groce, J. Mubarak, C.L. Tang, and R. Gartman. 1998. Southern California Bight 1994 Pilot Project: V. Demersal fishes and megabenthic invertebrates. So. Calif. Coast. Wat. Res. Proj., Westminster, CA. 324 p.

Allen, M.J., R.W. Smith, E.T. Jarvis, V. Raco-Rands, B.B. Bernstein, and K.T. Herbinson. 2004. Temporal trends in southern California coastal fish populations relative to 30-year trends in oceanic conditions. Pp. 264-285 *in*: So. Calif. Coast. Water Res. Proj. Annual Report: 2003-2004. So. Calif. Coast. Water Res. Proj., Westminster, CA.

Ally, J. R. R. 1975. A description of the laboratory-reared larvae of *Cancer gracilis* Dana, 1852 (Decapoda, Brachyura). Crustaceana 23:231-246.

Ambrose, R.F. 1981. Observations on the embryonic development and early post-embryonic development of *Octopus bimaculatus*. Veliger 24:139-146.

Anderson, W.R. and R.F. Ford. 1976. Early development, growth and survival of the yellow crab *Cancer anthonyi* Rathbun (Decapoda, Brachyura) in the laboratory. Aquaculture, 7: 276-279.

Anderson, S.L., L.W. Botsford, and W.H. Clark. 1985b. Size distributions and sex ratios of ridgeback prawns (*Sicyonia ingentis*) in the Santa Barbara Channel (1979-1981). CalCOFI Rep. 26:169-174.

Anderson, S.L., W.H. Clark, and E.S. Chang. 1985a. Multiple spawning and molt synchrony in a free spawning shrimp (*Sicyonia ingentis*: Penaeoidea). Biol. Bull. 168:377-394.

Bane, G.W. and M. Robinson. 1970. Studies on the shiner perch, *Cymatogaster aggregata* Gibbons, in upper Newport Bay, California. Wassmann J. Biol. 28(2):259-268.

Barlow, G.W. 1963. Species structure of the Gobiid fish Gillichthys mirabilis from coastal sloughs of the Eastern Pacific. Pac. Sci., 17:47-72.

Barnes, N.B. and A.M. Wenner. 1968. Seasonal variation in the sand crab *Emerita analoga* (Decapoda, Hippidae) in the Santa Barbara area of California. Ecol. 49:465-475.

Barnett, A.M., A.E. Jahn, P.D. Sertic, and W. Watson. 1983. Distribution of ichthyoplankton off San Onofre, California, and methods for sampling very shallow coastal waters. Fish. Bull. U.S. 82(1):97-111.

Barnthouse, L. 2004. Consultant to the Atlantic States Marine Fisheries Commission. Telephone conversation with S. Beck, 24 September 2004.

Barsky, K.C. 2001. California spiny lobster. Pp. 98-100 in: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds). California's living marine resources: A status report. Calif. Dept. of Fish and Game. 592 p.

Bechtel Incorporated. 1971. Report on fish pumps. Prepared by the Hydro and Community Facilities Division, San Francisco, CA. 12 p. plus figures.

Beck, D.S. and K.T. Herbinson. 2003. Declines in abundance of three nearshore surfperches off Huntington Beach, California, 1971–2001. So. Calif. Acad. Sci., California State University Northridge, 9 May 2003.

Behrens, D.W. 1991. Pacific coast nudibranchs: A guide to the opistobranchs, Alaska to Baja California. Sea Challengers, Monterey, California. 107 p.

Bergen, D.R. and L.D. Jacobsen. 2001. Northern anchovy. Pp. 303-305 in: W.S. Leet, C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.), California's living marine resources: A status report. Calif. Dept. Fish and Game. 592 p.

Blake, J.A. and P.H. Scott. 1997. Taxonomic atlas of the benthic fauna of the Santa Maria Basin and Western Santa Barbara Channel. Vol. 10. The Arthropoda – The Pycnogonida – The Crustacea Part 1 – The Decapoda and Mysidacea. Santa Barbara Museum of Natural History. 151 p.

Boehm, A.B., B.F. Sanders, and C.D. Winant. 2002. Cross-shelf transport at Huntington Beach. Implications for the fate of sewage discharged through an offshore ocean outfall. Envir. Sci. Tech. 36:1899-1906.

Brewer, G. 1974. Thermal tolerance and sediment toxicity studies. Pp. 21-43 in: D.F. Soule and M. Oguri (eds.), Part 3, Marine studies of San Pedro Bay, California. Allan Hancock Found., Univ. So. Calif., Los Angeles, CA. 86 p.

Brewer, G.D. 1978. Reproduction and spawning of northern anchovy, *Engraulis mordax*, in San Pedro Bay, CA. Calif. Fish. Game 64(3):175-184.

Brooks, A.J., R.J. Schmitt, and S.J. Holbrook. 2002. Declines in regional fish populations: have species responded similarly to environmental change? Mar. Freshwater Res. 53:189-198.

Brothers, E.B. 1975. The comparative ecology and behavior of three sympatric California gobies. Ph.D. Dissertation, Univ. Calif., San Diego. 370 p.

Butler, J.L., P. E. Smith, and N.C.H. Lo. 1993. The effect of natural variability of life-history parameters on anchovy and sardine population growth. CalCOFI Rep. 34:104-111.

Butler, J., D. Fuller, and M. Yaremko. 1999. Age and growth of market squid (*Loligo opalescens*) off California during 1998. CalCOFI Rep. 40:191-195.

Caddell, S.M., D.M. Gadomski, and L.R. Abbott. 1990. Induced spawning of the California halibut, *Paralichthys californicus*, under artificial and natural conditions. California Department of Fish and Game, Fish Bulletin 174:175-197.

Cailliet, G.M., K.A. Karpov, and D.A. Ambrose. 1979. Pelagic assemblages as determined from purse seine and large midwater trawl catches in Monterey Bay and their affinities with the market squid, *Loligo opalescens*. CalCOFI Rep. 20:21-30.

California Coastal Commission. 2000. Executive Director's determination that fish behavioral barriers tested at SONGS are ineffective. Staff Report TH-15. Sep. 2000.

California Department of Fish and Game. 1999. Review of some fisheries for 1998: Pacific sardine, Pacific mackerel, Pacific herring, market squid, sea urchin, groundfishes, swordfish, sharks, nearshore finfishes, abalone, Dungeness crab, prawn, ocean salmon, white seabass, and recreational. CalCOFI Rep. 40:9-24.

California Department of Fish and Game. 2002. Catch Block data.

California Department of Fish and Game. 2004. Catch Block data.

California Energy Commission. 2001. Staff Assessment: AES Huntington Beach Generating Station Retool Project. Application for Certification 00-AFC-13. Orange County. March 2001.

Carroll, J.C. 1982. Seasonal abundance, size composition, and growth of rock crab, *Cancer antennarius*, off central California. J. Crustacean Biol. 2(4):549-561.

Carroll, J.C., and R.N. Winn. 1989. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Pacific Southwest): brown rock crab, red rock crab, and yellow crab. U.S. Fish and Wildlife Service, Biology Report 82(11.117). 16 p.

CCC. See California Coastal Commission.

CDFG. See California Department of Fish and Game.

CEC. See California Energy Commission.

Clark, G.H. 1930. California halibut. Calif. Fish and Game 16:315–317.

Clark, F.N. and J.B. Phillips. 1952. The northern anchovy (*Engraulis mordax*) in the California fishery. Calif. Dept. Fish and Game No. 38(2):189-208.

Cox, G.W. and G.H. Dudley. 1968. Seasonal pattern of reproduction of the sand crab, *Emerita analoga*, in southern California. Ecol. 49(4):746-751.

Cross, J. 1984. The Newport dory fishery. Pp. 69-80 in: Southern California Coastal Water Research Project Biennial Report, 1983-1984. So. Calif. Coast. Wat. Res. Proj., Westminster, CA. 332 p.

Daugherty, A.E., F.E. Felin, and J. MacGregor. 1955. Age and length composition of the northern anchovy catch off the coast of California in 1952–53 and 1953–54. California Department of Fish and Game Fishery Bulletin 101:36-66.

Dawson, M.N., K.D. Louie, M. Barlow, D.K. Jacobs, and C.C. Swift. 2002 Comparative phylogeography of sympatric sister species, *Clevlandia ios* and *Eucyclogobius newberryi* (Teleostei, Gobiidae), across the California Transition Zone. Molecular Ecol. 11:1065-1075.

DeMartini, E.E. and R.K. Fountain. 1981. Ovarian cycling frequency and batch fecundity in the queenfish, *Seriphus politus*: attributes representative of serial spawning fishes. Fish. Bull. U.S. 79(3):547-560.

Dillery, D.G. and L.V. Knapp. 1970. Longshore movement of the sand crab, *Emerita analoga* (Decapoda, Hippidae). Crustaceana 18:233-240.

Dorn, P., L. Johnson, and C. Darby. 1979. The swimming performance of nine species of common California inshore fishes. Trans. Amer. Fish. Soc. 108(4):366-372.

Dotson, R.C. and R.L. Charter. 2003. Trends in the southern California sport fishery. CalCOFI Rep. 44:94-106.

Downs, D.I. and K.R. Meddock. 1974. Engineering application of fish behavior studies in the design of intake systems for coastal generating stations. Presented at Amer. Soc. Civil Eng. Nat. Water Res. Conf., Los Angeles, CA. Jan. 21-25, 1974. 30 p.

Dudley, G.H. 1967. Population dynamics of the sand crab *Emerita analoga* (Stimpson) (Decapoda, Anomura). M.S. Thesis, San Diego State College. Aug. 1967. 115 p.

Dugan, D. Tenera Environmental. Personal communication with J. Carroll.

Dugan, J.E., A.M. Wenner and D.M. Hubbard. 1991. Geographic variation in the reproductive biology of the sand crab *Emerita analoga* (Stimpson) on the California coast. J. Exp. Mar. Biol. Ecol., 150:63-81.

Efford, I.E. 1969. Egg size in the sand crab, *Emerita analoga* (Decapoda, Hippidae). Crustaceana 16(2):15-26.

Efford, I.E. 1970. Recruitment to sedentary marine populations as exemplified by the sand crab, *Emerita analoga* (Decapoda, Hippidae). Crustaceana 18:293-308.

Eldridge, M.B. 1975. Early larvae of the diamond turbot, *Hypsopsetta guttulata*. Calif. Fish and Game 61:26-34.

Emmett, R.L., S.L. Stone, S.A. Hinton, and M.E. Monaco. 1991. Distribution and abundance of fishes and invertebrates in west coast estuaries, Vol. II. Species life history summaries. ELMR Rep. No. 8. NOAA/NOS Strategic Environmental Assessments Division, Rockville, MD. 329 p.

Environmental Quality Analysts, Inc. and Marine Biological Consultants, Inc. 1973. Huntington Beach Generating Station Thermal Effect Study. Final Summary Report. Prepared for Southern California Edison Company. Sept. 1973.

EPA. See U.S. Environmental Protection Agency.

EQA/MBC. See Environmental Quality Analysts, Inc. and Marine Biological Consultants, Inc.

Eschmeyer, W.N., E.S. Herald, and H. Hammann. 1983. A field guide to Pacific Coast fishes of North America. Houghton-Mifflin Co., Boston, MA. 336 p.

Feder, H.M., C.H. Turner, and C. Limbaugh.1974. Observations on fishes associated with kelp beds in southern California. Calif. Dept. Fish and Game, Fish Bull. 160. 138 p.

FES. See Fish Encounter Studies (Occidental College).

Fields, W.G. 1965. The structure, development, food relations, reproduction, and life history of the squid *Loligo opalescens* Berry. Calif. Dept. of Fish and Game. Fish Bull. 131.

Fish Encounter Studies (Occidental College), Fisheries Research Institute (Univ. Wash.), and Applied Physics Laboratory (Univ. Wash.). 1980. Southern California Edison fish entrapment study. 1979 summary report. March 1980.

Fitch, J.E. and R.J. Lavenberg.1971. Tidepool and nearshore fishes of California. Univ. Calif. Press, Berkeley, CA. 156 p.

Fitch, J.E. and R.J. Lavenberg.1975. Marine food and game fishes of California. Univ. Calif. Press, Berkeley, CA. 179 p.

Forsythe, J., N. Kangas, and R.T. Hanlon. 2004. Does the California market squid (Loligo opalescens) spawn naturally during the day or at night? A note on the successful use of ROVs to obtain basic fisheries biology data. Fish. Bull. U.S. 102(2):389-392.

Frey, H.W. (ed.). 1971. California's living marine resources and their utilization. Calif. Dept. Fish and Game. 148 p.

Fritzche, R.A. and P. Collier. 2001. Surfperches. Pp. 236-240 in: California's living marine resources: A status report. Calif. Dept. Fish and Game.

Fusaro, C. 1978. Growth rate of the sand crab, *Emerita analoga*, (Hippidae) in two different environments. Fish. Bull. U.S. 76(2):369-375.

Fusaro, C. 1980a. Temperature and egg production by the sand crab, *Emerita analoga* (Stimpson) (Decapoda, Hippidae). Crustaceana 38(1):55-60.

Fusaro, C. 1980b. Diel distribution differences in the sand crab, *Emerita analoga* (Stimpson) Decapoda, Hippidae). Crustaceana 39(3):287-300.

Gadomski, D.M., S.M. Caddell, L.R. Abbot, and T.C. Caro. 1990. Growth and development of larval and juvenile California halibut *Paralichthys californicus*, reared in the laboratory. California Department of Fish and Game, Fish Bulletin 174:85-98.

Garrison, K.J. and B.S. Miller. 1982. Review of the early life history of Puget Sound fishes. Fish. Res. Inst., Univ. Wash., Seattle, WA. FRI-UW-8216. 729 p.

Goldberg, S.R. 1981. Seasonal spawning cycle of the black croaker, *Cheilotrema saturnum* (Sciaenidae). Fish Bull 79(3): 561-562Quast, J. C. 1968. Estimates of the populations and the standing crop of fishes. In: W. J. North and C. L. Hubbs (eds.) Utilization of Kelp-Bed Resources in Southern California. Calif. Fish Game. Fish Bulletin 139. 264pp.

Goldberg, S.R. 1976. Seasonal spawning cycles of the sciaenid fishes *Genyonemus lineatus* and *Seriphus politus*. Fish. Bull. U.S. 74(4):983-984.

Goodyear, C.P. 1978. Entrainment impact estimates using the equivalent adult approach. U.S. Fish and Wildlife Ser., FWS/OBS-78/65. Ann Arbor, MI.

Gorman, G.C., L.W. Murray, and G.V. Leipzig. 1990. Talbert Marsh Restoration Project, Monitoring Report #1, Pre-Restoration to Spring, 1990. Huntington Beach Wetlands Conservancy. 24 p.

Graham, J.W., J.N. Stock, and P.H. Benson. 1977. Further studies on the use of heat treatment to control biofouling in seawater cooling systems. Oceans '77:23A1-6.

Graham, W.M. 1989. The influence of hydrography on the larval dynamics and recruitment of five *Cancer* crab species in northern Monterey Bay. M.S. Thesis, University of California, Santa Cruz. 170 p.

Grant, S.B., C. Webb, B.F. Sanders, A. Boehm, J.H. Kim, J.A. Redman, A.K. Chu, R. Morse, S. Jiang, N. Gardiner, and A. Brown. 2000. Huntington Beach Water Quality Investigation Phase II: An analysis of ocean, surf zone, watershed, sediment, and groundwater data collected from June 1998 through September 2000. Final Report. Dec. 15, 2000. Prepared for the Nat. Water Res. Inst., County of Orange, Orange County San. Dist., and Cities of Hunt. Beach, Fountain Valley, Costa Mesa, Santa Ana, and Newport Beach.

Gregory, P.A. 2001. Silversides. Pp. 243-245 in: W.S. Leet, C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.), California's living marine resources: A status report. Calif. Dept. Fish and Game. 592 p.

Gutierrez, A.T. 2003. Successful reintroduction of a tidewater goby (*Eucyclogobius newberryi*) population at San Mateo Lagoon, USMC Camp J. Pendleton, California. Southern California Academy of Sciences, California State University Northridge, 9 May 2003.

Haaker, P.L.1975. The biology of the California halibut, *Paralichthys californicus* (Ayres), in Anaheim Bay, California. Pages 137–151 *in* E.D. Lane and C.W. Hill, eds. The marine resources of Anaheim Bay. Calif. Dept. Fish and Game, Fish Bull. 165.

Hart, J.L. 1973. Pacific fishes of Canada. Fish. Res. Board Can., Bull. 180. 740 p.

Haugen, C. W. (ed.) 1990. The California Halibut, *Paralichthys californicus*, Resource and Fisheries. State of California Resources Agency, Department of Fish and Game, Fish Bulletin 174. 475 pp.

Hays, S., R. Nason, and J.R. Skalski. 1995. Effects of an acoustic behavioral barrier on juvenile salmonid entrainment at an irrigation canal intake on the Wenatchee River at Dryden Dam, Washington. Prepared for Sonalysts, Inc. by Mid-Columbia Consulting, Inc. and Skalski Statistical Services. Sep. 1995. 44 p.

Helvey, M. 1985. Behavioral factors influencing fish entrapment at offshore cooling-water intake structures in southern California. Mar. Fish. Rev. 47(1):18-26.

Herbinson, K.T., M.J. Allen, and S.L. Moore. 2001. Historical trends in nearshore croaker (Family Sciaenidae) populations in southern California from 1977 through 1998. pp. 253-264 *in* S. B. Weisberg and D. Hallock (eds.), Southern California Coastal Water Research Project Annual Report 1999-2000, So. Calif. Coast. Wat. Res. Proj., Westminster, CA.

Herbinson, K.T. 1981. 316(b) fish impingement inventory. So.Calif. Edison Co. 87-RD-9. Apr. 1981. 221 p.

Herbinson, K.T. and M. Larson. 2001. Sand crab. Pp. 138-139 in: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds). California's living marine resources: A status report. Calif. Dept. of Fish and Game. 592 p.

Hickey, B.M., E.L. Dobbins, and S.E. Allen. 2003. Local and remote forcing of currents and temperature in the central Southern California Bight. J. Geophys. Res. 108(C3): art. no. 3081.

Hines, A.H. 1991. Fecundity and reproductive output in nine species of *Cancer* crabs (Crustacea, Brachyura, Cancridae). Canadian Journal of Fisheries and Aquatic Sciences. 48:267-275.

Hobson, E.S. and J.R. Chess. 1976. Trophic interactions among fishes and zooplankters near shore at Santa Catalina Island, California. Fish. Bull. U.S. 74(3):567-598.

Hobson, E. S., W. N. McFarland, and J. R. Chess. 1981. Crepuscular and nocturnal activities of Californian nearshore fishes, with consideration of their scotopic visual pigments and the photic environment. Fish. Bull. U.S. 79(1): 1-17.

Holbrook, S.J., R.J. Schmitt, and J.S. Stephens, Jr. 1997. Changes in an assemblage of temperate reef fishes associated with a climate shift. Ecol. Appl. 7(4):1299-1310.

Horn, M.H. and L.G. Allen. 1976. Numbers of species and faunal resemblance of marine fishes in California bays and estuaries. Bull. So. Calif. Acad. Sci. 75(2):159-170.

Horn, M.H. and J.S. Stephens, Jr. 2006. Climate change and overexploitation. Ch. 25 *in*: Allen, L.G., D.J. Pondella, and M.H. Horn (eds.). The Ecology of Marine Fishes: California and Adjacent Waters. Univ. Calif. Press, Los Angeles, CA. 660 p.

Horst, T.J. 1975. The assessment of impact due to entrainment of ichthyoplankton. Pp. 107-118 *in*: S.B. Saila (ed.). Fisheries and energy production: A symposium. Lexington Books, D.C. Heath and Co., Lexington, MA.

Hunter, J.R. and B.J. Macewicz. 1980. Sexual maturity, batch fecundity, spawning frequency, and temporal pattern of spawning for the northern anchovy, *Engraulis mordax*, during the 1979 spawning season. CalCOFI Rep. 21:139-149.

Hunter, J.R. and K.M. Coyne. 1982. The onset of schooling in northern anchovy larvae, *Engraulis mordax*. CalCOFI Rep. 23:246-251.

Hurley, A.C. 1977. Mating behavior of the squid *Loligo opalescens*. Mar. Behav. Physiol. 1977(4):195-203.

Intersea Research Corporation. 1981. Scattergood Generating Station cooling water intake study: 316(b) demonstration program. Prepared for Los Angeles Dept. of Water and Power. Nov. 1981.

IRC. Intersea Research Corporation.

Jacobson, L.D., N.C.H. Lo, and J.T. Barnes. 1997. A biomass based assessment model for northern anchovy, *Engraulis mordax*. Fish. Bull. U.S. 92:711-724.

Jackson, G.D. 1998. Research into the life history of *Loligo opalescens*: where to from here? CalCOFI Rep. 39:101-107.

Jefferts, K. 1983. Squid distribution, biology, and life history. Pp. 3-10 *in* Proceedings of the West Coast Squid Symposium, Newport, OR. Oregon St. Univ. Sea Grant Rep.

Jenkins, S.A. and J. Wasyl. 2002. Hydrodynamic modeling of source water make-up and concentrated seawater dilution for the ocean desalination project at the AES Huntington Beach Power Station. Part II: Analysis of issues to source water. Revised 13 Jan. 2002. Submitted to Poseidon Resources, Long Beach, CA. 78 p. plus appendices.

Jensen, G.C. 1995. Pacific coast crabs and shrimps. Sea Challengers, Monterey, CA. 87 p.

Johnson, L., P. Dorn, K. Muench, and M. Hood. 1976. An evaluation of entrapment associated with the offshore cooling water intake system at Redondo Beach Steam Generating Station Units 7 and 8. Report for Phase II: Aug. 1975 to Aug. 1976. Prepared for Southern California Edison Company. 77-RD-12. 36 p.

Johnson, M.E. and H.J. Snook. 1927. Seashore animals of the Pacific Coast. Dover Publ., New York, N.Y. 659 p.

Johnson, M.W. 1939. The correlation of water movements and dispersal of pelagic larval stages of certain littoral animals, especially the sand crab, Emerita. J. Mar. Res. 2:236-245.

Johnson, M.W. 1956. The larval development of the California spiny lobster, *Panulirus interruptus*, (Randall), with notes on *Panulirus gracilis* Streets. Proc. Calif. Acad. Sci. Fourth Series 29(1):1-19.

Johnson M.W. and W. M. Lewis. 1942. Pelagic larval development of the sand crab *Emerita analoga* (Stimpson), *Blepharipoda occidentalis* Randall, and *Lepidopa myops* Stimpson. Biol. Bull . 83:67–87.

Jordan, D.S. and B.W. Evermann. 1896. The fishes of Middle and North America: A descriptive catalogue of the species of fish-like vertebrates found in the waters of North America, north of the isthmus of Panama. Part I. Smithsonian Inst., U.S. Nat. Mus., Wash. D.C.

Joseph, D. C. 1962. Growth characteristics of two southern California surffishes, the California corbina and spotfin croaker, Family Sciaenidae. Calif. Dept. Fish and Game. Fish Bull. 119. 53 p.

Karpov, K. A. and G.M. Cailliet. 1979. Prey composition of the market squid, *Loligo opalescens* Berry, in relation to depth and location of capture, size of squid, and sex of spawning squid. CalCOFI Rep. 20:51-57.

Kim, J.H., S.B. Grant, C.D. McGee, B.F. Sanders, and J.L. Largier. 2004. Locating sources of surf zone pollution: A mass budget analysis of fecal indicator bacteria at Huntington Beach, California. Env. Sci. Tech. 38(9):2626-2636.

Kramer, S.H. 1991. Growth, mortality, and movements of juvenile California halibut *Paralichthys californicus* in shallow coastal and bay habitats of San Diego County, California. Fish. Bull. U.S. 89(2):195-207.

Kramer, S.H. and J.S. Sunada. 2001. California halibut. Pp. 195-197 *in*: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson. (eds.). California's Living Marine Resources: A Status Report. Calif. Dept. Fish and Game. 592 pp.

LACSD. See Los Angeles County Sanitation Districts.

Lane, E.D. 1975. Quantitative aspects of the life history of the diamond turbot, *Hypsopsetta guttulata* (Girard), in Anaheim Bay. pp. 153-173 *in* E.D. Lane and C.W. Hill (eds.), The Marine Resources of Anaheim Bay. Calif. Dept. Fish and Game. Fish Bull. 165.

Lang, M.A and F.G. Hochberg (eds). 1997. Proceedings of the Workshop on the Fishery and Market Potential of Octopus in California. Univ. So. Calif., Catalina Mar. Sci. Center, 31 Aug. – 8 Sep. 1989. Smith. Inst., Wash. D.C. 191 p.

Largier, J.L. 2003. Considerations in estimating larval dispersal distances from oceanographic data. Ecol. Appl. 13(1) Supplement:S71-S89.

Lavenberg, R.J., G.E. McGowen, T.C. Sciarrotta, A.E. Jahn, and J.H. Peterson. 1986. Abundance of Southern California nearshore ichthyoplankton: 1978-1984. CalCOFI Rep. 27:53-64.

Lawler, Matusky & Skeller Engineers. 1982. Intake technology review: final draft. Prepared for Southern California Edison Company. Sep. 1982.

Lea, R.N. and R.H. Rosenblatt. 2000. Observations on fishes associated with the 1997-98 El Niño off California. CalCOFI Rep. 41:117-129.

Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson. 2001. California's Living Marine Resources: A Status Report. Calif. Dept. Fish and Game. 592 pp.

Leos, R. 2001. Other flatfishes. Pp. 203-204 *in*: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.). California's Living Marine Resources: A Status Report. Calif. Dept. Fish and Game. 592 pp.

Limbaugh, C. 1955. Fish life in the kelp bed and the effects of kelp harvesting. Calif Inst Mar Res, IMR Ref. 156pp.

Limbaugh, C. 1961. Life-history and ecological notes on the black croaker. Calif. Fish Game 47: 163-174.

LMS. See Lawler, Matusky & Skeller Engineers.

Los Angeles County Sanitation District. 2000. Palos Verdes Ocean Monitoring Annual Report.

Love, M. 1991. Probably more than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, CA. 215 p.

Love, M. 1996. Probably more than you want to know about the fishes of the Pacific Coast. Really Big Press, Santa Barbara, CA. 381 p.

Love, M.S., G.E. McGowen, W. Westphal, R.J. Lavenberg, and L. Martin. 1984. Aspects of the life history and fishery of the white croaker, *Genyonemus lineatus* (Sciaenidae) off California. Fish. Bull. U.S. 82(1):179-198.

Love, M.S., M. Sandhu, J. Stein, K.T. Herbinson, R.H. Moore, M. Mullin, and J.S. Stephens, Jr. 1989. Analysis of fish diversion and survivorship in the fish return system at San Onofre Nuclear Generating Station. NOAA Tech. Rep. NMFS 76. April 1989. 16 p.

MacCall, A.D., K.R. Parker, R. Leithiser, and B. Jesse. 1983. Power plant impact assessment: A simple fishery production model approach. Fish. Bull. U.S. 81(3):613-619.

MacDonald, C.K. 1975. Notes on the family Gobiidae from Anaheim Bay. Pp. 117-121 *in*: Lane, E.D. and C.W. Hill (eds.). The marine resources of Anaheim Bay. Calif. Dept. Fish and Game, Fish Bull. 165. 195 p.

Macewicz, B.J., J.R. Hunter, N.C.H. Lo, and E.L. LaCasella. 2004. Fecundity, egg deposition, and mortality of market squid (*Loligo opalescens*). Fish. Bull. U.S. 102(2):306-327.

MacGinitie, G.E. 1938. Movements and mating habits of the sand crab, *Emerita analoga*. Amer. Mid. Nat. 19(2):471-481.

Marsh, G. 1992. Plants and animals of the Santa Ana River in Orange County. Prepared for Orange County Environmental Management Agency. July 1992. 180 p.

MBC and K.T. Herbinson. Unpublished El Segundo Generating Station heat treatment data 1976-2003.

MBC Applied Environmental Sciences. 1987. Ecology of important fisheries species offshore California. OCS Study 86-0093. Prepared for Minerals Management Service, Pacific OCS Region. 251 p.

MBC Applied Environmental Sciences. 1993. National Pollutant Discharge Elimination System, 1993 receiving water monitoring report, AES Huntington Beach L.L.C. generating station, Orange County, California. 1993 survey. Prepared for Southern California Edison Company. 49 p. plus appendices.

MBC Applied Environmental Sciences. 1999. Upper Newport Bay, Special Studies of Fishes. Year Three Final Report. Prepared for the Irvine Ranch Water District. 25 June 1999. 26 p. plus appendices.

MBC Applied Environmental Sciences. 2000. Results of vegetation mapping in the Santa Ana River, between Riverside Ave. and the San Bernardino Water Reclamation Plant, for the fourth year of operation of the RIX Facility, Agua Mansa Rd., San Bernardino County, California. Prepared for Colton/San Bernardino Regional Tertiary Treatment and Water Reclamation Authroity, San Bernardino, California. 24 p. plus appendices.

MBC Applied Environmental Sciences. 2001. National Pollutant Discharge Elimination System, 2001 receiving water monitoring report, AES Huntington Beach L.L.C. generating station, Orange County, California. 2001 survey. Prepared for AES Huntington Beach L.L.C. 54 p. plus appendices.

MBC Applied Environmental Sciences. 2002a. National Pollutant Discharge Elimination System, 2002 receiving water monitoring report, Harbor Generating Station, Los Angeles County, California. 2002 survey. Prepared for Los Angeles Dept. Water and Power. 43 p. plus appendices.

MBC Applied Environmental Sciences. 2002b. National Pollutant Discharge Elimination System, 2002 receiving water monitoring report, Long Beach Generating Station, Los Angeles County, California. 2002 survey. Prepared for Long Beach Generation L.L.C. 76 p. plus appendices.

MBC Applied Environmental Sciences. 2003a. National Pollutant Discharge Elimination System, 2002 fish impingement monitoring report, AES Huntington Beach L.L.C. generating station, Orange County, California. Annual Report. Prepared for AES Huntington Beach L.L.C. February 2003. 15 p. plus appendices.

MBC Applied Environmental Sciences. 2003b. Physical and biological monitoring Golden Shore Marine Reserve, Long Beach, California, Year 5 (2002). Final Report. Prepared for the City of Long Beach. Jan. 2003. 45 p. plus appendices.

MBC Applied Environmental Sciences. 2004. National Pollutant Discharge Elimination System, 2003 fish impingement monitoring report, AES Huntington Beach L.L.C. generating station, Orange County, California. 2003 Survey. Prepared for AES Huntington Beach L.L.C. February 2004. 16 p. plus appendices.

MBC. See Marine Biological Consultants or MBC Applied Environmental Sciences.

McGowan, J.A. 1954. Observations on the sexual behavior and spawning of the squid, *Loligo opalescens*, at La Jolla, California. Calif. Dept. Fish and Game. 40(1):47-54.

McGowen, G.E. 1993. Coastal ichthyoplankton assemblages with emphasis on the Southern California Bight. Bull. Mar. Sci. 53(2):692-722.

McGroddy, P.M., L.E. Larson, and D.R. Deneen. 1981. Physical and hydraulic descriptions of Southern California Edison Company generating station circulating water systems. Southern California Edison Company Research & Development Series 79-RD-63. Jan. 1981. 184 p.

Mearns, A.J. 1982. Assigning trophic levels to marine animals. Pp. 125-141 in: W. Bascom (ed.). Coastal Water Research Project Biennial Report 1981-1982. So. Calif. Coast. Wat. Res. Proj. Long Beach, CA. 294 p.

Methot, R. D., Jr. and D. Kramer. 1979. Growth of the northern anchovy, *Engraulis mordax*, larvae in the sea. Fish. Bull. U.S. 77:413-420.

Miller, D.J. and R.N. Lea. 1972. Guide to the coastal marine fishes of California. California Fish Bulletin No. 157. 249 p.

Miller, E.F. MBC Applied Environmental Sciences. Personal observation of salema gonadal condition, April, June, and September 2004.

Miller, E.F., D.J. Pondella, and L.G. Allen. In prep a. Aspects of the life history of black croaker, *Cheilotrema saturnum*, within the Southern California Bight.

Miller, E. F., D. J. Pondella, and L. G. Allen. In prep b. Distribution and reproduction of two common southern California sciaenids, spotfin croaker (*Roncador stearnsii*) and California corbina (*Menticirrhus undulatus*).

Mitchell, C.T. 1999. The southern California commercial sportfish catch database. Prepared for NMFS. Saltonstall-Kennedy Grant No. NA76FD0050.

Mitchell, C.T. 2003. President, MBC Applied Environmental Sciences. Conversation with S. Beck, 10 July 2003.

Mitchell, C.T., C.H. Turner, and A.R. Strachan. 1969. Observations on the biology and behavior of the California spiny lobster, *Panulirus interruptus* (Randall). Calif. Fish and Game 55(2):121-131.

Moore, S.L. 2001. Age and growth of white croaker (*Genyonemus lineatus*) off Palos Verdes and Dana Point, California. Pp. 154-163 in: SCCWRP Annual Report 1999-2000. So. Calif. Coast. Wat. Res. Proj., Westminster, CA. March 2001. 308 p.

Moore, S.L. and P.W. Wild. 2001. White croaker. Pp. 234-235 in: W.S. Leet, C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.), California's living marine resources: A status report. Calif. Dept. Fish and Game. 592 p.

Morris, R.H., D.P. Abbot, and E.C. Haderlie. 1980. Intertidal invertebrates of California. Stanford Univ. Press, Stanford, CA. 690 p.

Moser, H.G. (ed.). 1996. The early stages of fishes in the California Current Region. CalCOFI Atlas No. 33. Allen Press, Inc., Lawrence, KS. 1505 p.

Moser, H.G., R.L. Charter, P.E. Smith, D.A. Ambrose, W. Watson, S.R. Charter, and E.M. Sandknop. 2001. Distributional atlas of fish larvae and eggs in the Southern California Bight region: 1951-1998. CalCOFI Atlas No. 34. 166 p.

Moser, H.G., R.L. Charter, P.E. Smith, D.A. Ambrose, W. Watson, S.R. Charter, and E.M. Sandknop. 2002. Distributional atlas of fish larvae and eggs from manta (surface) samples collected on CalCOFI surveys from 1977 to 2000. CalCOFI Atlas No. 35. 97 p.

Moyle, P.B. and Cech. 1988. Fishes: An Introduction to Ichthyology. Department of Wildlife and Fisheries Biology, U.C. Davis. Prentice Hall, Englewood Cliffs, NJ.

Murdoch, W.W., B.J. Mechalas, and R.C. Fay. 1989a. Technical Report to the California Coastal Commission. D. Adult-Equivalent Loss. 33 pp.

Murdoch, W.W., B.J. Mechalas, and R.C. Fay. 1989b. Technical Report to the California Coastal Commission. N. Integration of local repressions and increases in fish stocks with inplant losses.

Murdoch, W.W., R.C. Fay, and B.J. Mechalas. 1989c. Final Report of the Marine Review Committee to the California Coastal Commission, MRC Doc. No. 89-02, 346 p.

National Marine Fisheries Service. 1999. Our living oceans. Report on the status of the U.S. living marine resources, 1999. U.S. Dept. Commerce, NOAA Tech. Memo. NMFS-F/SPO-41. 301 p.

NCSS. See Number Cruncher Statistical Systems.

Nelson, J.S., E.J. Crossman, H. Espinoza-Pérez, L.T. Findley, C.R. Gilbert, R.N. Lea, and J.D. Williams. 2004. Common and Scientific Names of Fishes from the United States, Canada, and Mexico. American Fisheries Society Special Publication 29, Bethesda, MD. 386 p.

Nelson, J. S. 1994. Fishes of the World, 3rd Ed. John Wiley and Sons, Inc., New York, NY. 600 p.

Ninos, M. 1984. Settlement and metamorphosis in Hypsoblennius (Pisces, Blenniidae). Ph.D Thesis, University of Southern California. 86 p.

NMFS. See National Marine Fisheries Service.

NOAA Fisheries. 2004. Recreational Sport Fisheries Data for Southern California. Website: http://swfscdata.nmfs.noaa.gov/latimes.

Noble, M. and Jingping Xu (eds.). 2004. Huntington Beach Shoreline Contamination Investigation, Phase III, Final Report. Coastal circulation and transport patterns: The likelihood of OCSD's plume impacting Huntington Beach shoreline. U.S. Geol. Sur. Open-File Report 2004-1019 Ver. 1.0. http://pubs.usgs.gov/of/2004/1019.

Number Cruncher Statistical Systems. 2000. NCSS 2000 Statistical System for Windows.

OCSD. See Orange County Sanitation District.

Orange County Sanitation District. 2000. Marine monitoring 2000 annual report. CD-ROM.

Orange County Sanitation District. 2005. ftp://ftp.ocsd.com/.

Orensanz, J. M. and V. F. Gallucci. 1988. Comparative study of post-larval life-history schedules in four sympatric species of *Cancer* (Decapoda: Brachyura: Cancridae). J. Crustacean Biol., 8(2):187-220.

Pacific Fishery Management Council. 1983. Northern anchovy management plan incorporating the final supplementary EIS/OPIR/IRFA. Pac. Fish. Mgmt. Council, Portland, OR.

Pacific Fishery Management Council. 1998. Coastal Pelagic Species Fishery Management Plan (Amendment 8 to the Northern Anchovy Fishery Management Plan). Dec. 1998.

Pacific States Marine Fisheries Commission. 2004. Recreational Fisheries Information Network (RecFIN). Website: http://www.psfmc.org/recfin.

Parker, D. 2001. Rock crabs. Pp. 112-114 in: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds). California's living marine resources: A status report. Calif. Dept. Fish and Game. 592 p.

Parker, K.R. and E.E. DeMartini. 1989. Chapter D: Adult-equivalent loss. Technical Report to the California Coastal Commission. Prepared by Marine Review Committee, Inc. 56 p.

Parrish, R.H., C.S. Nelson, and A. Bakun. 1986. Transport mechanisms and reproductive success of fishes in the California Current. Biol. Oceanog. 1(2):175-203.

Pearcy, W.G. and S.S. Myers. 1974. Larval fishes of Yaquina Bay, Oregon: nursery ground for marine fishes? Fish. Bull. 72:201-213.

PFMC. See Pacific Fishery Management Council.

Plummer, K.M., E.E. DeMartini, and D.A. Roberts.1983. The feeding habits and distribution of juvenile-small adult California halibut (*Paralichthys californicus*) in coastal waters off northern San Diego County. CalCOFI Rep. 24:194–201.

Pondella, D. J. and L. G. Allen. 2000. The nearshore fish assemblage of Santa Catalina Island. The proceedings of the fifth California Islands Symposium, Minerals Management Service and Santa Barbara Museum of Natural History. Pp. 394-400.

Popper, A. N. Professor, Dept. Biology, Univ. Maryland, Co-Director, Center for Comparative and Evolutionary Biol. of Hearing. Electronic mail transmittal to S. Beck. April 2005.

Power, J. H. 1986. A model of the drift of northern anchovy, *Engraulis mordax* larvae in the California Current. Fish. Bull. U.S. 78(4):855-876.

Prasad, R. R. 1958. Reproduction in *Clevelandia ios* (Jordan and Gilbert), with an account of the embryonic and larval development. India Nat. Inst. Sci., Proceed. Vol. 25, B(1):12-30.

PSFMC. See Pacific States Marine Fisheries Commission.

Quast, J. C. 1968. Observations on the food of the kelp-bed fishes. California Department of Fish and Game, Fish Bull. 139:109-142. 55 p. plus appendices.

Recksiek, C.W. and H.W. Frey. 1978. Background of market squid research program, basic life history, and the California fishery. Pp. 7-10 in: C.W Recksiek and H.W Frey (eds.), Biological, oceanographic, and acoustic aspects of the market squid, *Loligo opalescens* Berry. Calif. Dept. of Fish and Game Bull. 169.

Recksiek, C.W. and J. Kashiwada. 1979. Distribution of larval squid, *Loligo opalescens,* in various nearshore locations. CalCOFI Rep. 20:31-34.

Richards, D.V. 1996. Sand beach and coastal lagoon monitoring, Santa Rosa Island, 1994 Annual Report. National Park Service, Channel Islands National Park. Tech. Rep. CHIS-95-06.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board of Canada. Bull. 91. 382 p.

Roberts, D.A., E.E. DeMartini, and K.M. Plummer. 1984. The feeding habits of juvenile – small adult barred sand bass (*Paralabrax nebulifer*) in nearshore waters off northern San Diego County. CalCOFI Rep. 25:105-111.

Robertson, D. R. and G. R. Allen. 2002. Shorefishes of the tropical eastern Pacific: an information system. Smithsonian Tropical Research Institution, Balboa, Panamá.

Roemmich, D. and J. McGowan. 1995. Climatic warming and the decline of zooplankton in the California Current. Science 267:1324-1326.

Roesijadi, G. 1976. Descriptions of the prezoeae of *Cancer magister* Dana and *Cancer productus* Randall and the larval stages of *Cancer antennarius* Stimpson (Decapoda, Brachyura). Crustaceana 31:275-295.

SAIC. See Science Applications International Corporation.

Sakagawa, G.T. and M. Kimura. 1976. Growth of laboratory-reared northern anchovy, *Engraulis mordax*, from southern California. Fish. Bull. U.S. 74(2):271-279.

SCE. See Southern California Edison.

Schlotterbeck, R.E. and D.W. Connally. 1982. Vertical stratification of three nearshore southern California larval fishes (*Engraulis mordax*, *Genyonemus lineatus*, and *Seriphus politus*). Fish. Bull. U.S. 80(4):895-902.

Schlotterbeck, R.E., L.E. Larson, P. Dorn, R.C. Miracle, R.G. Kanter, R.R. Ware, D.B. Cadien, and D.W. Connally. 1979. Physical and biological categorization process for selection of Southern California Edison Company representative 316(b) study sites. Marine Biological Consultants and Southern California Edison Company. May 1979. 63 p.

Science Applications International Corporation. 2001. Strategic Process Study #1: Plume Tracking – Ocean Currents. Final Report to OCSD. 61 p.

Schuler, V.J. 1974. Experimental studies in the reduction of intake of fishes at offshore intake structures. Prepared for Southern California Edison Company by Ichthyological Associates, Inc., Middletown, DE. Apr. 1974. 42 p.

Seber, G.A.F. 1982. The Estimation of Animal Abundance and Related Parameters. McMillan. London. 654 p.

Serfling, S.A. and R.F. Ford. 1975. Ecological studies of the puerulus larval stage of the California spiny lobster, *Panulirus interruptus*. Fish. Bull. U.S. 73(2):360-377.

Shanks, A.L. 1985. Behavioral basis of internal-wave-induced shoreward transport of megalopae of the crab *Pachygrapsus crassipes*. Mar. Ecol. Prog. Ser. 24:289-295.

Sikkel, P. C. 1986. Interspecific cleaning by juvenile salema, Xenistius californiensis (Pisces, Haemulidae). Calif. Fish and Game. 72:172-174.

Smith, P.E. 1972. The increase in spawning biomass of northern anchovy, *Engraulis mordax*. Fish. Bull. U.S. 70:849-874.

Sokal, R.R. and F.J. Rolf. 1995. Biometry: The principles and practice of statistics in biological research. W.H. Freeman and Co., New York, N.Y. 887 p.

Sonalysts, Inc. and MBC Applied Environmental Sciences. 1995a. Testing responses of fishes to acoustic signals at the Redondo Marine Laboratory. Prepared for Southern California Edison Company. November 17, 1995. Contract No. C4035907. 36 p. plus appendices.

Sonalysts, Inc. and MBC Applied Environmental Sciences. 1995b. Feasibility study for an acoustic behavioral barrier at the San Onofre Nuclear Generating Station. Prepared for Southern California Edison Company. November 17, 1995. Contract No. C4035907. 21 p.

Southern California Edison. 1975. Summary of experiences with, and studies of, methods to reduce fish entrainment at coastal generating stations. Prepared for Scripps Institution of Oceanography.

Southern California Edison. 1983. Huntington Beach Generating Station 316(b) demonstration. Prepared for the California Regional Water Quality Control Board, Santa Ana Region. July 1983. 36 p. plus appendices.

Southern California Edison. 2000. Annual marine environmental analysis and interpretation: San Onofre Nuclear Generating Station. Report on 1999 data.

Southern California Edison. 2001. 2000 Annual marine environmental analysis and interpretation: San Onofre Nuclear Generating Station. July 2001.

Southern California Edison. 2004. 2003 Annual marine environmental analysis and interpretation: San Onofre Nuclear Generating Station. July 2004.

Spratt, J.D. 1979. Age and growth of the market squid, *Loligo opalescens* Berry, from statoliths. CalCOFI Rep. 20:58-64.

Starr, R.M., J.M. Cope, and L.A. Kerr. 2002. Trends and fisheries and fishery resources associated with the Monterey Bay National Marine Sanctuary from 1981–2000. Publ. No. T-046. California Sea Grant College System, Univ. Calif., La Jolla, CA. 156 p.

Starr, R.M., K.A. Johnson, E.A. Laman, and G.M. Cailliet. 1998. Fishery resources of the Monterey Bay National Marine Sanctuary. Publ. No. T-042. California Sea Grant College System, Univ. Calif., La Jolla, CA. 102 p.

Stephens, J. S. Jr. 1969. Growth, longevity, and the effect of size on the biology of certain Blennioid fishes. Final Report. Nat. Sci. Found. GB 5940. 83 pp.

Stephens, J.S. Jr., R.K. Johnson, G.S. Key and J.E. McCosker. 1970. The comparative ecology of three sympatric species of California blennies of the genus *Hypsoblennius* Gill (Teleostomi, Blenniidae). Ecol. Monogr. 40(2):213-233.

Stevens, E.G. and H.G. Moser. 1982. Observations on the early life history of the mussel blenny, *Hypsoblennius jenkinsi*, and the bay blenny, *Hypsoblennius gentilis*, from specimens reared in the laboratory. CalCOFI Rep. 23:269-275.

Stipanov, J.A. 1979. Investigations into minimizing fish loss at steam electric generating stations. Pp. 198-218 in: Report of a Workshop on the Impact of Thermal Power Plant Cooling Systems on Aquatic Environments. Electric Power Res. Inst. EPRI SR-38, Vol. I and II. Special Report.

Stull, J.K. and C. Tang. 1996. Demersal fish trawls off Palos Verdes, Southern California, 1973-1993. CalCOFI Rep. 37:211-264.

Sunada, J. 1984. Spot prawn (*Pandalus platyceros*) and ridgeback prawn (*Sicyonia ingentis*) fisheries in the Santa Barbara Channel. CalCOFI Rep. 25:100-104.

Sunada, J.S., J.B. Richards, and L.M. Laughlin. 2001. Ridgeback prawn. Pp. 124-125 in: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds). California's living marine resources: A status report. Calif. Dept. Fish and Game. 592 p.

Swift, C.C. 2002. Biological consultant, telephone conversation 31 December 2002.

Tegner, M.J. and L.A. Levin. 1983. Spiny lobsters and sea urchins: Analysis of a predator-prey interaction. J. Exp. Mar. Biol. Ecol. 73:125-150.

Tenera Environmental. 2000a. Diablo Canyon Power Plant: 316(b) Demonstration Report. Prepared for Pacific Gas and Elec. Co., San Francisco, CA. Doc. No. E9-055.0.

Tenera Environmental. 2000b. Moss Landing Power Plant Modernization Project: 316(b) Resource Assessment. Prepared for Duke Energy Moss Landing, L.L.C., Oakland, CA.

Tenera Environmental. 2001. Morro Bay Power Plant Modernization Project 316(b) Resource Assessment. Prepared for Duke Energy Morro Bay LLC.

Tenera Environmental. 2004. SBPP Cooling Water System Effects on San Diego Bay, Volume II: Compliance with Section 316(b) of the Clean Water Act for the South Bay Power Plant. Prepared for Duke Energy South Bay.

Tenera. See Tenera Environmental.

Thomas G. L., L. Johnson, R. E. Thorne, and W. C. Acker. 1979. Techniques for assessing the response of fish assemblages to offshore cooling water intake systems. University of Washington College of

Fisheries Fisheries Research Institute Report FRI-UW-7927. Prepared for Southern California Edison. 97 p + appendices.

Thomas, G. L., and R. L. Johnson. 1980. Density Dependence and vulnerability of fish to entrapment by offshore-sited cooling water intakes. Oceans IEEE Journal. 15:504-508.

Thomas G. L., L. Johnson, R. E. Thorne, T. B. Stables, and W. C. Acker. 1980a. A field evaluation of the recirculation of cooling water on the entrapment of fish at Huntington Beach generating station. University of Washington College of Fisheries Fisheries Research Institute Report FRI-UW-8012. Prepared for Southern California Edison. 44 p + appendices.

Thomas G. L., L. Johnson, R. E. Thorne, and W. C. Acker. 1980b. A comparison of fish entrapment at four Southern California Edison Company cooling water intake systems. University of Washington College of Fisheries Fisheries Research Institute Report FRI-UW-8023. Prepared for Southern California Edison. 61 p + appendices.

Thomas G. L., R. E. Thorne, W. C. Acker, and T. B. Stables. 1980c. The effectiveness of a velocity cap and decreased flow in reducing fish entrapment. University of Washington College of Fisheries Fisheries Research Institute Report FRI-UW-8027. Prepared for Southern California Edison.

Thomas, G. L., R. E. Thorne, W. C. Acker, T. B. Stables, and A. S. Kolok. 1980d. The effectiveness of a velocity cap and decreased flow in reducing fish entrapment. Final Report to Southern California Edison Company. Univ. Wash. Coll. Fisheries, Fisheries Res. Inst. FRI-UW-8027. 31 Dec. 1980. 22 p. plus appendices.

Thorne, R. E. 1980. Assessment of population abundance by echo integration. SCOR Working Group 52. Presented at Symposium on Assessment of Micronekton.Thomas, G. L. and R. L. Johnson. 1980. Density Dependence and vulnerability of fish to entrapment by offshore-sited cooling water intakes. Oceans IEEE Journal. 15:504-508.

Turgeon, D.D., A.E. Bogan, E.V. Coan, W.K. Emerson, W.G. Lyons, W.L. Pratt, C.F.E. Roper, A. Scheltema, F.G. Thompson, and J.D. Williams. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: mollusks. Amer. Fish. Soc., Special Publication 16. 277 p.

U.S. Environmental Protection Agency. 2001. Technical Development Document for the final regulations addressing cooling water intake structures for new facilities. EPA-821-R-01-036. Nov. 2001.

U.S. Environmental Protection Agency. 2002a. National Pollutant Discharge Elimination System--Proposed Regulations to Establish Requirements for Cooling Water Intake Structures at Phase II Existing Facilities; Proposed Rule. 40 CFR Parts 9, et al. Federal Register, April 9, 2002. 17122-17225.

U.S. Environmental Protection Agency. 2002b. Case study analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule. EPA-821-R-02-002. Feb. 28, 2002.

U.S. Environmental Protection Agency. 2004. Technical Development Document for the Final Section 316(b) Phase II Existing Facilities Rule. Feb. 12, 2004.

USEPA. See U.S. Environmental Protection Agency.

Valle, C. F. and M. S. Oliphant. 2001. Spotfin croaker. In: W.S. Leet, C.M. Dewees, R. Klingbeil, and E.J. Larson (eds.) California's Living Marine Resources: A Status Report. University of California, Agriculture and Natural Resources Publication SG01-11, 592pp.

VanBlaricom, G.R. 1979. Experimental analyses of structural regulation in a marine sand community exposed to oceanic swell. Ecol. Monogr., Vol. 52(3), pp. 283-305.

Vojkovich, M. 1998. The California fishery for market squid (*Loligo opalescens*). CalCOFI Rep. 39:55-60.

Vojkovich, M. and S. Crooke. 2001. White seabass. Pp. 206-208 *in*: Leet, W.S., C.M. Dewees, R. Klingbeil, and E.J. Larson (eds). California's living marine resources: A status report. Calif. Dept. Fish and Game. 592 p.

Wang, J.C.S. 1981. Taxonomy of the early life stages of fishes - Fishes of the Sacramento-San Joaquin Estuary and Moss Landing Harbor-Elkhorn Slough. Prepared for Pacific Gas and Electric Company. San Francisco, California.

Ware, R.R. 1979. The food habits of the white croaker *Genyonemus lineatus* and an infaunal analysis near areas of waste discharge in Outer Los Angeles Harbor. Thesis, Calif. State Univ., Long Beach. August 1979. 163 p.

Watson, W. 1982. Development of eggs and larvae of the white croaker, *Genyonemus lineatus* Ayres (Pisces: Sciaenidae) off the southern California coast. Fish. Bull. U.S. 80(3):403-417.

Weight, R.H. 1958. Ocean cooling water system for 800 MW power station. Proc. of the Amer. Soc. of Civil Eng., Proc. Paper 1888. Dec. 1958.

Wenner, A.W., D.M. Hubbard, J. Dugan, J. Shoffner, and K. Jellison. 1987. Egg production by sand crabs (*Emerita analoga*) as a function of size and year class. Biol. Bull. 172:225-235.

Williams, A.B., L.G. Abele, D.L. Felder, H.H. Hobbs, Jr., R.B. Manning, P.A. McLaughlin, and I. Perez Farfante. 1988. Common and scientific names of aquatic invertebrates from the United States and Canada: decapod crustaceans. Amer. Fish. Soc., Special Publication 17. 77 p.

Wilson, D.C. and R.E. Millemann. 1969. Relationships of female age and size embryo number and size in the shiner perch, *Cymatogaster aggregata*. J. Fish. Res. Board Can. 267:2339-2344.

Wilson, R.C. 1948. A review of the southern California spiny lobster fishery. Calif. Fish and Game 34(2):71-80.

Winn, R.N. 1985. Comparative ecology of three cancrid crab species (*Cancer anthonyi*, *C. antennarius*, *C. productus*) in marine subtidal habitats in southern California. Ph.D. Dissertation, Univ. So. Calif. 235 p.

Word, J.Q. and D.K. Charwat. 1976. Invertebrates of southern California coastal waters. II. Natantia. So. Calif. Coast. Wat. Res. Proj. 238 p.

Wrobel, D. and C. Mills. 1998. Pacific coast pelagic invertebrates: A guide to the common gelatinous animals. Sea Challengers and Monterey Bay Aquarium, Monterey, California. 108 p.

Yang, W.T., R.F. Hixon, P.E. Turk, M.E. Krejci, W.H. Hulet, and R.T. Hanlon. 1986. Growth, behavior, and sexual maturation of the market squid, *Loligo opalescens*, cultured through the life cycle. Fish. Bull. U.S. 84(4):771-798.

Zeidberg, L.D., W. Hamner, K. Moorehead, and E. Kristof. 2004. Egg masses of *Loligo opalescens* (Cephalopoda: Myopsida) in Monterey Bay, California following the El Niño event of 1997–1998. Bull. Mar. Sci. 74(1):129-141.

9.0 GLOSSARY

AEL	Adult Equivalent Loss. Forecast the number of adults that would have resulted from the number of entrained larvae, assuming the larvae survived entrainment. Calculated using available estimates of natural mortality rates applied to various life stages.
benthic	Occurring on or in the seafloor.
BRRT	Biological Resources Research Team. The working group overseeing the development, implementation, and analysis of the Entrainment and Impingement Study.
CalCOFI	California Cooperative Oceanic Fisheries Investigations. Large-scale physical and biological monitoring program sponsored by the California Department of Fish and Game, the National Marine Fisheries Service, and the Scripps Institute of Oceanography.
Catch Block	10-km x 10-km areas fishery management areas offshore California. Overseen by the California Department of Fish and Game.
CCC	California Coastal Commission.
CDFG	California Department of Fish and Game.
CEC	California Energy Commission.
CIQ Goby Complex	A group of three goby species (*Clevelandia ios*, *Ilypnus gilberti*, and *Quietula y-cauda*) that cannot be distinguished during their earliest larval stages.
CPFV	Commercial Passenger Fishing Vessel.
CTD	An instrument used to collect conductivity, temperature, and depth measurements as a function of depth.
CWIS	Cooling Water Intake System. The entire cooling water system of the HBGS, including the offshore intake structure, conduits, forebay, condensers, and discharge structure.
demersal	Living close to the seafloor (just above bottom).
entrainment	Passage of planktonic organisms through the HBGS cooling water system.
entrapment	The occurrence of organisms within a cooling water intake system that have been entrained but not impinged on traveling screens, and cannot escape the cooling water intake flow.
EPA	U.S. Environmental Protection Agency.

ETM	Empirical Transport Model. A mathematical model that estimates the total annual probability of mortality (P_m) due to entrainment using *PE* estimates.
FH	Fecundity Hindcasting. The number of larvae entrained are hindcast to estimate the number of eggs by applying mortality estimates; the number of eggs is then used to estimate the number of adult females that would have produced that quantity of eggs.
forebay	The exposed area of the cooling water intake system at the HBGS directly upcurrent from the trash racks and traveling screens (see Figure 6-1).
FRS	Fish Return System. A mechanical system designed to collect juvenile and adult fish (and invertebrates) entrained in a cooling water intake system and return them alive to the source waters.
HBGS	The AES Huntington Beach L.L.C. Generating Station, formerly the Huntington Beach Generating Station.
heat treatment	Operational procedure to eliminate the growth of marine organisms, primarily mussels and barnacles, within a cooling water intake system. During this procedure, heated discharge waters are circulated through the cooling water intake system to raise the water temperature for a sufficient time period to eliminate fouling marine organisms that occlude cooling water flow.
impingement	The entrapment of macroscopic fish and invertebrates on traveling screens.
MBC	MBC Applied Environmental Sciences, formerly Marine Biological Consultants.
megalops	Advanced larval stage of crabs following zoea.
mgd	Million gallons per day.
molt	Periodic shedding of the cuticle (outer skeletal structure) in arthropods (crabs, shrimps, and lobster).
NMFS	National Marine Fisheries Service, now referred to as NOAA Fisheries.
normal operations	Referring to the normal operation of the cooling water intake system of a generating station. Distinguished from heat treatment operations.
NPDES	National Pollutant Discharge Elimination System. Permitting system of Section 401 of the Clean Water Act to enforce effluent limitations.
oblique	At a slanted angle; neither perpendicular nor parallel to a given surface.
OCSD	Orange County Sanitation District.

PE	Proportional Entrainment. A mathematical value comparing the number of larvae entrained to the number of larvae available in the source water body.
pelagic	Occurring in the open water, between the water surface and the seafloor.
PFMC	Pacific Fishery Management Council.
phyllosoma	Early larval (zoea) stage of California spiny lobster.
P_m	Annual probability of mortality due to entrainment.
P_s	The proportion of the population of inference represented by the number of larvae in the source water (study grid).
PSMFC	Pacific States Marine Fisheries Commission.
puerulus	Final larval stage of California spiny lobster, resembling the adult, transparent, and free-swimming.
recruitment	Measure of the number of fish that enter a class during a specified time period, such as the spawning class. Usually refers to the first year class settling from larvae.
RWQCB	Regional Water Quality Control Board. There are three RWQCBs in southern California: the Los Angeles RWQCB, the Santa Ana RWQCB, and the San Diego RWQCB.
SONGS	San Onofre Nuclear Generating Station (San Clemente, California).
subpopulations	A group of individuals of a species which interbreeds but is reproductively isolated from other such groups of the same species.
traveling screens	Mechanical system designed to prevent debris and marine organisms larger than the screen mesh size (usually 3/8-in. or 5/8-in.) from passing through the condensers and through the cooling water system. Usually rotated at periodic intervals.
velocity cap	Concrete pad mounted above offshore cooling water intake structures. Designed to direct cooling water flow horizontally rather than vertically (see Figure 2-3).
Z	Instantaneous mortality rate.
zoea	Early larval stage in crustaceans.

Appendix A

Circulating Water Flow Data, July 2003 – December 2005

Date	Flow (mgd)	Date	Flow (mgd)	Date	Flow (mgd)
7/1/2003	443.52	8/20/2003	316.8	10/9/2003	316.8
7/2/2003	443.52	8/21/2003	316.8	10/10/2003	316.8
7/3/2003	443.52	8/22/2003	316.8	10/11/2003	316.8
7/4/2003	443.52	8/23/2003	316.8	10/12/2003	316.8
7/5/2003	316.8	8/24/2003	316.8	10/13/2003	316.8
7/6/2003	316.8	8/25/2003	380.16	10/14/2003	316.8
7/7/2003	380.16	8/26/2003	380.16	10/15/2003	316.8
7/8/2003	380.16	8/27/2003	316.8	10/16/2003	380.16
7/9/2003	380.16	8/28/2003	253.44	10/17/2003	380.16
7/10/2003	443.52	8/29/2003	253.44	10/18/2003	316.8
7/11/2003	443.52	8/30/2003	190.08	10/19/2003	380.16
7/12/2003	253.44	8/31/2003	190.08	10/20/2003	380.16
7/13/2003	380.16	9/1/2003	190.08	10/21/2003	506.88
7/14/2003	443.52	9/2/2003	506.88	10/22/2003	506.88
7/15/2003	443.52	9/3/2003	506.88	10/23/2003	443.52
7/16/2003	380.16	9/4/2003	506.88	10/24/2003	443.52
7/17/2003	380.16	9/5/2003	506.88	10/25/2003	380.16
7/18/2003	380.16	9/6/2003	506.88	10/26/2003	506.88
7/19/2003	443.52	9/7/2003	506.88	10/27/2003	506.88
7/20/2003	443.52	9/8/2003	506.88	10/28/2003	506.88
7/21/2003	380.16	9/9/2003	506.88	10/29/2003	506.88
7/22/2003	380.16	9/10/2003	316.8	10/30/2003	506.88
7/23/2003	380.16	9/11/2003	316.8	10/31/2003	506.88
7/24/2003	380.16	9/12/2003	316.8	11/1/2003	506.88
7/25/2003	380.16	9/13/2003	316.8	11/2/2003	506.88
7/26/2003	380.16	9/14/2003	316.8	11/3/2003	506.88
7/27/2003	380.16	9/15/2003	316.8	11/4/2003	380.16
7/28/2003	506.88	9/16/2003	316.8	11/5/2003	316.8
7/29/2003	506.88	9/17/2003	316.8	11/6/2003	316.8
7/30/2003	506.88	9/18/2003	316.8	11/7/2003	316.8
7/31/2003	506.88	9/19/2003	380.16	11/8/2003	316.8
8/1/2003	506.88	9/20/2003	380.16	11/9/2003	316.8
8/2/2003	380.16	9/21/2003	506.88	11/10/2003	316.8
8/3/2003	380.16	9/22/2003	506.88	11/11/2003	190.08
8/4/2003	443.52	9/23/2003	506.88	11/12/2003	190.08
8/5/2003	316.8	9/24/2003	506.88	11/13/2003	190.08
8/6/2003	316.8	9/25/2003	506.88	11/14/2003	253.44
8/7/2003	316.8	9/26/2003	506.88	11/15/2003	253.44
8/8/2003	316.8	9/27/2003	506.88	11/16/2003	253.44
8/9/2003	316.8	9/28/2003	506.88	11/17/2003	253.44
8/10/2003	380.16	9/29/2003	506.88	11/18/2003	253.44
8/11/2003	190.08	9/30/2003	316.8	11/19/2003	253.44
8/12/2003	443.52	10/1/2003	316.8	11/20/2003	253.44
8/13/2003	506.88	10/2/2003	316.8	11/21/2003	253.44
8/14/2003	506.88	10/3/2003	316.8	11/22/2003	253.44
8/15/2003	506.88	10/4/2003	316.8	11/23/2003	380.16
8/16/2003	506.88	10/5/2003	316.8	11/24/2003	380.16
8/17/2003	506.88	10/6/2003	316.8	11/25/2003	380.16
8/18/2003	506.88	10/7/2003	316.8	11/26/2003	380.16
8/19/2003	380.16	10/8/2003	316.8	11/27/2003	316.8

Date	Flow (mgd)	Date	Flow (mgd)	Date	Flow (mgd)
11/28/2003	316.8	1/17/2004	253.44	3/7/2004	316.8
11/29/2003	316.8	1/18/2004	253.44	3/8/2004	316.8
11/30/2003	380.16	1/19/2004	253.44	3/9/2004	316.8
12/1/2003	316.8	1/20/2004	253.44	3/10/2004	316.8
12/2/2003	253.44	1/21/2004	253.44	3/11/2004	380.16
12/3/2003	253.44	1/22/2004	253.44	3/12/2004	380.16
12/4/2003	253.44	1/23/2004	253.44	3/13/2004	380.16
12/5/2003	253.44	1/24/2004	253.44	3/14/2004	380.16
12/6/2003	253.44	1/25/2004	316.8	3/15/2004	380.16
12/7/2003	253.44	1/26/2004	506.88	3/16/2004	380.16
12/8/2003	253.4	1/27/2004	506.88	3/17/2004	380.16
12/9/2003	253.44	1/28/2004	506.88	3/18/2004	380.16
12/10/2003	253.44	1/29/2004	506.88	3/19/2004	443.52
12/11/2003	253.44	1/30/2004	253.44	3/20/2004	443.52
12/12/2003	253.44	1/31/2004	380.16	3/21/2004	443.52
12/13/2003	316.8	2/1/2004	316.8	3/22/2004	443.52
12/14/2003	316.8	2/2/2004	316.8	3/23/2004	443.52
12/15/2003	380.16	2/3/2004	316.8	3/24/2004	443.52
12/16/2003	380.16	2/4/2004	316.8	3/25/2004	443.52
12/17/2003	316.8	2/5/2004	380.16	3/26/2004	443.52
12/18/2003	316.8	2/6/2004	380.16	3/27/2004	443.52
12/19/2003	316.8	2/7/2004	380.16	3/28/2004	443.52
12/20/2003	316.8	2/8/2004	380.16	3/29/2004	443.52
12/21/2003	316.8	2/9/2004	380.16	3/30/2004	443.52
12/22/2003	316.8	2/10/2004	380.16	3/31/2004	443.52
12/23/2003	316.8	2/11/2004	380.16	4/1/2004	443.52
12/24/2003	316.8	2/12/2004	316.8	4/2/2004	443.52
12/25/2003	316.8	2/13/2004	316.8	4/3/2004	443.52
12/26/2003	316.8	2/14/2004	253.44	4/4/2004	443.52
12/27/2003	316.8	2/15/2004	253.44	4/5/2004	443.52
12/28/2003	316.8	2/16/2004	253.44	4/6/2004	443.52
12/29/2003	316.8	2/17/2004	253.44	4/7/2004	443.52
12/30/2003	316.8	2/18/2004	253.44	4/8/2004	443.52
12/31/2003	316.8	2/19/2004	253.44	4/9/2004	443.52
1/1/2004	316.8	2/20/2004	253.44	4/10/2004	443.52
1/2/2004	316.8	2/21/2004	253.44	4/11/2004	443.52
1/3/2004	316.8	2/22/2004	253.44	4/12/2004	443.52
1/4/2004	316.8	2/23/2004	253.44	4/13/2004	380.16
1/5/2004	316.8	2/24/2004	253.44	4/14/2004	380.16
1/6/2004	253.44	2/25/2004	253.44	4/15/2004	316.8
1/7/2004	316.8	2/26/2004	253.44	4/16/2004	316.8
1/8/2004	316.8	2/27/2004	253.44	4/17/2004	316.8
1/9/2004	316.8	2/28/2004	253.44	4/18/2004	316.8
1/10/2004	316.8	2/29/2004	253.44	4/19/2004	316.8
1/11/2004	253.44	3/1/2004	253.44	4/20/2004	380.16
1/12/2004	253.44	3/2/2004	253.44	4/21/2004	380.16
1/13/2004	253.44	3/3/2004	253.44	4/22/2004	190.08
1/14/2004	253.44	3/4/2004	253.44	4/23/2004	190.08
1/15/2004	253.44	3/5/2004	253.44	4/24/2004	190.08
1/16/2004	253.44	3/6/2004	316.8	4/25/2004	190.08

Date	Flow (mgd)	Date	Flow (mgd)	Date	Flow (mgd)
4/26/2004	253.44	6/15/2004	380.16	8/4/2004	316.8
4/27/2004	253.44	6/16/2004	380.16	8/5/2004	316.8
4/28/2004	253.44	6/17/2004	380.16	8/6/2004	316.8
4/29/2004	253.44	6/18/2004	380.16	8/7/2004	316.8
4/30/2004	253.44	6/19/2004	380.16	8/8/2004	506.88
5/1/2004	316.8	6/20/2004	380.16	8/9/2004	506.88
5/2/2004	380.16	6/21/2004	380.16	8/10/2004	506.88
5/3/2004	380.16	6/22/2004	380.16	8/11/2004	506.88
5/4/2004	380.16	6/23/2004	380.16	8/12/2004	506.88
5/5/2004	316.8	6/24/2004	380.16	8/13/2004	506.88
5/6/2004	316.8	6/25/2004	253.44	8/14/2004	506.88
5/7/2004	253.44	6/26/2004	253.44	8/15/2004	506.88
5/8/2004	253.44	6/27/2004	253.44	8/16/2004	506.88
5/9/2004	316.8	6/28/2004	253.44	8/17/2004	506.88
5/10/2004	316.8	6/29/2004	253.44	8/18/2004	506.88
5/11/2004	316.8	6/30/2004	253.44	8/19/2004	380.16
5/12/2004	316.8	7/1/2004	253.44	8/20/2004	316.8
5/13/2004	316.8	7/2/2004	253.44	8/21/2004	253.44
5/14/2004	316.8	7/3/2004	253.44	8/22/2004	253.44
5/15/2004	316.8	7/4/2004	253.44	8/23/2004	253.44
5/16/2004	316.8	7/5/2004	380.16	8/24/2004	316.8
5/17/2004	316.8	7/6/2004	380.16	8/25/2004	316.8
5/18/2004	316.8	7/7/2004	380.16	8/26/2004	316.8
5/19/2004	316.8	7/8/2004	316.8	8/27/2004	253.44
5/20/2004	316.8	7/9/2004	253.44	8/28/2004	380.16
5/21/2004	316.8	7/10/2004	316.8	8/29/2004	380.16
5/22/2004	316.8	7/11/2004	506.88	8/30/2004	506.88
5/23/2004	316.8	7/12/2004	316.8	8/31/2004	506.88
5/24/2004	190.08	7/13/2004	506.88	9/1/2004	506.88
5/25/2004	190.08	7/14/2004	380.16	9/2/2004	506.88
5/26/2004	253.44	7/15/2004	506.88	9/3/2004	506.88
5/27/2004	253.44	7/16/2004	506.88	9/4/2004	316.8
5/28/2004	253.44	7/17/2004	506.88	9/5/2004	316.8
5/29/2004	316.8	7/18/2004	506.88	9/6/2004	443.52
5/30/2004	380.16	7/19/2004	506.88	9/7/2004	506.88
5/31/2004	380.16	7/20/2004	506.88	9/8/2004	506.88
6/1/2004	380.16	7/21/2004	506.88	9/9/2004	506.88
6/2/2004	380.16	7/22/2004	506.88	9/10/2004	506.88
6/3/2004	380.16	7/23/2004	380.16	9/11/2004	506.88
6/4/2004	380.16	7/24/2004	380.16	9/12/2004	506.88
6/5/2004	316.8	7/25/2004	380.16	9/13/2004	506.88
6/6/2004	316.8	7/26/2004	506.88	9/14/2004	506.88
6/7/2004	506.88	7/27/2004	506.88	9/15/2004	506.88
6/8/2004	506.88	7/28/2004	443.52	9/16/2004	506.88
6/9/2004	443.52	7/29/2004	443.52	9/17/2004	506.88
6/10/2004	443.52	7/30/2004	316.8	9/18/2004	380.16
6/11/2004	316.8	7/31/2004	316.8	9/19/2004	380.16
6/12/2004	316.8	8/1/2004	380.16	9/20/2004	380.16
6/13/2004	316.8	8/2/2004	380.16	9/21/2004	380.16
6/14/2004	443.52	8/3/2004	380.16	9/22/2004	380.16

Date	Flow (mgd)	Date	Flow (mgd)	Date	Flow (mgd)
9/23/2004	380.16	11/12/2004	316.8	1/1/2005	253.44
9/24/2004	380.16	11/13/2004	316.8	1/2/2005	253.44
9/25/2004	316.8	11/14/2004	316.8	1/3/2005	253.44
9/26/2004	316.8	11/15/2004	316.8	1/4/2005	316.8
9/27/2004	506.88	11/16/2004	316.8	1/5/2005	316.8
9/28/2004	443.52	11/17/2004	316.8	1/6/2005	316.8
9/29/2004	316.8	11/18/2004	316.8	1/7/2005	316.8
9/30/2004	316.8	11/19/2004	380.16	1/8/2005	316.8
10/1/2004	316.8	11/20/2004	380.16	1/9/2005	316.8
10/2/2004	443.52	11/21/2004	316.8	1/10/2005	316.8
10/3/2004	443.52	11/22/2004	380.16	1/11/2005	380.16
10/4/2004	443.52	11/23/2004	380.16	1/12/2005	316.8
10/5/2004	506.88	11/24/2004	380.16	1/13/2005	316.8
10/6/2004	506.88	11/25/2004	380.16	1/14/2005	316.8
10/7/2004	506.88	11/26/2004	380.16	1/15/2005	380.16
10/8/2004	380.16	11/27/2004	380.16	1/16/2005	380.16
10/9/2004	380.16	11/28/2004	380.16	1/17/2005	380.16
10/10/2004	380.16	11/29/2004	380.16	1/18/2005	380.16
10/11/2004	443.52	11/30/2004	380.16	1/19/2005	380.16
10/12/2004	443.52	12/1/2004	380.16	1/20/2005	380.16
10/13/2004	380.16	12/2/2004	380.16	1/21/2005	380.16
10/14/2004	380.16	12/3/2004	380.16	1/22/2005	380.16
10/15/2004	380.16	12/4/2004	380.16	1/23/2005	380.16
10/16/2004	380.16	12/5/2004	380.16	1/24/2005	253.44
10/17/2004	380.16	12/6/2004	380.16	1/25/2005	316.8
10/18/2004	380.16	12/7/2004	380.16	1/26/2005	316.8
10/19/2004	380.16	12/8/2004	380.16	1/27/2005	316.8
10/20/2004	380.16	12/9/2004	380.16	1/28/2005	316.8
10/21/2004	380.16	12/10/2004	380.16	1/29/2005	316.8
10/22/2004	506.88	12/11/2004	380.16	1/30/2005	316.8
10/23/2004	506.88	12/12/2004	253.44	1/31/2005	316.8
10/24/2004	506.88	12/13/2004	316.8	2/1/2005	316.8
10/25/2004	506.88	12/14/2004	316.8	2/2/2005	316.8
10/26/2004	506.88	12/15/2004	316.8	2/3/2005	380.16
10/27/2004	380.16	12/16/2004	316.8	2/4/2005	380.16
10/28/2004	380.16	12/17/2004	506.88	2/5/2005	253.44
10/29/2004	380.16	12/18/2004	506.88	2/6/2005	253.44
10/30/2004	316.8	12/19/2004	380.16	2/7/2005	316.8
10/31/2004	316.8	12/20/2004	380.16	2/8/2005	316.8
11/1/2004	380.16	12/21/2004	316.8	2/9/2005	316.8
11/2/2004	253.44	12/22/2004	316.8	2/10/2005	316.8
11/3/2004	253.44	12/23/2004	316.8	2/11/2005	253.44
11/4/2004	253.44	12/24/2004	316.8	2/12/2005	253.44
11/5/2004	380.16	12/25/2004	316.8	2/13/2005	253.44
11/6/2004	380.16	12/26/2004	316.8	2/14/2005	190.08
11/7/2004	380.16	12/27/2004	316.8	2/15/2005	253.44
11/8/2004	380.16	12/28/2004	316.8	2/16/2005	253.44
11/9/2004	380.16	12/29/2004	253.44	2/17/2005	253.44
11/10/2004	380.16	12/30/2004	253.44	2/18/2005	253.44
11/11/2004	316.8	12/31/2004	253.44	2/19/2005	253.44

Date	Flow (mgd)	Date	Flow (mgd)	Date	Flow (mgd)
2/20/2005	253.44	4/11/2005	63.36	5/31/2005	253.44
2/21/2005	253.44	4/12/2005	126.72	6/1/2005	253.44
2/22/2005	253.44	4/13/2005	126.72	6/2/2005	253.44
2/23/2005	253.44	4/14/2005	190.08	6/3/2005	253.44
2/24/2005	253.44	4/15/2005	380.16	6/4/2005	253.44
2/25/2005	253.44	4/16/2005	190.08	6/5/2005	253.44
2/26/2005	253.44	4/17/2005	380.16	6/6/2005	253.44
2/27/2005	211.2	4/18/2005	380.16	6/7/2005	253.44
2/28/2005	190.08	4/19/2005	380.16	6/8/2005	253.44
3/1/2005	0	4/20/2005	380.16	6/9/2005	253.44
3/2/2005	190.08	4/21/2005	380.16	6/10/2005	190.08
3/3/2005	380.16	4/22/2005	253.44	6/11/2005	190.08
3/4/2005	380.16	4/23/2005	63.36	6/12/2005	190.08
3/5/2005	380.16	4/24/2005	126.72	6/13/2005	506.88
3/6/2005	380.16	4/25/2005	126.72	6/14/2005	506.88
3/7/2005	380.16	4/26/2005	63.36	6/15/2005	506.88
3/8/2005	316.8	4/27/2005	63.36	6/16/2005	506.88
3/9/2005	380.16	4/28/2005	63.36	6/17/2005	506.88
3/10/2005	380.16	4/29/2005	63.36	6/18/2005	506.88
3/11/2005	253.44	4/30/2005	95.04	6/19/2005	506.88
3/12/2005	253.44	5/1/2005	253.44	6/20/2005	506.88
3/13/2005	190.08	5/2/2005	253.44	6/21/2005	506.88
3/14/2005	126.72	5/3/2005	337.92	6/22/2005	380.16
3/15/2005	126.72	5/4/2005	337.92	6/23/2005	506.88
3/16/2005	126.72	5/5/2005	506.88	6/24/2005	443.52
3/17/2005	126.72	5/6/2005	506.88	6/25/2005	380.16
3/18/2005	126.72	5/7/2005	506.88	6/26/2005	253.44
3/19/2005	126.72	5/8/2005	506.88	6/27/2005	253.44
3/20/2005	63.36	5/9/2005	506.88	6/28/2005	380.16
3/21/2005	126.72	5/10/2005	506.88	6/29/2005	380.16
3/22/2005	126.72	5/11/2005	506.88	6/30/2005	506.88
3/23/2005	126.72	5/12/2005	506.88	7/1/2005	506.88
3/24/2005	126.72	5/13/2005	253.44	7/2/2005	506.88
3/25/2005	126.72	5/14/2005	253.44	7/3/2005	506.88
3/26/2005	126.72	5/15/2005	253.44	7/4/2005	380.16
3/27/2005	126.72	5/16/2005	253.44	7/5/2005	380.16
3/28/2005	126.72	5/17/2005	253.44	7/6/2005	506.88
3/29/2005	126.72	5/18/2005	190.08	7/7/2005	506.88
3/30/2005	190.08	5/19/2005	316.8	7/8/2005	506.88
3/31/2005	126.72	5/20/2005	506.88	7/9/2005	506.88
4/1/2005	126.72	5/21/2005	506.88	7/10/2005	506.88
4/2/2005	126.72	5/22/2005	506.88	7/11/2005	506.88
4/3/2005	126.72	5/23/2005	506.88	7/12/2005	506.88
4/4/2005	253.44	5/24/2005	506.88	7/13/2005	506.88
4/5/2005	253.44	5/25/2005	506.88	7/14/2005	506.88
4/6/2005	253.44	5/26/2005	316.8	7/15/2005	506.88
4/7/2005	380.16	5/27/2005	253.44	7/16/2005	506.88
4/8/2005	380.16	5/28/2005	253.44	7/17/2005	506.88
4/9/2005	126.72	5/29/2005	253.44	7/18/2005	506.88
4/10/2005	63.36	5/30/2005	253.44	7/19/2005	506.88

Date	Flow (mgd)	Date	Flow (mgd)	Date	Flow (mgd)
7/20/2005	506.88	9/13/2005	253.44	11/7/2005	190.08
7/21/2005	506.88	9/14/2005	253.44	11/8/2005	253.44
7/22/2005	506.88	9/15/2005	316.8	11/9/2005	253.44
7/23/2005	506.88	9/16/2005	316.8	11/10/2005	253.44
7/24/2005	443.52	9/17/2005	253.44	11/11/2005	253.44
7/25/2005	443.52	9/18/2005	253.44	11/12/2005	253.44
7/26/2005	506.88	9/19/2005	316.8	11/13/2005	126.72
7/27/2005	506.88	9/20/2005	316.8	11/14/2005	126.72
7/28/2005	506.88	9/21/2005	316.8	11/15/2005	190.08
7/29/2005	506.88	9/22/2005	506.88	11/16/2005	316.8
7/30/2005	506.88	9/23/2005	506.88	11/17/2005	316.8
7/31/2005	506.88	9/24/2005	506.88	11/18/2005	316.8
8/1/2005	506.88	9/25/2005	506.88	11/19/2005	316.8
8/2/2005	506.88	9/26/2005	253.44	11/20/2005	253.44
8/3/2005	506.88	9/27/2005	253.44	11/21/2005	253.44
8/4/2005	506.88	9/28/2005	506.88	11/22/2005	316.8
8/5/2005	506.88	9/29/2005	506.88	11/23/2005	316.8
8/6/2005	506.88	9/30/2005	443.52	11/24/2005	316.8
8/7/2005	506.88	10/1/2005	443.52	11/25/2005	316.8
8/8/2005	443.52	10/2/2005	443.52	11/26/2005	126.72
8/9/2005	443.52	10/3/2005	443.52	11/27/2005	126.72
8/10/2005	506.88	10/4/2005	253.44	11/28/2005	253.44
8/11/2005	506.88	10/5/2005	316.8	11/29/2005	253.44
8/12/2005	506.88	10/6/2005	506.88	11/30/2005	253.44
8/13/2005	506.88	10/7/2005	506.88	12/1/2005	253.44
8/14/2005	443.52	10/8/2005	506.88	12/2/2005	253.44
8/15/2005	443.52	10/9/2005	380.16	12/3/2005	126.72
8/16/2005	506.88	10/10/2005	253.44	12/4/2005	126.72
8/17/2005	506.88	10/11/2005	253.44	12/5/2005	126.72
8/18/2005	506.88	10/12/2005	253.44	12/6/2005	126.72
8/19/2005	506.88	10/13/2005	253.44	12/7/2005	253.44
8/20/2005	506.88	10/14/2005	380.16	12/8/2005	253.44
8/21/2005	506.88	10/15/2005	380.16	12/9/2005	253.44
8/22/2005	506.88	10/16/2005	316.8	12/10/2005	253.44
8/23/2005	506.88	10/17/2005	253.44	12/11/2005	253.44
8/24/2005	506.88	10/18/2005	253.44	12/12/2005	240.24
8/25/2005	506.88	10/19/2005	190.08	12/13/2005	190.08
8/26/2005	506.88	10/20/2005	190.08	12/14/2005	190.08
8/27/2005	506.88	10/21/2005	253.44	12/15/2005	190.08
8/28/2005	506.88	10/22/2005	190.08	12/16/2005	190.08
8/29/2005	506.88	10/23/2005	190.08	12/17/2005	126.72
8/30/2005	506.88	10/24/2005	190.08	12/18/2005	126.72
8/31/2005	443.52	10/25/2005	190.08	12/19/2005	190.08
9/1/2005	380.16	10/26/2005	190.08	12/20/2005	190.08
9/2/2005	443.52	10/27/2005	190.08	12/21/2005	316.8
9/3/2005	506.88	10/28/2005	190.08	12/22/2005	253.44
9/4/2005	506.88	10/29/2005	190.08	12/23/2005	253.44
9/5/2005	506.88	10/30/2005	190.08	12/24/2005	126.72
9/6/2005	506.88	10/31/2005	316.8	12/25/2005	126.72
9/7/2005	506.88	11/1/2005	253.44	12/26/2005	126.72
9/8/2005	506.88	11/2/2005	253.44	12/27/2005	126.72
9/9/2005	506.88	11/3/2005	253.44	12/28/2005	126.72
9/10/2005	506.88	11/4/2005	253.44	12/29/2005	190.08
9/11/2005	316.8	11/5/2005	253.44	12/30/2005	253.44
9/12/2005	168.96	11/6/2005	190.08	12/31/2005	253.44

Appendix B

B1: Entrainment Data by Survey

B2: Source Water Data by Survey and Station

B3: Estimated Entrainment of Target Species by Survey

Appendix B-1. Larval fish and target invertebrate counts and mean concentrations (#/1000m^3) for entrainment surveys.

		Survey	1		2		3		4		5	
		Date	09/17/03		09/29/03		10/13/03		10/20/03		11/03/03	
		Sample Count	8		8		8		8		8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	96	265.4	84	214.6	81	229.0	40	106.4	30	88.0
Engraulis mordax	northern anchovy	1,152	20	53.6	30	82.6	32	77.6	30	76.1	4	10.4
Roncador stearnsi	spotfin croaker	912	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	446	7	17.0	7	19.4	4	11.2	6	16.0	1	3.0
Seriphus politus	queenfish	306	-	-	-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	244	1	3.2	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	161	-	-	1	2.2	-	-	-	-	9	27.6
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	98	-	-	1	2.0	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	96	1	2.4	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	87	-	-	-	-	2	5.4	2	5.0	3	11.0
Atherinopsis californiensis	jacksmelt	59	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	57	6	18.8	-	-	-	-	-	-	1	2.8
larval fish fragment	unidentified larval fishes	51	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	43	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39	-	-	-	-	-	-	-	-	-	-
Paralabrax spp.	sand bass	36	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30	1	3.2	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	27	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silversides	25	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	24	1	2.4	-	-	2	5.9	-	-	-	-
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20	-	-	-	-	2	5.1	-	-	-	-
Lepidogobius lepidus	bay goby	18	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	15	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	6	1	3.2	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	-	-	-	-	-	-	-	-	1	3.0
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	1	2.9	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	9	30.0	3	7.9	10	29.0	3	7.7	-	-
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	-	-	-	-	-	-
Cancer gracilis (meg.)	slender crab	31	-	-	-	-	-	-	-	-	1	2.8
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3	-	-	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**143**		**126**		**134**		**81**		**50**	

(continued)

Appendix B-1. (Continued).

	Survey Date Station Count		6 11/10/03 8		7 11/17/03 8		8 11/24/03 8		9 12/01/03 8		10 12/08/03 8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	1	2.6	81	186.6	28	66.8	41	121.0	10	26.8
Engraulis mordax	northern anchovy	1,152	11	31.1	11	25.7	2	5.1	3	7.8	9	24.0
Roncador stearnsi	spotfin croaker	912	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	446	2	5.2	16	37.7	17	43.4	4	12.9	10	26.8
Seriphus politus	queenfish	306	-	-	-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	244	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	161	10	28.1	-	-	2	5.0	2	5.3	2	5.1
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	98	2	5.5	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	96	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	87	1	3.1	1	2.3	3	8.5	2	5.7	-	-
Atherinopsis californiensis	jacksmelt	59	-	-	-	-	-	-	1	3.2	-	-
Engraulidae	anchovies	57	-	-	-	-	-	-	-	-	-	-
larval fish fragment	unidentified larval fishes	51	1	2.6	1	2.2	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	43	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39	-	-	-	-	-	-	1	2.6	-	-
Paralabrax spp.	sand bass	36	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	27	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silversides	25	-	-	-	-	-	-	-	-	1	2.9
Ilypnus gilberti	cheekspot goby	24	-	-	-	-	1	2.9	4	11.5	-	-
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20	-	-	1	2.3	-	-	1	3.2	1	2.7
Lepidogobius lepidus	bay goby	18	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16	-	-	-	-	1	2.4	-	-	2	5.1
Acanthogobius flavimanus	yellowfin goby	15	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	1	2.9	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	6	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	1	2.9	1	2.3	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	1	2.6	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	1	2.2	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	1	2.6	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	1	2.9	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	1	2.9	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	6	15.8	1	2.4	6	18.5	2	6.2	5	13.0
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	-	-	-	-	-	-
Cancer gracilis (meg.)	slender crab	31	-	-	-	-	1	2.9	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3	-	-	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**40**		**114**		**61**		**61**		**40**	

(continued)

Appendix B-1. (Continued).

		Survey	11		12		13		14		15	
		Date	12/15/03		12/22/03		12/29/03		01/05/04		01/12/04	
		Station Count	8		16		16		16		16	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	89	243.2	48	65.3	46	58.2	29	41.9	37	53.6
Engraulis mordax	northern anchovy	1,152	63	180.0	4	5.7	11	14.2	4	5.6	2	2.8
Roncador stearnsi	spotfin croaker	912	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	446	30	83.6	3	4.3	1	1.2	8	10.5	22	30.9
Seriphus politus	queenfish	306	-	-	-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	244	-	-	-	-	1	1.2	1	1.5	4	5.6
Hypsoblennius spp.	blennies	161	1	2.7	1	1.5	-	-	1	1.4	-	-
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	98	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	96	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	87	-	-	2	2.8	4	4.9	1	1.4	-	-
Atherinopsis californiensis	jacksmelt	59	-	-	-	-	-	-	1	1.5	1	1.4
Engraulidae	anchovies	57	-	-	-	-	-	-	-	-	-	-
larval fish fragment	unidentified larval fishes	51	2	6.4	2	2.8	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	43	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39	-	-	-	-	-	-	-	-	-	-
Paralabrax spp.	sand bass	36	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	27	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silversides	25	1	2.7	1	1.4	1	1.3	-	-	-	-
Ilypnus gilberti	cheekspot goby	24	1	2.7	1	1.4	1	1.1	3	4.2	-	-
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20	3	8.9	1	1.4	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	18	7	19.9	-	-	-	-	1	1.5	2	2.8
Leptocottus armatus	Pacific staghorn sculpin	16	2	5.7	-	-	1	1.2	-	-	4	5.7
Acanthogobius flavimanus	yellowfin goby	15	8	22.0	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	6	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	1	1.2	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	1	1.5
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	2	5.1	14	19.7	5	6.5	14	20.1	9	12.8
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	-	-	-	-	2	2.8
Cancer gracilis (meg.)	slender crab	31	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	2	2.7	-	-
Cancer spp. (meg.)	cancer crabs	3	-	-	-	-	1	1.2	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**209**		**77**		**73**		**65**		**84**	

(continued)

Appendix B-1. (Continued).

	Survey Date Station Count		16 01/19/04 8		17 01/26/04 8		18 02/02/04 8		19 02/09/04 8		20 02/17/04 8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	29	78.5	80	215.1	5	13.6	16	41.9	7	18.6
Engraulis mordax	northern anchovy	1,152	5	13.9	1	2.5	-	-	1	2.6	2	5.4
Roncador stearnsi	spotfin croaker	912	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	446	34	94.4	11	28.3	-	-	6	15.6	3	7.2
Seriphus politus	queenfish	306	-	-	-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	244	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	161	-	-	-	-	-	-	1	2.6	1	2.4
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	98	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	96	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	87	1	2.8	3	8.1	1	2.6	-	-	2	5.1
Atherinopsis californiensis	jacksmelt	59	8	22.7	1	2.2	5	13.6	1	2.5	3	8.4
Engraulidae	anchovies	57	-	-	-	-	-	-	-	-	-	-
larval fish fragment	unidentified larval fishes	51	3	8.8	-	-	-	-	1	2.5	-	-
Hypsypops rubicundus	garibaldi	43	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39	1	2.8	-	-	-	-	-	-	-	-
Paralabrax spp.	sand bass	36	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30	4	11.6	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	27	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silversides	25	1	2.7	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	24	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20	1	2.8	-	-	-	-	1	2.6	1	2.7
Lepidogobius lepidus	bay goby	18	2	5.9	-	-	-	-	1	2.9	2	5.3
Leptocottus armatus	Pacific staghorn sculpin	16	2	6.1	-	-	-	-	1	2.6	1	2.4
Acanthogobius flavimanus	yellowfin goby	15	-	-	5	12.4	-	-	-	-	1	2.3
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	1	3.1	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	1	2.8	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	6	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	1	2.5	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	3	8.5	5	13.7	6	17.2	1	2.4	2	5.0
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	-	-	-	-	-	-
Cancer gracilis (meg.)	slender crab	31	1	2.9	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3	-	-	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**97**		**106**		**17**		**31**		**25**	

(continued)

Appendix B-1. (Continued).

	Survey Date Station Count		21 02/23/04 8		22 03/03/04 2		23 03/08/04 8		24 03/15/04 8		25 03/22/04 8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	122	282.2	1	12.0	46	134.1	89	242.6	48	131.0
Engraulis mordax	northern anchovy	1,152	-	-	-	-	12	33.6	13	35.0	24	68.9
Roncador stearnsi	spotfin croaker	912	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	446	-	-	1	12.0	5	14.0	2	5.3	20	54.0
Seriphus politus	queenfish	306	-	-	-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	244	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	161	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	98	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	96	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	87	-	-	-	-	1	3.2	-	-	1	2.7
Atherinopsis californiensis	jacksmelt	59	4	9.6	-	-	-	-	-	-	7	19.8
Engraulidae	anchovies	57	-	-	-	-	-	-	-	-	-	-
larval fish fragment	unidentified larval fishes	51	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	43	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39	1	2.5	-	-	-	-	-	-	-	-
Paralabrax spp.	sand bass	36	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30	-	-	1	12.0	-	-	-	-	-	-
Oxyjulis californica	senorita	27	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silversides	25	-	-	-	-	1	3.0	3	9.1	-	-
Ilypnus gilberti	cheekspot goby	24	-	-	-	-	1	3.0	2	4.8	1	3.3
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20	1	2.8	-	-	1	3.0	-	-	1	3.3
Lepidogobius lepidus	bay goby	18	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16	2	4.5	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	15	1	2.0	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	4	8.7	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	6	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	3	7.0	-	-	-	-	9	24.7	33	92.5
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	-	-	-	-	-	-
Cancer gracilis (meg.)	slender crab	31	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3	-	-	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**138**		**3**		**67**		**118**		**135**	

(continued)

Appendix B-1. (Continued).

		Survey	26		27		28		29		30	
		Date	03/26/04		04/05/04		04/12/04		04/19/04		04/23/04	
		Station Count	0		8		8		6		6	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458			32	75.1	13	31.7	48	158.3	1	3.0
Engraulis mordax	northern anchovy	1,152			13	31.6	18	44.4	26	87.8	15	51.7
Roncador stearnsi	spotfin croaker	912			-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	446			1	2.6	35	83.1	29	97.6	17	56.0
Seriphus politus	queenfish	306			-	-	-	-	-	-	-	-
Sciaenidae unid.	croakers	244			-	-	2	4.5	1	3.2	2	8.1
Hypsoblennius spp.	blennies	161			-	-	1	2.2	3	10.4	2	7.5
Xenistius californiensis	salema	153			-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136			2	4.5	-	-	-	-	2	7.0
Paralichthys californicus	California halibut	98			-	-	1	2.3	1	3.7	9	33.1
Cheilotrema saturnum	black croaker	96			-	-	-	-	-	-	2	7.1
Hypsopsetta guttulata	diamond turbot	87			1	2.5	5	11.8	2	6.5	1	3.5
Atherinopsis californiensis	jacksmelt	59			1	2.5	1	2.4	-	-	-	-
Engraulidae	anchovies	57			2	4.5	-	-	-	-	-	-
larval fish fragment	unidentified larval fishes	51			-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	43			-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43			-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39			1	2.7	-	-	1	3.2	-	-
Paralabrax spp.	sand bass	36			-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30			2	4.2	-	-	-	-	2	7.0
Oxyjulis californica	senorita	27			1	2.4	-	-	-	-	-	-
Atherinopsidae	silversides	25			-	-	-	-	3	10.5	-	-
Ilypnus gilberti	cheekspot goby	24			1	2.7	1	2.6	1	3.6	-	-
Umbrina roncador	yellowfin croaker	24			-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20			1	2.5	-	-	1	3.1	-	-
Lepidogobius lepidus	bay goby	18			-	-	1	2.3	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16			-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	15			-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15			-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14			-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13			-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	12			-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12			-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12			-	-	1	2.3	-	-	-	-
Diaphus theta	California headlight fish	11			-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10			-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8			-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	6			-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5			-	-	-	-	-	-	-	-
Haemulidae	grunts	5			-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5			-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5			-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4			-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3			-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3			-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3			-	-	-	-	1	3.1	-	-
Clevelandia ios	arrow goby	2			-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2			-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2			-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2			-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2			-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2			-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2			-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1			-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1			-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1			-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1			-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1			-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1			-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1			-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1			-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1			-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1			-	-	1	2.2	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1			-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1			-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1			-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1			-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1			-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1			-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1			-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1			-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1			-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1			-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399			114	295.0	416	1,053.7	54	187.0	77	275.6
Cancer anthonyi (meg.)	yellow crab	77			-	-	-	-	1	3.2	1	3.5
Cancer gracilis (meg.)	slender crab	31			-	-	-	-	1	3.6	-	-
Cancer antennarius (meg.)	brown rock crab	18			-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3			-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3			-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2			-	-	-	-	2	7.3	-	-
	Total:	**17,489**			**172**		**496**		**175**		**131**	

(continued)

Appendix B-1. (Continued).

	Survey		31		32		33		34		35	
	Date		05/03/04		05/07/04		05/17/04		05/24/04		06/01/04	
	Station Count		8		6		8		8		8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	145	356.0	58	191.6	32	93.5	20	50.6	29	74.1
Engraulis mordax	northern anchovy	1,152	75	186.6	17	55.2	23	66.3	68	160.5	128	365.8
Roncador stearnsi	spotfin croaker	912	2	4.8	-	-	7	18.3	11	26.7	-	-
Genyonemus lineatus	white croaker	446	56	137.9	35	117.6	25	71.7	16	39.2	6	17.5
Seriphus politus	queenfish	306	-	-	-	-	11	31.1	2	4.5	-	-
Sciaenidae unid.	croakers	244	4	10.0	-	-	17	46.7	26	64.1	1	2.0
Hypsoblennius spp.	blennies	161	-	-	4	15.2	9	25.5	7	17.9	3	6.8
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	3	8.6	-	-	2	6.1	3	9.2	-	-
Paralichthys californicus	California halibut	98	3	7.6	-	-	1	3.0	2	5.0	2	4.0
Cheilotrema saturnum	black croaker	96	-	-	-	-	7	20.2	1	2.3	-	-
Hypsopsetta guttulata	diamond turbot	87	-	-	2	7.1	3	8.4	-	-	-	-
Atherinopsis californiensis	jacksmelt	59	23	57.4	2	6.9	-	-	-	-	-	-
Engraulidae	anchovies	57	1	2.6	4	14.7	1	3.0	7	18.8	3	5.9
larval fish fragment	unidentified larval fishes	51	1	2.5	-	-	3	8.9	2	4.7	-	-
Hypsypops rubicundus	garibaldi	43	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	39	-	-	-	-	1	2.3	-	-	3	6.9
Paralabrax spp.	sand bass	36	-	-	-	-	2	5.6	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	30	1	3.0	-	-	3	9.0	1	2.6	-	-
Oxyjulis californica	senorita	27	-	-	-	-	2	4.9	1	2.3	-	-
Atherinopsidae	silversides	25	7	17.5	-	-	-	-	1	2.3	5	12.8
Ilypnus gilberti	cheekspot goby	24	3	7.5	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	1	2.6	-	-
Gillichthys mirabilis	longjaw mudsucker	20	2	5.0	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	18	1	2.6	1	3.5	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	15	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	15	34.4
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	-	-	1	2.8	2	6.0
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	-	-	-	-	1	3.0	-	-	-	-
Pleuronichthys spp.	turbots	12	2	4.9	-	-	-	-	3	8.2	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	4	10.4	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	1	3.0	-	-	-	-
Myctophidae unid.	lanternfishes	6	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	5	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	1	3.5	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	2	4.5	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	1	2.5	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	1	2.3	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	1	2.3
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	78	175.1	292	1,020.9	119	346.1	216	573.1	16	41.1
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	1	3.0	-	-	2	4.6
Cancer gracilis (meg.)	slender crab	31	-	-	-	-	-	-	-	-	8	23.3
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	3	8.6
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3	1	2.5	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**415**		**416**		**271**		**390**		**227**	

(continued)

Appendix B-1. (Continued).

	Survey		36		37		38		39		40	
	Date		06/07/04		06/14/04		06/21/04		06/28/04		07/06/04	
	Station Count		8		8		8		8		8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	9	23.7	28	92.1	54	139.9	43	120.9	185	490.1
Engraulis mordax	northern anchovy	1,152	4	10.7	45	134.4	91	226.3	82	217.3	16	42.4
Roncador stearnsi	spotfin croaker	912	-	-	18	59.1	-	-	2	4.5	152	406.7
Genyonemus lineatus	white croaker	446	1	2.3	1	2.5	2	4.6	-	-	1	2.9
Seriphus politus	queenfish	306	-	-	7	24.4	-	-	3	8.1	2	5.8
Sciaenidae unid.	croakers	244	-	-	69	205.0	3	7.4	27	67.7	30	74.9
Hypsoblennius spp.	blennies	161	6	15.8	8	25.2	3	7.7	41	104.7	8	22.3
Xenistius californiensis	salema	153	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	2	5.1	68	224.3	-	-	38	102.2	-	-
Paralichthys californicus	California halibut	98	-	-	41	125.8	1	2.2	4	10.1	1	3.5
Cheilotrema saturnum	black croaker	96	-	-	3	8.1	-	-	3	7.2	3	9.0
Hypsopsetta guttulata	diamond turbot	87	-	-	-	-	-	-	-	-	2	5.1
Atherinopsis californiensis	jacksmelt	59	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	57	-	-	10	33.5	2	5.5	10	28.6	-	-
larval fish fragment	unidentified larval fishes	51	-	-	6	20.6	-	-	4	12.6	-	-
Hypsypops rubicundus	garibaldi	43	-	-	5	15.7	-	-	35	82.9	-	-
Menticirrhus undulatus	California corbina	43	-	-	2	5.0	-	-	10	27.4	1	2.2
larval/post-larval fish unid.	larval fishes	39	-	-	11	29.2	9	25.6	6	15.2	-	-
Paralabrax spp.	sand bass	36	-	-	9	31.2	-	-	10	24.2	1	2.1
Citharichthys stigmaeus	speckled sanddab	30	-	-	-	-	-	-	4	10.1	1	2.6
Oxyjulis californica	senorita	27	-	-	-	-	-	-	20	55.3	-	-
Atherinopsidae	silversides	25	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	24	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	24	-	-	21	64.5	1	2.2	1	2.3	-	-
Gillichthys mirabilis	longjaw mudsucker	20	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	18	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	15	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	-	-	1	3.2	-	-
Leuresthes tenuis	California grunion	13	-	-	-	-	1	2.2	3	9.0	3	8.5
Paralabrax clathratus	kelp bass	12	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	12	-	-	6	17.5	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	-	-	-	-	9	22.5
Gibbonsia spp.	clinid kelpfishes	10	-	-	-	-	-	-	1	2.3	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	-	-	-	-	2	5.6
Myctophidae unid.	lanternfishes	6	-	-	-	-	-	-	-	-	2	5.8
Atractoscion nobilis	white seabass	5	-	-	2	4.8	-	-	-	-	-	-
Haemulidae	grunts	5	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	5	-	-	2	5.0	-	-	-	-	-	-
Pleuronectidae unid.	flounders	5	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	2	5.0	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	2	5.8	-	-
Ophidion scrippsae	basketweave cusk-eel	2	1	3.3	-	-	-	-	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	1	3.9	-	-	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	1	2.3	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	-	-	1	3.2	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	1	2.5	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	-	-	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	1	2.3	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	1	3.8	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	1	3.0	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	1	3.2	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	1	2.8	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	1	2.8	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	515	1,357.4	1,142	3,633.1	773	2,004.8	1,674	4,775.0	2,349	6,305.5
Cancer anthonyi (meg.)	yellow crab	77	-	-	-	-	-	-	-	-	1	2.8
Cancer gracilis (meg.)	slender crab	31	4	11.2	1	3.8	1	2.4	1	3.0	-	-
Cancer antennarius (meg.)	brown rock crab	18	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	3	-	-	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**546**		**1,509**		**941**		**2,029**		**2,769**	

(continued)

Appendix B-1. (Continued).

	Survey		41		42		43		44		45	
	Date		07/12/04		07/19/04		07/26/04		08/24/04		08/31/04	
	Station Count		8		8		8		8		8	
Taxon	**Common Name**	**Total**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**	**Count**	**Mean Conc.**
Gobiidae unid.	gobies	2,458	160	428.6	112	298.9	70	197.9	118	287.0	117	330.9
Engraulis mordax	northern anchovy	1,152	72	187.5	45	119.4	78	219.8	18	46.7	24	64.9
Roncador stearnsi	spotfin croaker	912	-	-	-	-	3	8.2	716	1,803.9	1	2.7
Genyonemus lineatus	white croaker	446	-	-	-	-	-	-	-	-	1	2.4
Seriphus politus	queenfish	306	28	74.1	10	28.9	7	18.7	111	281.3	125	322.4
Sciaenidae unid.	croakers	244	-	-	13	34.6	6	16.4	24	56.2	12	27.5
Hypsoblennius spp.	blennies	161	5	12.2	15	40.2	3	8.6	9	23.1	3	7.8
Xenistius californiensis	salema	153	-	-	-	-	1	2.5	152	336.1	-	-
larvae, unidentified yolksac	unidentified yolksac larvae	136	2	5.2	-	-	3	7.8	8	19.4	3	6.7
Paralichthys californicus	California halibut	98	3	8.0	1	2.5	8	21.4	14	35.9	3	6.0
Cheilotrema saturnum	black croaker	96	-	-	-	-	7	18.5	68	161.3	1	2.0
Hypsopsetta guttulata	diamond turbot	87	-	-	1	2.5	-	-	40	101.1	-	-
Atherinopsis californiensis	jacksmelt	59	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	57	2	4.8	-	-	8	21.2	-	-	-	-
larval fish fragment	unidentified larval fishes	51	1	2.4	3	8.4	2	5.2	11	24.1	8	18.0
Hypsypops rubicundus	garibaldi	43	-	-	-	-	3	8.6	-	-	-	-
Menticirrhus undulatus	California corbina	43	-	-	-	-	-	-	30	67.9	-	-
larval/post-larval fish unid.	larval fishes	39	-	-	-	-	4	11.1	-	-	-	-
Paralabrax spp.	sand bass	36	-	-	-	-	7	19.1	4	9.7	3	7.8
Citharichthys stigmaeus	speckled sanddab	30	-	-	-	-	9	23.4	-	-	1	3.1
Oxyjulis californica	senorita	27	-	-	-	-	3	8.1	-	-	-	-
Atherinopsidae	silversides	25	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	24	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	24	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	20	-	-	-	-	-	-	-	-	1	3.9
Lepidogobius lepidus	bay goby	18	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	16	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	15	-	-	-	-	-	-	-	-	-	-
Syngnathidae unid.	pipefishes	15	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	14	-	-	-	-	6	15.6	7	15.9	-	-
Leuresthes tenuis	California grunion	13	-	-	1	3.2	-	-	-	-	2	5.7
Paralabrax clathratus	kelp bass	12	-	-	-	-	7	18.8	-	-	5	10.7
Pleuronichthys ritteri	spotted turbot	12	-	-	1	2.9	1	2.6	1	2.2	1	2.0
Pleuronichthys spp.	turbots	12	-	-	1	2.5	2	5.7	3	8.2	-	-
Diaphus theta	California headlight fish	11	-	-	-	-	2	5.3	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	10	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	8	-	-	-	-	3	8.0	1	2.7	-	-
Myctophidae unid.	lanternfishes	6	-	-	-	-	1	2.7	1	2.7	1	2.7
Atractoscion nobilis	white seabass	5	-	-	-	-	2	6.0	1	2.2	-	-
Haemulidae	grunts	5	-	-	-	-	1	2.8	3	6.6	1	2.7
Hypsoblennius jenkinsi	mussel blenny	5	-	-	-	-	-	-	2	5.3	1	2.0
Pleuronectidae unid.	flounders	5	-	-	-	-	1	2.8	-	-	1	2.0
Sardinops sagax	Pacific sardine	4	-	-	-	-	-	-	-	-	4	10.9
Labrisomidae unid.	labrisomid kelpfishes	3	-	-	-	-	-	-	-	-	1	2.7
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	2	4.4	1	3.1
Stenobrachius leucopsarus	northern lampfish	3	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	2	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	2	-	-	-	-	1	2.5	-	-	-	-
Paralichthyidae unid.	lefteye flounders &	2	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	2	-	-	-	-	1	2.5	-	-	-	-
Scomber japonicus	Pacific mackerel	2	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	2	-	-	-	-	1	2.5	-	-	-	-
Agonidae unid.	poachers	1	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	1	2.7	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	1	-	-	-	-	1	2.8	-	-	-	-
larval fish - damaged	unidentified larval fishes	1	-	-	-	-	-	-	-	-	1	2.7
Merluccius productus	Pacific hake	1	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_De	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	-	-	-	-
Strongylura exilis	California needlefish	1	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	1	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	1	-	-	-	-	-	-	1	2.6	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	1	-	-	-	-	-	-	-	-	-	-
Invertebrates												
Emerita analoga (zoea)	mole crab	10,399	1,072	2,954.4	60	161.6	236	683.7	1,042	2,718.1	3	8.6
Cancer anthonyi (meg.)	yellow crab	77	22	59.8	3	7.7	3	9.0	41	106.7	-	-
Cancer gracilis (meg.)	slender crab	31	3	8.0	3	7.7	2	5.3	-	-	4	9.9
Cancer antennarius (meg.)	brown rock crab	18	3	8.2	4	12.2	1	3.2	4	10.1	3	8.1
Cancer productus (meg.)	red rock crab	3	-	-	-	-	-	-	1	2.6	-	-
Cancer spp. (meg.)	cancer crabs	3	1	2.7	-	-	-	-	-	-	-	-
Emerita analoga (meg.)	mole crab	2	-	-	-	-	-	-	-	-	-	-
	Total:	**17,489**	**1,375**		**273**		**494**		**2,433**		**332**	

Appendix B-2. Larval fish and target invertebrate counts and mean concentrations (#/1000m^3) for source water surveys.

Survey: 1		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 09/17/03		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
		Survey		**Mean**		**Mean**		**Mean**		**Mean**		**Mean**		**Mean**
Taxon	**Common Name**	**Count**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**
Gobiidae unid.	gobies	534	246	549.5	205	543.6	16	32.4	6	15.0	36	89.4	25	60.9
Engraulis mordax	northern anchovy	49	13	30.9	4	10.7	10	24.3	7	17.6	9	22.4	6	15.8
Seriphus politus	queenfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	27	2	3.8	4	9.6	9	20.1	2	4.5	5	12.2	5	13.0
Sciaenidae unid.	croaker	7	3	7.8	1	2.8	-	-	2	5.2	-	-	1	2.8
Paralichthys californicus	California halibut	11	1	1.9	-	-	2	6.5	6	14.5	1	2.4	1	2.6
Hypsoblennius spp.	blennies	20	-	-	2	6.2	5	15.4	11	25.4	1	2.3	1	2.8
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	12	1	2.7	1	2.8	3	4.6	1	2.1	4	9.8	2	5.4
Citharichthys stigmaeus	speckled sanddab	1	1	2.1	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	42	41	110.0	-	-	-	-	1	2.8	-	-	-	-
Lepidogobius lepidus	bay goby	5	-	-	-	-	4	8.6	1	2.5	-	-	-	-
larval fish fragment	unidentified larval fishes	6	-	-	1	2.4	-	-	2	3.9	2	4.9	1	2.8
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	1	-	-	-	-	-	-	1	3.1	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	8	-	-	-	-	2	6.8	6	11.8	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	10	-	-	-	-	1	2.5	1	2.6	1	2.9	7	17.2
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	3	1	3.2	-	-	1	3.1	1	3.1	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	1	-	-	-	-	-	-	1	2.2	-	-	-	-
Ilypnus gilberti	cheekspot goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	1	1.5	-	-	-	-	-	-
Pleuronichthys spp.	turbots	-	-	-	-	-	-	-	-	-	-	-	-	-
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	1	1	2.7	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	1	1	1.9	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	2	-	-	-	-	-	-	-	-	-	-	2	5.1
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	1	-	-	-	-	-	-	1	2.6	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	4	-	-	-	-	-	-	4	7.7	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	3	-	-	1	2.4	1	3.1	-	-	1	2.5	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 1 (continued)		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 09/17/03		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	3	-	-	-	-	-	-	3	5.8	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	1	-	-	-	-	-	-	-	-	1	2.9	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	1	-	-	-	-	-	-	1	2.2	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	1	-	-	-	-	1	1.6	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	1	1	1.9	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	1	-	-	-	-	-	-	-	-	-	-	1	2.2
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	73	2	5.4	4	10.9	13	30.6	-	-	53	109.3	1	2.2
Cancer gracilis (meg.)	slender crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	1	-	-	-	-	-	-	-	-	1	2.3	-	-
	Total:	832	314		223		69		58		115		53	

Appendix B-2. (Continued).

Survey: 3	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 10/13/2003	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Gobiidae unid.	gobies	697	51	146.3	602	1,695.1	1	2.5	2	5.0	28	74.9	13	37.5
Engraulis mordax	northern anchovy	178	42	107.5	32	91.1	11	28.3	41	117.8	42	116.3	10	26.6
Seriphus politus	queenfish	4	-	-	4	11.8	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	30	2	5.4	13	36.5	3	9.0	8	24.5	4	10.6	-	-
Sciaenidae unid.	croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	3	-	-	-	-	-	-	3	10.1	-	-	-	-
Hypsoblennius spp.	blennies	20	-	-	-	-	11	29.1	-	-	2	6.6	7	20.7
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	1	1	2.3	-	-	-	-	-	-	-	-	-	-
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	23	4	11.6	3	8.4	2	5.9	1	3.3	5	16.1	8	24.6
Citharichthys stigmaeus	speckled sanddab	3	-	-	-	-	-	-	2	4.9	-	-	1	2.5
Engraulidae	anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	2	-	-	1	2.3	-	-	1	2.5	-	-	-	-
larval fish fragment	unidentified larval fishes	1	-	-	1	2.3	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	2	-	-	-	-	-	-	2	5.1	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	-	-	1	2.6	1	3.2	1	3.6
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius califoriensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	2	-	-	-	-	1	2.4	1	3.6	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	1	-	-	1	2.9	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	2	-	-	1	2.9	1	3.0	-	-	-	-	-	-
Pleuronichthys spp.	turbots	3	-	-	1	2.6	-	-	1	3.3	1	3.1	-	-
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	1	-	-	-	-	-	-	1	3.6	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	1	-	-	-	-	-	-	-	-	-	-	1	2.5
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	1	-	-	-	-	-	-	-	-	1	2.5	-	-
Gobiesox spp.	clingfishes	1	-	-	1	3.0	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 3 (continued)		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 10/13/2003		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	1	3.2	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	116	15	40.7	19	58.8	2	5.5	3	9.5	9	24.9	68	228.1
Cancer gracilis (meg.)	slender crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	1	1	2.0	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	1,097	116		680		32		67		93		109	

Appendix B-2. (Continued).

Survey: 6	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 11/10/2003	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Gobiidae unid.	gobies	10	1	3.0	3	8.4	1	2.5	1	2.7	2	5.4	2	5.7
Engraulis mordax	northern anchovy	99	17	46.8	15	43.3	15	38.1	18	47.0	13	35.5	21	58.7
Seriphus politus	queenfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	97	3	7.8	4	12.1	39	104.9	14	38.1	14	40.4	23	65.5
Sciaenidae unid.	croaker	6	-	-	-	-	3	7.3	1	2.4	1	2.8	1	2.7
Paralichthys californicus	California halibut	18	1	2.6	-	-	5	12.5	6	15.6	3	8.5	3	8.8
Hypsoblennius spp.	blennies	35	4	9.6	2	5.7	7	18.2	-	-	7	19.0	15	41.1
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	6	-	-	1	2.5	-	-	-	-	2	5.5	3	7.7
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	11	1	2.6	-	-	3	8.7	-	-	1	2.7	6	17.4
Citharichthys stigmaeus	speckled sanddab	35	2	5.5	-	-	13	33.5	13	33.4	-	-	7	18.8
Engraulidae	anchovies	2	-	-	1	2.9	-	-	1	2.4	-	-	-	-
Lepidogobius lepidus	bay goby	1	-	-	-	-	-	-	1	2.4	-	-	-	-
larval fish fragment	unidentified larval fishes	3	-	-	-	-	-	-	-	-	-	-	3	7.7
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	3	-	-	-	-	2	4.8	-	-	1	2.6	-	-
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	1	2.8	1	3.1	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	11	3	8.3	-	-	2	5.6	1	2.7	3	8.3	2	5.4
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	1	-	-	1	2.5	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	1	-	-	-	-	-	-	-	-	-	-	1	2.8
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	1	-	-	-	-	-	-	-	-	1	3.1	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	9	-	-	1	3.0	3	8.2	4	11.5	1	2.6	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	2	-	-	-	-	-	-	1	2.3	1	2.8	-	-
Citharichthys spp.	sanddabs	7	-	-	-	-	1	2.5	3	9.0	2	5.9	1	2.4
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	2	-	-	-	-	-	-	-	-	1	2.6	1	3.1
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	1	-	-	-	-	-	-	-	-	1	2.7	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 6 (continued)	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 11/10/2003	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	3	-	-	-	-	-	-	1	2.7	2	5.6	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	2	-	-	-	-	2	5.4	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	2	-	-	-	-	-	-	1	2.5	1	2.6	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	1	-	-	-	-	1	2.9	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	1	-	-	-	-	-	-	1	3.1	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	11	2	5.2	-	-	-	-	3	7.6	1	2.7	5	14.4
Cancer gracilis (meg.)	slender crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	383	34		28		98		71		58		94	

Appendix B-2. (Continued).

Survey: 10			D2		D4		O2		O4		U2		U4	
Start Date: 12/8/2003	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Gobiidae unid.	gobies	361	72	192.7	246	634.4	20	56.1	3	7.9	14	38.0	6	15.6
Engraulis mordax	northern anchovy	37	15	39.9	6	14.7	4	11.5	3	8.0	7	18.9	2	5.1
Seriphus politus	queenfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	142	12	29.8	46	119.5	39	107.8	26	68.9	9	24.4	10	26.1
Sciaenidae unid.	croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	16	1	2.8	4	9.9	3	8.2	1	2.8	3	8.4	4	10.5
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	13	2	5.1	9	22.2	1	2.8	-	-	-	-	1	2.8
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	3	-	-	-	-	1	3.0	1	2.8	1	2.8	-	-
Citharichthys stigmaeus	speckled sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	20	-	-	1	2.7	15	44.9	4	10.7	-	-	-	-
larval fish fragment	unidentified larval fishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	1	-	-	-	-	-	-	-	-	1	2.7	-	-
Pleuronichthys verticalis	hornyhead turbot	1	-	-	-	-	-	-	1	2.8	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	1	-	-	-	-	1	2.5	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	17	2	4.8	11	28.2	-	-	1	2.6	-	-	3	8.1
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	6	2	4.9	4	10.3	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	1	1	2.2	-	-	-	-	-	-	-	-	-	-
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	17	5	13.4	6	16.4	2	6.0	-	-	3	8.2	1	2.5
Acanthogobius flavimanus	yellowfin goby	11	-	-	1	2.5	10	30.0	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	2	-	-	-	-	-	-	2	5.1	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	1	1	2.8	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	-	-	-	-	-	-	1	2.9	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 10 (continued)			**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 12/8/2003	**Sample Count**		**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	1	2.6	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	54	17	39.2	1	2.7	6	16.4	4	10.8	16	42.5	10	28.2
Cancer gracilis (meg.)	slender crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	4	1	2.6	2	5.2	-	-	1	2.8	-	-	-	-
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	710	132		337		102		48		54		37	

Appendix B-2. (Continued).

Survey: 14		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 01/05/04		**Sample Count**	**16**		**16**		**16**		**16**		**16**		**16**	
		Survey		**Mean**		**Mean**		**Mean**		**Mean**		**Mean**		**Mean**
Taxon	**Common Name**	**Count**	**Count**	**Conc.**	**Count**	**Conc.**	**Count**	**Conc.**	**Count**	**Conc.**	**Count**	**Conc.**	**Count**	**Conc.**
Gobiidae unid.	gobies	152	58	81.0	69	94.4	5	7.3	1	1.4	9	12.4	10	13.4
Engraulis mordax	northern anchovy	19	9	12.5	5	6.6	2	2.8	-	-	2	2.5	1	1.4
Seriphus politus	queenfish	3	-	-	1	1.4	2	3.1	-	-	-	-	-	-
Genyonemus lineatus	white croaker	51	15	20.3	4	5.3	7	10.0	13	18.6	9	12.4	3	4.1
Sciaenidae unid.	croaker	12	7	9.5	4	5.5	1	1.6	-	-	-	-	-	-
Paralichthys californicus	California halibut	2	-	-	-	-	-	-	2	2.6	-	-	-	-
Hypsoblennius spp.	blennies	11	4	5.5	2	2.6	1	1.4	1	1.2	1	1.4	2	2.8
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	7	1	1.5	2	2.7	1	1.4	-	-	1	1.3	2	2.8
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	19	-	-	2	2.9	-	-	3	4.4	14	19.2	-	-
Citharichthys stigmaeus	speckled sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	7	-	-	-	-	3	4.5	4	5.9	-	-	-	-
larval fish fragment	unidentified larval fishes	1	1	1.4	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	8	3	4.6	1	1.2	2	2.9	1	1.4	-	-	1	1.4
larval/post-larval fish unid.	larval fishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	3	-	-	2	2.5	-	-	-	-	-	-	1	1.4
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	-	-	-	-	-	-	-	-	-	-	-	-	-
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	2	1	1.4	-	-	-	-	1	1.6	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	1	-	-	-	-	-	-	1	1.6	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	1	-	-	1	1.4	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	1	-	-	1	1.2	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	1	1	1.4	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	1	1.6	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 14 (continued)	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 01/05/04	Sample Count		16		16		16		16		16		16	
		Survey		Mean		Mean		Mean		Mean		Mean		Mean
Taxon	**Common Name**	**Count**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**	**Count**	**Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	1	-	-	1	1.3	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	10	6	8.0	1	1.5	-	-	-	-	1	1.5	2	2.6
Cancer gracilis (meg.)	slender crab	2	-	-	-	-	1	1.4	-	-	-	-	1	1.4
Cancer antennarius (meg.)	brown rock crab	1	-	-	-	-	-	-	-	-	1	1.4	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	316	106		96		26		27		38		23	

Appendix B-2. (Continued).

Survey: 19	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 02/09/04	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Gobiidae unid.	gobies	314	156	388.0	131	366.4	2	5.8	1	2.8	18	44.8	6	15.6
Engraulis mordax	northern anchovy	8	1	2.7	4	11.6	1	2.8	-	-	1	2.4	1	2.3
Seriphus politus	queenfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	33	11	26.6	7	18.6	6	15.0	-	-	4	10.8	5	12.4
Sciaenidae unid.	croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	1	1	2.4	-	-	-	-	-	-	-	-	-	-
Hypsoblennius spp.	blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	20	2	4.6	14	39.2	1	2.8	2	5.6	-	-	1	2.3
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	5	2	4.8	1	2.8	-	-	-	-	-	-	2	5.7
Citharichthys stigmaeus	speckled sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	6	3	7.5	1	2.8	-	-	-	-	2	4.9	-	-
larval fish fragment	unidentified larval fishes	1	-	-	-	-	1	2.4	-	-	-	-	-	-
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	1	-	-	-	-	1	2.9	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	3	2	4.8	-	-	-	-	-	-	1	2.5	-	-
Pleuronichthys spp.	turbots	-	-	-	-	-	-	-	-	-	-	-	-	-
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	5	1	2.5	3	8.2	-	-	-	-	-	-	1	2.7
Acanthogobius flavimanus	yellowfin goby	4	1	2.5	3	8.4	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	1	-	-	-	-	-	-	-	-	-	-	1	2.3
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	1	1	2.5	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 19 (continued)	**Stations**		**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 02/09/04	**Sample Count**		**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	4	2	4.8	2	4.9	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-	1	2.4	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonii	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	1	1	2.4	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	8	-	-	3	8.1	-	-	1	2.8	4	10.5	-	-
Cancer gracilis (meg.)	slender crab	2	-	-	-	-	-	-	2	5.7	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	1	-	-	-	-	-	-	-	-	-	-	1	2.3
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	420	184		169		12		7		30		18	

Appendix B-2. (Continued).

Survey: 23	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 03/08/04	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Gobiidae unid.	gobies	461	205	565.5	224	619.4	3	8.0	2	4.5	19	55.9	8	23.0
Engraulis mordax	northern anchovy	42	13	35.8	8	20.4	3	7.9	-	-	16	46.3	2	5.7
Seriphus politus	queenfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	30	1	2.8	8	20.3	5	13.7	3	8.4	4	11.6	9	23.5
Sciaenidae unid.	croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthys californicus	California halibut	3	-	-	-	-	-	-	3	8.6	-	-	-	-
Hypsoblennius spp.	blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	4	1	3.2	1	2.3	-	-	-	-	2	4.8	-	-
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	16	8	22.6	1	2.2	-	-	1	2.4	1	2.7	5	12.9
Citharichthys stigmaeus	speckled sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Engraulidae	anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Lepidogobius lepidus	bay goby	3	-	-	2	5.0	-	-	-	-	-	-	1	2.9
larval fish fragment	unidentified larval fishes	2	-	-	-	-	-	-	-	-	2	6.2	-	-
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	1	-	-	1	2.5	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	2	2	5.5	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	8	3	8.2	4	10.9	-	-	-	-	1	3.1	-	-
Pleuronichthys spp.	turbots	1	-	-	1	3.0	-	-	-	-	-	-	-	-
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	1	-	-	1	2.8	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	5	3	8.4	2	5.3	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	2	1	2.8	-	-	1	2.7	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	-	-	1	2.2	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 23 (continued)		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 03/08/04		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	2	-	-	2	5.7	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	15	8	21.5	3	7.3	1	3.2	1	2.2	1	2.1	1	2.7
Cancer gracilis (meg.)	slender crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	599	245		258		13		11		46		26	

Appendix B-2. (Continued).

Survey: 27			D2		D4		O2		O4		U2		U4	
Start Date: 04/05/04	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Gobiidae unid.	gobies	104	11	25.4	8	21.2	2	5.0	4	11.0	34	86.5	45	116.7
Engraulis mordax	northern anchovy	139	11	27.1	19	48.0	23	50.7	43	111.9	32	84.1	11	28.3
Seriphus politus	queenfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Genyonemus lineatus	white croaker	25	1	2.4	3	7.2	8	19.6	8	21.5	2	5.2	3	7.2
Sciaenidae unid.	croaker	3	1	2.4	1	2.2	1	2.1	-	-	-	-	-	-
Paralichthys californicus	California halibut	4	1	2.7	-	-	3	6.6	-	-	-	-	-	-
Hypsoblennius spp.	blennies	1	-	-	-	-	1	2.1	-	-	-	-	-	-
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	10	2	4.9	2	5.0	-	-	-	-	-	-	6	15.3
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	5	4	9.6	-	-	-	-	1	2.5	-	-	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	3	-	-	-	-	-	-	3	8.2	-	-	-	-
Engraulidae	anchovies	9	6	15.2	1	2.3	-	-	-	-	1	2.4	1	2.6
Lepidogobius lepidus	bay goby	1	-	-	-	-	-	-	1	2.8	-	-	-	-
larval fish fragment	unidentified larval fishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	2	-	-	-	-	-	-	2	5.5	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Typhlogobius californiensis	blind goby	49	-	-	-	-	-	-	-	-	1	2.9	48	124.6
Oxyjulis californica	senorita	-	-	-	-	-	-	-	-	-	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius califoriensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	1	-	-	-	-	1	2.4	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	2	-	-	1	2.5	-	-	-	-	1	2.8	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	-	-	-	-	1	2.6	-	-
Pleuronichthys spp.	turbots	1	-	-	-	-	1	2.2	-	-	-	-	-	-
Icelinus spp.	sculpins	1	-	-	-	-	-	-	-	-	1	2.7	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	1	-	-	-	-	-	-	-	-	-	-	1	2.3
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	1	-	-	-	-	-	-	-	-	-	-	1	2.5
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	1	-	-	-	-	-	-	1	2.5	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	2	2	4.5	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 27 (continued)			**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 04/05/04	**Sample Count**		**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	-	-	1	2.7	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonii	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	1	-	-	1	2.3	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	1	-	-	-	-	-	-	1	2.5	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	1,059	32	78.9	98	218.1	42	92.7	48	132.0	66	175.6	773	2,008.4
Cancer gracilis (meg.)	slender crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer antennarius (meg.)	brown rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	1	-	-	-	-	1	2.1	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	1,429	71		134		83		113		139		889	

Appendix B-2. (Continued).

Survey: 31		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 05/03/04		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Gobiidae unid.	gobies	491	90	250.1	92	245.4	10	24.0	1	2.2	86	209.6	212	578.1
Engraulis mordax	northern anchovy	337	28	71.1	30	76.7	40	102.2	19	48.5	99	253.9	121	328.9
Seriphus politus	queenfish	2	-	-	1	2.3	1	2.4	-	-	-	-	-	-
Genyonemus lineatus	white croaker	361	24	62.6	28	74.6	110	265.0	59	157.2	53	126.6	87	242.2
Sciaenidae unid.	croaker	59	12	30.7	3	7.6	11	28.3	12	29.7	12	31.5	9	25.4
Paralichthys californicus	California halibut	25	2	5.3	4	10.2	4	9.3	9	24.1	2	4.9	4	10.6
Hypsoblennius spp.	blennies	11	2	4.8	-	-	-	-	3	7.9	2	4.7	4	11.3
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	75	9	24.5	5	11.8	4	10.0	3	8.2	45	106.6	9	24.1
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	23	2	4.9	-	-	6	14.5	6	16.0	4	10.7	5	12.6
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	10	4	10.7	-	-	1	2.2	1	2.6	4	10.8	-	-
Citharichthys stigmaeus	speckled sanddab	5	-	-	1	2.7	2	4.7	1	2.9	1	2.2	-	-
Engraulidae	anchovies	4	1	2.4	1	2.7	-	-	2	5.2	-	-	-	-
Lepidogobius lepidus	bay goby	14	3	7.3	1	2.2	5	12.5	1	2.8	2	4.7	2	5.2
larval fish fragment	unidentified larval fishes	10	2	5.5	-	-	-	-	4	10.8	2	4.7	2	5.7
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	2	-	-	1	2.4	1	2.6	-	-	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	1	-	-	-	-	-	-	1	2.8	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	9	2	5.0	-	-	1	2.3	2	5.4	3	7.5	1	2.2
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	2	-	-	-	-	1	2.2	1	2.5	-	-	-	-
Roncador stearnsi	spotfin croaker	7	2	4.8	1	2.5	1	2.7	-	-	2	5.0	1	3.0
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	14	5	13.9	-	-	3	8.0	-	-	2	4.9	4	10.2
larval/post-larval fish unid.	larval fishes	1	-	-	-	-	-	-	-	-	1	2.5	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	13	2	4.8	5	11.7	-	-	-	-	4	10.3	2	5.4
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	7	4	11.8	1	2.7	1	2.1	-	-	1	2.6	-	-
Pleuronichthys spp.	turbots	3	1	2.2	-	-	1	2.1	-	-	1	2.8	-	-
Icelinus spp.	sculpins	5	-	-	-	-	-	-	5	11.8	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	1	1	2.7	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	-	-	-	-	-	-	-	-	-	-	-	-	-
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	13	2	5.5	4	10.1	1	2.1	1	2.5	2	4.9	3	9.0
Atractoscion nobilis	white seabass	-	-	-	-	-	-	-	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	4	-	-	1	3.1	1	2.6	-	-	-	-	2	4.8
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	1	1	2.5	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	1	-	-	-	-	-	-	1	2.9	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 31 (continued)	**Stations**		**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 05/03/04	**Sample Count**		**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	2	-	-	1	3.1	-	-	-	-	1	2.7	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	1	-	-	-	-	-	-	1	2.7	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonii	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	1	1	3.4	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	1	-	-	-	-	-	-	1	2.7	-	-	-	-
Parophrys vetulus	English sole	1	-	-	-	-	-	-	1	2.8	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	388	9	25.1	49	122.4	24	64.1	12	31.3	213	547.9	81	242.2
Cancer gracilis (meg.)	slender crab	2	-	-	-	-	-	-	1	2.9	1	2.7	-	-
Cancer antennarius (meg.)	brown rock crab	2	-	-	-	-	1	2.6	-	-	1	2.7	-	-
Cancer anthonyi (meg.)	yellow crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	1,909	209		229		230		148		544		549	

Appendix B-2. (Continued).

Survey: 35		Stations	D2		D4		O2		O4		U2		U4	
Start Date: 06/01/04		Sample Count	8		8		8		8		8		8	
		Survey		Mean		Mean		Mean		Mean		Mean		Mean
Taxon	Common Name	Count	Count	Conc	Count	Conc	Count	Conc	Count	Conc	Count	Conc	Count	Conc
Gobiidae unid.	gobies	245	100	297.0	56	149.0	4	10.6	2	5.8	59	161.4	24	64.2
Engraulis mordax	northern anchovy	643	75	216.0	37	97.0	149	409.4	104	301.2	146	435.5	132	350.9
Seriphus politus	queenfish	3	-	-	-	-	-	-	2	6.0	-	-	1	2.4
Genyonemus lineatus	white croaker	59	3	8.6	1	2.5	37	104.6	13	34.5	-	-	5	12.6
Sciaenidae unid.	croaker	13	2	5.7	2	5.4	-	-	1	2.4	7	19.1	1	2.7
Paralichthys californicus	California halibut	34	2	6.0	1	2.4	9	23.9	21	61.8	-	-	1	2.5
Hypsoblennius spp.	blennies	45	2	5.8	6	14.8	-	-	16	44.0	9	26.0	12	32.2
Paralabrax spp.	sand bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsis californiensis	jacksmelt	32	2	6.3	6	16.3	-	-	-	-	22	60.4	2	5.7
Chromis punctipinnis	blacksmith	-	-	-	-	-	-	-	-	-	-	-	-	-
larvae, unidentified yolksac	larvae	3	1	2.5	1	2.4	-	-	-	-	1	2.8	-	-
Sphyraena argentea	California barracuda	-	-	-	-	-	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	7	-	-	-	-	-	-	7	22.4	-	-	-	-
Engraulidae	anchovies	38	1	2.5	8	20.7	5	12.8	18	49.3	1	3.4	5	13.1
Lepidogobius lepidus	bay goby	4	-	-	-	-	1	2.9	3	7.2	-	-	-	-
larval fish fragment	unidentified larval fishes	2	1	2.5	-	-	-	-	1	2.4	-	-	-	-
Leuresthes tenuis	California grunion	66	49	141.0	1	2.7	-	-	-	-	3	9.1	13	34.2
Pleuronichthys ritteri	spotted turbot	4	-	-	-	-	2	5.5	2	5.0	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	3	-	-	-	-	1	2.9	2	5.0	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	5	2	5.3	1	2.4	-	-	2	7.0	-	-	-	-
Typhlogobius californiensis	blind goby	6	-	-	-	-	1	2.5	1	2.6	-	-	4	10.3
Oxyjulis californica	senorita	1	-	-	-	-	-	-	1	2.5	-	-	-	-
Roncador stearnsi	spotfin croaker	-	-	-	-	-	-	-	-	-	-	-	-	-
Xenistius californiensis	salema	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinopsidae	silverside	16	3	8.2	5	13.4	-	-	-	-	2	5.8	6	16.0
larval/post-larval fish unid.	larval fishes	6	3	8.3	2	5.1	-	-	-	-	1	2.5	-	-
Hypsoblennius jenkinsi	mussel blenny	-	-	-	-	-	-	-	-	-	-	-	-	-
Ilypnus gilberti	cheekspot goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	1	-	-	-	-	1	2.9	-	-	-	-	-	-
Pleuronichthys spp.	turbots	5	-	-	1	2.7	-	-	3	7.5	-	-	1	2.5
Icelinus spp.	sculpins	2	-	-	-	-	-	-	2	5.0	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	5	2	5.1	2	5.3	-	-	-	-	-	-	1	2.7
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	2	-	-	-	-	1	2.9	-	-	-	-	1	2.7
Menticirrhus undulatus	California corbina	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys sordidus	Pacific sanddab	-	-	-	-	-	-	-	-	-	-	-	-	-
Semicossyphus pulcher	California sheephead	1	-	-	-	-	-	-	1	2.4	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Hippoglossina stomata	bigmouth sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	1	1	2.5	-	-	-	-	-	-	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	5	-	-	-	-	-	-	-	-	-	-	5	14.2
Rhinogobiops nicholsi	blackeye goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Diaphus theta	California headlight fish	1	-	-	-	-	-	-	1	2.5	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 35 (continued)		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 06/01/04		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	-	-	-	-	-	-	-	-	-	-	-	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	1	-	-	-	-	1	2.6	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	2	1	3.3	-	-	1	2.9	-	-	-	-	-	-
Anisotremus davidsonil	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	1	-	-	-	-	-	-	-	-	1	3.0	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	1,747	10	26.7	112	289.4	22	61.2	112	303.6	285	909.6	1,206	3,113.4
Cancer gracilis (meg.)	slender crab	28	1	2.8	9	23.1	12	32.0	1	2.5	1	3.4	4	11.2
Cancer antennarius (meg.)	brown rock crab	24	4	11.6	4	10.8	10	27.1	4	11.1	1	2.5	1	2.7
Cancer anthonyi (meg.)	yellow crab	6	-	-	-	-	2	5.5	-	-	3	9.5	1	2.5
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	3,067	265		255		259		320		542		1,426	

Appendix B-2. (Continued).

Survey: 41		**Stations**	**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 07/12/04		**Sample Count**	**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Gobiidae unid.	gobies	269	87	239.2	111	287.8	19	45.9	3	8.9	44	114.8	5	13.2
Engraulis mordax	northern anchovy	332	58	162.5	47	120.0	40	105.6	78	214.4	40	106.8	69	184.8
Seriphus politus	queenfish	230	57	155.0	87	232.2	3	7.8	5	13.1	39	103.5	39	100.9
Genyonemus lineatus	white croaker	19	-	-	-	-	8	21.7	11	29.2	-	-	-	-
Sciaenidae unid.	croaker	20	-	-	1	2.6	2	5.4	13	35.2	1	3.2	3	9.2
Paralichthys californicus	California halibut	34	1	2.9	2	5.6	3	7.9	22	60.3	6	15.7	-	-
Hypsoblennius spp.	blennies	75	16	40.7	5	12.6	27	74.2	8	21.8	12	30.2	7	18.4
Paralabrax spp.	sand bass	15	1	2.9	-	-	2	5.9	9	24.4	-	-	3	8.8
Paralabrax clathratus	kelp bass	22	-	-	-	-	3	8.1	19	51.5	-	-	-	-
Atherinopsis californiensis	jacksmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromis punctipinnis	blacksmith	4	-	-	-	-	2	5.0	1	2.5	-	-	1	2.5
larvae, unidentified yolksac	larvae	21	1	3.0	-	-	3	8.8	10	25.5	1	2.2	6	16.7
Sphyraena argentea	California barracuda	3	2	5.6	1	2.9	-	-	-	-	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsopsetta guttulata	diamond turbot	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	13	-	-	-	-	1	2.7	12	30.0	-	-	-	-
Engraulidae	anchovies	15	2	5.8	-	-	2	5.5	9	24.5	-	-	2	5.8
Lepidogobius lepidus	bay goby	20	-	-	-	-	8	21.0	12	32.0	-	-	-	-
larval fish fragment	unidentified larval fishes	8	1	2.9	3	7.9	-	-	-	-	2	5.3	2	5.0
Leuresthes tenuis	California grunion	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys ritteri	spotted turbot	8	1	2.8	-	-	3	7.4	4	10.4	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	13	-	-	-	-	6	16.3	6	16.0	1	2.2	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-	-	-	-	-	-	-	-	-	-
Cheilotrema saturnum	black croaker	16	5	12.2	3	7.9	-	-	4	11.1	-	-	4	10.8
Typhlogobius californiensis	blind goby	1	-	-	-	-	1	2.8	-	-	-	-	-	-
Oxyjulis californica	senorita	18	-	-	1	2.7	2	5.5	11	30.9	-	-	4	12.2
Roncador stearnsi	spotfin croaker	3	1	2.4	1	2.2	-	-	-	-	-	-	1	2.9
Xenistius californiensis	salema	4	-	-	-	-	-	-	4	11.0	-	-	-	-
Atherinopsidae	silverside	2	-	-	1	2.6	-	-	-	-	1	2.9	-	-
larval/post-larval fish unid.	larval fishes	1	-	-	-	-	-	-	-	-	-	-	1	2.5
Hypsoblennius jenkinsi	mussel blenny	2	-	-	1	2.8	-	-	1	2.6	-	-	-	-
Ilypnus gilberti	cheekspot goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	-	-	-	-	-	-	-	-	-	-	-	-	-
Gillichthys mirabilis	longjaw mudsucker	2	1	3.0	1	2.7	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	3	-	-	-	-	-	-	3	7.6	-	-	-	-
Icelinus spp.	sculpins	17	-	-	-	-	1	2.5	16	41.1	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	14	3	7.1	4	10.4	2	5.5	-	-	4	9.0	1	2.9
Xystreurys liolepis	fantail sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Triphoturus mexicanus	Mexican lampfish	12	-	-	1	2.8	3	8.2	7	18.7	-	-	1	2.8
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	9	2	5.1	-	-	-	-	7	18.3	-	-	-	-
Menticirrhus undulatus	California corbina	7	-	-	-	-	3	8.3	2	5.2	-	-	2	5.3
Citharichthys sordidus	Pacific sanddab	1	-	-	-	-	-	-	1	2.5	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-	-	-	-	-	-	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	6	-	-	-	-	1	2.5	-	-	1	2.8	4	10.5
Labrisomidae unid.	labrisomid kelpfishes	4	-	-	-	-	-	-	-	-	4	11.0	-	-
Hippoglossina stomata	bigmouth sole	1	-	-	-	-	1	2.7	-	-	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectidae unid.	flounders	1	-	-	-	-	-	-	1	2.6	-	-	-	-
Umbrina roncador	yellowfin croaker	2	-	-	-	-	1	2.7	1	2.7	-	-	-	-
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	1	-	-	-	-	1	2.6	-	-	-	-	-	-
Diaphus theta	California headlight fish	3	-	-	-	-	1	2.7	2	5.3	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 41 (continued)	Stations		D2		D4		O2		O4		U2		U4	
Start Date: 07/12/04	Sample Count		8		8		8		8		8		8	
Taxon	Common Name	Survey Count	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc	Count	Mean Conc
Atherinidae unid.	silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Haemulidae	grunts	3	-	-	-	-	-	-	1	3.2	2	5.1	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	-	-	-	-	-	-	-	-	-	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	-	-	-	-	-	-	-	-	-	-	-	-	-
Labridae	wrasses	-	-	-	-	-	-	-	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	1	-	-	-	-	1	2.6	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonii	sargo	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	-	-	-	-	-	-	-	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-
Cottidae unid.	sculpins	1	-	-	-	-	1	2.7	-	-	-	-	-	-
Girella nigricans	opaleye	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	428	237	619.7	78	168.3	-	-	2	4.9	89	244.9	22	58.8
Cancer gracilis (meg.)	slender crab	47	2	5.8	4	10.8	11	29.2	7	19.2	15	42.0	8	23.2
Cancer antennarius (meg.)	brown rock crab	33	2	5.8	5	13.4	9	23.9	5	13.3	5	14.3	7	19.8
Cancer anthonyi (meg.)	yellow crab	60	13	36.7	8	21.3	9	23.9	7	18.8	17	46.6	6	16.8
Cancer spp. (meg.)	cancer crabs	2	-	-	1	2.6	-	-	1	2.5	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer productus (meg.)	red rock crab	1	-	-	-	-	-	-	1	2.8	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	1,827	493		366		180		306		284		198	

Appendix B-2. (Continued).

Survey: 45	**Stations**		**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 08/31/04	**Sample Count**		**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Gobiidae unid.	gobies	823	162	462.9	412	1,177.3	26	75.5	-	-	64	157.6	159	443.0
Engraulis mordax	northern anchovy	114	13	35.3	15	42.7	29	83.1	24	63.2	19	49.9	14	40.7
Seriphus politus	queenfish	1,023	133	351.2	408	1,151.7	100	289.0	104	274.9	73	180.8	205	560.8
Genyonemus lineatus	white croaker	259	-	-	-	-	118	345.8	132	367.9	9	25.3	-	-
Sciaenidae unid.	croaker	402	25	68.3	6	18.3	108	304.7	133	379.9	44	105.7	86	261.2
Paralichthys californicus	California halibut	251	7	21.8	3	8.8	50	137.2	147	408.1	27	50.9	17	43.5
Hypsoblennius spp.	blennies	142	7	21.2	2	6.2	28	67.5	66	180.3	13	23.4	26	77.4
Paralabrax spp.	sand bass	212	10	27.9	2	6.6	50	149.0	118	315.2	14	28.6	18	53.2
Paralabrax clathratus	kelp bass	151	4	14.8	1	3.0	33	99.3	95	277.6	11	26.5	7	21.7
Atherinopsis californiensis	jacksmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Chromis punctipinnis	blacksmith	162	-	-	-	-	5	11.2	156	361.3	-	-	1	3.0
larvae, unidentified yolksac	larvae	106	3	8.4	2	5.7	42	101.8	22	60.2	12	18.8	25	72.2
Sphyraena argentea	California barracuda	142	4	15.1	-	-	32	95.2	98	258.0	4	10.6	4	9.8
Sardinops sagax	Pacific sardine	143	-	-	-	-	33	94.4	86	241.9	11	29.4	13	36.2
Hypsopsetta guttulata	diamond turbot	17	4	11.3	2	5.3	3	7.6	2	6.2	2	3.5	4	9.8
Citharichthys stigmaeus	speckled sanddab	47	-	-	-	-	4	9.8	40	112.6	1	3.5	2	4.4
Engraulidae	anchovies	3	1	2.5	1	3.6	-	-	1	2.8	-	-	-	-
Lepidogobius lepidus	bay goby	-	-	-	-	-	-	-	-	-	-	-	-	-
larval fish fragment	unidentified larval fishes	41	2	5.0	2	5.1	9	23.9	16	45.4	12	22.6	-	-
Leuresthes tenuis	California grunion	4	1	2.5	-	-	1	3.2	-	-	2	5.4	-	-
Pleuronichthys ritteri	spotted turbot	46	2	6.9	-	-	11	27.7	25	66.6	3	5.2	5	13.8
Pleuronichthys verticalis	hornyhead turbot	31	-	-	-	-	6	17.2	22	59.4	1	2.1	2	5.0
Ophidion scrippsae	basketweave cusk-eel	63	-	-	-	-	7	21.4	55	145.7	1	1.4	-	-
Cheilotrema saturnum	black croaker	19	1	2.8	3	8.7	5	13.7	4	11.9	3	5.2	3	8.6
Typhlogobius californiensis	blind goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxyjulis californica	senorita	29	1	2.8	2	5.2	4	12.7	17	43.3	2	4.7	3	8.3
Roncador stearnsi	spotfin croaker	40	6	19.9	3	8.5	1	1.8	1	2.9	13	30.1	16	39.8
Xenistius californiensis	salema	46	-	-	-	-	24	72.6	19	55.3	2	5.1	1	3.0
Atherinopsidae	silverside	-	-	-	-	-	-	-	-	-	-	-	-	-
larval/post-larval fish unid.	larval fishes	11	2	5.0	-	-	-	-	8	24.5	-	-	1	3.2
Hypsoblennius jenkinsi	mussel blenny	34	1	2.5	-	-	6	15.3	23	55.9	2	5.0	2	5.0
Ilypnus gilberti	cheekspot goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Ophidiidae unid.	cusk-eels	36	3	8.1	-	-	10	28.2	19	58.1	1	2.1	3	8.7
Gillichthys mirabilis	longjaw mudsucker	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronichthys spp.	turbots	12	-	-	-	-	2	3.6	6	16.3	3	9.2	1	3.1
Icelinus spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Acanthogobius flavimanus	yellowfin goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Hypsypops rubicundus	garibaldi	1	-	-	-	-	-	-	-	-	-	-	1	2.5
Xystreurys liolepis	fantail sole	19	-	-	-	-	7	16.3	7	19.3	2	5.7	3	7.6
Triphoturus mexicanus	Mexican lampfish	4	-	-	2	5.3	-	-	2	5.1	-	-	-	-
Gibbonsia spp.	clinid kelpfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Atractoscion nobilis	white seabass	1	-	-	-	-	1	1.8	-	-	-	-	-	-
Menticirrhus undulatus	California corbina	7	-	-	1	2.9	-	-	-	-	-	-	6	17.0
Citharichthys sordidus	Pacific sanddab	3	-	-	-	-	-	-	3	7.3	-	-	-	-
Semicossyphus pulcher	California sheephead	12	-	-	-	-	5	13.0	7	15.6	-	-	-	-
Stenobrachius leucopsarus	northern lampfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Citharichthys spp.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox spp.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Labrisomidae unid.	labrisomid kelpfishes	2	-	-	1	2.9	-	-	1	2.8	-	-	-	-
Hippoglossina stomata	bigmouth sole	5	-	-	-	-	2	6.0	3	8.6	-	-	-	-
Peprilus simillimus	Pacific butterfish	7	-	-	-	-	1	3.0	6	19.1	-	-	-	-
Pleuronectidae unid.	flounders	-	-	-	-	-	-	-	-	-	-	-	-	-
Umbrina roncador	yellowfin croaker	4	-	-	1	2.9	1	2.9	1	2.3	-	-	1	2.8
Paralichthyidae unid.	sanddabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Ruscarius creaseri	rouchcheek sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Symphurus atricauda	California tonguefish	6	-	-	-	-	-	-	6	15.3	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinogobiops nicholsi	blackeye goby	2	-	-	-	-	-	-	2	5.7	-	-	-	-
Diaphus theta	California headlight fish	-	-	-	-	-	-	-	-	-	-	-	-	-

(continued)

Appendix B-2. (Continued).

Survey: 45 (continued)	**Stations**		**D2**		**D4**		**O2**		**O4**		**U2**		**U4**	
Start Date: 08/31/04	**Sample Count**		**8**		**8**		**8**		**8**		**8**		**8**	
Taxon	**Common Name**	**Survey Count**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**	**Count**	**Mean Conc**
Atherinidae unid.	silversides	4	-	-	1	2.9	-	-	3	8.8	-	-	-	-
Haemulidae	grunts	1	-	-	-	-	-	-	-	-	1	2.1	-	-
Merluccius productus	Pacific hake	-	-	-	-	-	-	-	-	-	-	-	-	-
Etrumeus teres	round herring	3	-	-	-	-	1	3.2	2	5.5	-	-	-	-
Halichoeres semicinctus	rock wrasse	3	-	-	-	-	1	3.2	2	6.2	-	-	-	-
Lythrypnus spp.	gobies	-	-	-	-	-	-	-	-	-	-	-	-	-
Medialuna californiensis	halfmoon	3	-	-	-	-	1	2.9	1	2.1	-	-	1	2.5
Sebastes spp. V	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus spp.	pipefishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Clevelandia ios	arrow goby	-	-	-	-	-	-	-	-	-	-	-	-	-
Gobiesox rhessodon	California clingfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hexagrammidae unid.	greenlings	-	-	-	-	-	-	-	-	-	-	-	-	-
Kyphosidae	sea chubs	2	-	-	-	-	-	-	2	5.4	-	-	-	-
Labridae	wrasses	2	-	-	-	-	2	5.8	-	-	-	-	-	-
Myctophidae unid.	lanternfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oxylebius pictus	painted greenling	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp.	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. V_D	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Syngnathus leptorhynchus	bay pipefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Anisotremus davidsonil	sargo	1	-	-	-	-	-	-	-	-	-	-	1	3.1
Artedius lateralis	smoothhead sculpin	-	-	-	-	-	-	-	-	-	-	-	-	-
Artedius spp.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Aulorhynchus flavidus	tubesnout	1	-	-	-	-	1	2.7	-	-	-	-	-	-
Chaenopsidae unid.	tube blennies	-	-	-	-	-	-	-	-	-	-	-	-	-
Clupeiformes	herrings and anchovies	1	-	-	-	-	1	1.8	-	-	-	-	-	-
Cottidae unid.	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Girella nigricans	opaleye	1	-	-	-	-	1	3.3	-	-	-	-	-	-
Gobiesocidae unid.	clingfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Oligocottus / Clinocottus	sculpins	-	-	-	-	-	-	-	-	-	-	-	-	-
Parophrys vetulus	English sole	-	-	-	-	-	-	-	-	-	-	-	-	-
Pleuronectiformes unid.	flatfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Pomacentridae	damselfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Scombridae unid.	mackerels & tunas	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenichthys marmoratus	cabezon	-	-	-	-	-	-	-	-	-	-	-	-	-
Scorpaenidae	scorpionfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Sebastes spp. VD	rockfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Zaniolepis spp.	combfishes	-	-	-	-	-	-	-	-	-	-	-	-	-
Invertebrates														
Emerita analoga (zoea)	mole crab	239	3	10.6	-	-	91	261.6	9	22.3	135	330.1	1	2.5
Cancer gracilis (meg.)	slender crab	11	1	3.0	1	2.9	2	5.8	3	8.6	4	9.1	-	-
Cancer antennarius (meg.)	brown rock crab	23	1	2.4	1	2.9	3	9.0	3	7.7	13	32.4	2	5.1
Cancer anthonyi (meg.)	yellow crab	12	-	-	-	-	2	5.8	2	5.7	7	15.4	1	2.5
Cancer spp. (meg.)	cancer crabs	-	-	-	-	-	-	-	-	-	-	-	-	-
Cancer oregonsis (zoea V)	pygmy rock crab	2	-	-	-	-	-	-	-	-	2	5.7	-	-
Cancer productus (meg.)	red rock crab	-	-	-	-	-	-	-	-	-	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-	-	-	-	-	-	-	-	-	-
	Total:	4,791	397		872		870		1,504		513		635	

Appendix B-3. Estimated entrainment of HBGS entrainment target species by survey.

			CIQ gobies		northern anchovy		spotfin croaker	
Survey	**Date**	**Days in Period**	Period Entrainment	Entrainment Std. Error	Period Entrainment	Entrainment Std. Error	Period Entrainment	Entrainment Std. Error
HBS001	9/18/2003	19	9,763,905	6,961,871	2,637,926	1,939,235	0	0
HBS002	9/29/2003	12	4,942,612	3,115,340	1,902,173	1,522,446	0	0
HBS003	10/13/2003	11	4,959,000	7,039,118	1,637,744	2,018,418	0	0
HBS004	10/20/2003	10	2,042,279	2,349,529	1,459,738	2,490,356	0	0
HBS005	11/3/2003	11	1,858,154	1,753,450	279,946	559,892	0	0
HBS006	11/10/2003	7	34,621	69,243	417,603	404,931	0	0
HBS007	11/17/2003	7	2,506,595	3,467,022	345,362	471,093	0	0
HBS008	11/24/2003	7	937,064	866,153	68,105	80,295	0	0
HBS009	12/1/2003	7	1,780,282	2,377,385	105,454	125,473	0	0
HBS010	12/8/2003	7	359,485	457,961	322,292	295,833	0	0
HBS011	12/15/2003	7	3,303,348	1,963,821	2,417,927	3,434,637	0	0
HBS012	12/22/2003	7	1,783,140	2,128,965	152,890	205,972	0	0
HBS013	12/29/2003	7	1,559,717	763,133	379,870	581,588	0	0
HBS014	1/5/2004	7	1,232,451	1,579,086	149,928	210,800	0	0
HBS015	1/12/2004	7	1,436,569	1,177,765	75,086	150,172	0	0
HBS016	1/19/2004	7	1,054,365	1,047,181	186,833	230,674	0	0
HBS017	1/26/2004	7	2,889,116	1,226,888	33,218	66,435	0	0
HBS018	2/2/2004	7	182,559	267,950	0	0	0	0
HBS019	2/9/2004	7	562,313	382,491	34,337	68,674	0	0
HBS020	2/17/2004	7	249,875	217,546	72,535	84,274	0	0
HBS021	2/23/2004	8	4,333,117	7,624,209	0	0	0	0
HBS022	3/3/2004	7	161,125	0	0	0	0	.
HBS023	3/8/2004	6	1,578,937	1,577,955	386,427	616,148	0	0
HBS024	3/15/2004	7	3,323,459	1,942,136	470,690	551,490	0	0
HBS025	3/22/2004	10	2,577,297	1,716,506	1,322,354	1,568,970	0	0
HBS027	4/5/2004	11	1,641,550	1,962,205	761,976	1,028,047	0	0
HBS028	4/12/2004	7	461,735	537,881	596,744	801,731	0	0
HBS029	4/19/2004	5	1,554,008	1,621,313	842,925	451,615	0	0
HBS030	4/23/2004	7	40,499	70,146	695,085	650,715	0	0
HBS031	5/3/2004	7	4,943,840	2,929,025	2,541,328	2,527,280	64,409	74,431
HBS032	5/7/2004	7	2,574,053	2,453,940	938,986	595,791	0	0
HBS033	5/17/2004	9	1,614,503	1,976,404	1,197,871	624,159	315,526	215,633
HBS034	5/24/2004	7	680,326	366,737	2,409,481	2,238,136	359,224	171,155
HBS035	6/1/2004	7	996,027	767,680	4,993,619	6,324,286	0	0
HBS036	6/7/2004	7	318,403	313,129	143,152	118,181	0	0
HBS037	6/14/2004	7	1,236,673	1,060,869	2,256,271	1,149,322	794,500	726,474
HBS038	6/21/2004	7	1,879,662	1,193,451	3,114,339	2,827,049	0	0
HBS039	6/28/2004	7	1,623,829	2,261,321	3,303,799	2,689,029	60,830	121,660
HBS040	7/6/2004	7	6,583,673	4,467,024	570,105	399,564	5,464,332	6,178,803
HBS041	7/12/2004	7	5,758,655	7,215,916	2,583,753	2,359,182	0	0
HBS042	7/19/2004	7	4,016,186	5,722,304	1,603,501	1,939,648	0	0
HBS043	7/26/2004	18	6,835,518	3,163,680	8,326,402	7,846,825	282,947	370,068
HBS044	8/24/2004	18	9,915,429	1,879,568	1,614,609	2,343,448	62,317,931	35,251,477
HBS045	8/31/2004	8	5,080,879	2,284,615	996,637	1,290,573	41,890	83,780
			113,166,833		54,349,021		69,701,589	

Appendix B-3. (Continued).

			queenfish		white croaker		black croaker	
Survey	**Date**	**Days in Period**	Period Entrainment	Entrainment Std. Error	Period Entrainment	Entrainment Std. Error	Period Entrainment	Entrainment Std. Error
HBS001	9/18/2003	19	0	0	621,719	1,001,194	87,422	174,845
HBS002	9/29/2003	12	0	0	446,570	488,034	0	0
HBS003	10/13/2003	11	0	0	236,706	354,742	0	0
HBS004	10/20/2003	10	0	0	306,897	379,484	0	0
HBS005	11/3/2003	11	0	0	63,669	127,338	0	0
HBS006	11/10/2003	7	0	0	69,941	80,769	0	0
HBS007	11/17/2003	7	0	0	506,437	394,563	0	0
HBS008	11/24/2003	7	0	0	582,951	539,511	0	0
HBS009	12/1/2003	7	0	0	173,834	347,668	0	0
HBS010	12/8/2003	7	0	0	360,166	630,777	0	0
HBS011	12/15/2003	7	0	0	1,123,540	893,076	0	0
HBS012	12/22/2003	7	0	0	114,657	229,314	0	0
HBS013	12/29/2003	7	0	0	32,042	64,085	0	0
HBS014	1/5/2004	7	0	0	280,532	462,330	0	0
HBS015	1/12/2004	7	0	0	827,911	1,552,401	0	0
HBS016	1/19/2004	7	0	0	1,268,216	295,474	0	0
HBS017	1/26/2004	7	0	0	379,601	466,112	0	0
HBS018	2/2/2004	7	0	0	0	0	0	0
HBS019	2/9/2004	7	0	0	208,937	233,414	0	0
HBS020	2/17/2004	7	0	0	96,196	118,796	0	0
HBS021	2/23/2004	8	0	0	0	0	0	0
HBS022	3/3/2004	7	0	0	161,125	0	0	.
HBS023	3/8/2004	6	0	0	160,882	244,948	0	0
HBS024	3/15/2004	7	0	0	70,552	81,619	0	0
HBS025	3/22/2004	10	0	0	1,036,912	974,438	0	0
HBS027	4/5/2004	11	0	0	54,242	108,484	0	0
HBS028	4/12/2004	7	0	0	1,116,812	1,304,875	0	0
HBS029	4/19/2004	5	0	0	936,570	876,949	0	0
HBS030	4/23/2004	7	0	0	752,025	900,105	95,558	82,768
HBS031	5/3/2004	7	0	0	1,852,787	1,406,469	0	0
HBS032	5/7/2004	7	0	0	1,580,468	1,410,789	0	0
HBS033	5/17/2004	9	536,753	369,006	1,239,186	1,286,931	348,260	316,953
HBS034	5/24/2004	7	61,100	70,552	526,170	571,779	30,510	61,020
HBS035	6/1/2004	7	0	0	235,136	299,384	0	0
HBS036	6/7/2004	7	0	0	30,937	61,873	0	0
HBS037	6/14/2004	7	327,588	335,536	33,479	66,958	108,195	130,697
HBS038	6/21/2004	7	0	0	61,956	123,912	0	0
HBS039	6/28/2004	7	108,219	146,983	0	0	97,189	194,379
HBS040	7/6/2004	7	78,202	90,391	39,027	78,054	121,023	242,045
HBS041	7/12/2004	7	995,105	1,178,519	0	0	0	0
HBS042	7/19/2004	7	388,690	609,623	0	0	0	0
HBS043	7/26/2004	18	647,366	788,438	0	0	638,447	311,889
HBS044	8/24/2004	18	9,716,995	5,305,198	0	0	5,571,043	6,231,731
HBS045	8/31/2004	8	4,949,845	5,620,490	36,473	72,946	30,480	60,961
			17,809,863		17,625,261		7,128,127	

Appendix B-3. (Continued).

			salema		combtooth blennies		diamond turbot	
Survey	**Date**	**Days in Period**	Period Entrainment	Entrainment Std. Error	Period Entrainment	Entrainment Std. Error	Period Entrainment	Entrainment Std. Error
HBS001	9/18/2003	19	0	0	0	0	0	0
HBS002	9/29/2003	12	0	0	51,247	102,494	0	0
HBS003	10/13/2003	11	0	0	0	0	113,051	132,009
HBS004	10/20/2003	10	0	0	0	0	95,824	191,647
HBS005	11/3/2003	11	0	0	583,665	447,948	231,263	317,251
HBS006	11/10/2003	7	0	0	376,866	648,490	41,219	82,437
HBS007	11/17/2003	7	0	0	0	0	30,721	61,443
HBS008	11/24/2003	7	0	0	67,602	79,898	114,442	138,476
HBS009	12/1/2003	7	0	0	70,715	83,050	76,696	88,567
HBS010	12/8/2003	7	0	0	68,837	137,674	0	0
HBS011	12/15/2003	7	0	0	35,768	71,536	0	0
HBS012	12/22/2003	7	0	0	41,052	82,105	74,541	86,104
HBS013	12/29/2003	7	0	0	0	0	132,535	107,157
HBS014	1/5/2004	7	0	0	38,047	76,093	38,138	76,277
HBS015	1/12/2004	7	0	0	0	0	0	0
HBS016	1/19/2004	7	0	0	0	0	38,197	76,394
HBS017	1/26/2004	7	0	0	0	0	108,261	136,499
HBS018	2/2/2004	7	0	0	0	0	34,546	69,092
HBS019	2/9/2004	7	0	0	35,303	70,606	0	0
HBS020	2/17/2004	7	0	0	32,435	64,870	68,528	79,354
HBS021	2/23/2004	8	0	0	0	0	0	0
HBS022	3/3/2004	7	0	.	0	.	0	.
HBS023	3/8/2004	6	0	0	0	0	36,655	73,310
HBS024	3/15/2004	7	0	0	0	0	0	0
HBS025	3/22/2004	10	0	0	0	0	52,640	105,281
HBS027	4/5/2004	11	0	0	0	0	53,246	106,491
HBS028	4/12/2004	7	0	0	29,420	58,841	158,273	120,180
HBS029	4/19/2004	5	0	0	99,789	105,033	62,176	107,692
HBS030	4/23/2004	7	0	0	100,926	92,375	47,301	81,927
HBS031	5/3/2004	7	0	0	0	0	0	0
HBS032	5/7/2004	7	0	0	204,519	179,587	95,083	164,689
HBS033	5/17/2004	9	0	0	440,064	523,694	144,449	99,099
HBS034	5/24/2004	7	0	0	240,389	131,691	0	0
HBS035	6/1/2004	7	0	0	91,995	118,095	0	0
HBS036	6/7/2004	7	0	0	212,576	84,337	0	0
HBS037	6/14/2004	7	0	0	404,869	297,390	0	0
HBS038	6/21/2004	7	0	0	102,892	69,495	0	0
HBS039	6/28/2004	7	0	0	1,406,634	710,572	0	0
HBS040	7/6/2004	7	0	0	299,867	599,735	68,685	80,773
HBS041	7/12/2004	7	0	0	163,288	196,416	0	0
HBS042	7/19/2004	7	0	0	539,435	277,308	34,014	68,027
HBS043	7/26/2004	18	86,333	172,666	295,574	392,788	0	0
HBS044	8/24/2004	18	11,610,627	22,003,691	982,007	833,364	3,492,636	1,818,773
HBS045	8/31/2004	8	0	0	149,729	178,757	0	0
			11,696,960		7,165,510		5,443,120	

Appendix B-3. (Continued).

			California halibut	
Survey	**Date**	**Days in Period**	Period Entrainment	Entrainment Std. Error
HBS001	9/18/2003	19	0	0
HBS002	9/29/2003	12	46,158	92,317
HBS003	10/13/2003	11	0	0
HBS004	10/20/2003	10	0	0
HBS005	11/3/2003	11	0	0
HBS006	11/10/2003	7	73,624	85,153
HBS007	11/17/2003	7	0	0
HBS008	11/24/2003	7	0	0
HBS009	12/1/2003	7	0	0
HBS010	12/8/2003	7	0	0
HBS011	12/15/2003	7	0	0
HBS012	12/22/2003	7	0	0
HBS013	12/29/2003	7	0	0
HBS014	1/5/2004	7	0	0
HBS015	1/12/2004	7	0	0
HBS016	1/19/2004	7	0	0
HBS017	1/26/2004	7	0	0
HBS018	2/2/2004	7	0	0
HBS019	2/9/2004	7	0	0
HBS020	2/17/2004	7	0	0
HBS021	2/23/2004	8	0	0
HBS022	3/3/2004	7	0	.
HBS023	3/8/2004	6	0	0
HBS024	3/15/2004	7	0	0
HBS025	3/22/2004	10	0	0
HBS027	4/5/2004	11	0	0
HBS028	4/12/2004	7	31,110	62,221
HBS029	4/19/2004	5	35,728	61,883
HBS030	4/23/2004	7	445,098	333,817
HBS031	5/3/2004	7	102,680	132,680
HBS032	5/7/2004	7	0	0
HBS033	5/17/2004	9	51,305	102,609
HBS034	5/24/2004	7	66,638	78,421
HBS035	6/1/2004	7	53,075	106,150
HBS036	6/7/2004	7	0	0
HBS037	6/14/2004	7	1,690,567	866,751
HBS038	6/21/2004	7	29,508	59,016
HBS039	6/28/2004	7	136,144	180,466
HBS040	7/6/2004	7	46,767	93,535
HBS041	7/12/2004	7	107,760	137,465
HBS042	7/19/2004	7	34,014	68,027
HBS043	7/26/2004	18	739,401	568,589
HBS044	8/24/2004	18	1,240,150	803,738
HBS045	8/31/2004	8	91,441	182,882
			5,021,168	

Appendix C

C1: Impingement Data by Survey - Fishes

C2: Impingement Data by Survey - Macroinvertebrates

Fishes		7/29/2003 N.O. #1		8/5/2003 N.O. #2	
Scientific Name	**Common Name**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
Seriphus politus	queenfish	5	0.143	1	0.016
Genyonemus lineatus	white croaker	2	0.070	-	-
Engraulis mordax	northern anchovy	4	0.048	-	-
Phanerodon furcatus	white seaperch	5	0.045	-	-
Cymatogaster aggregata	shiner perch	2	0.014	-	-
Hyperprosopon argenteum	walleye surfperch	1	0.009	2	0.023
Paralichthys californicus	California halibut	-	-	-	-
Myliobatis californica	bat ray	-	-	-	-
Porichthys myriaster	specklefin midshipman	-	-	-	-
Sardinops sagax	Pacific sardine	-	-	-	-
Peprilus simillimus	Pacific butterfish	-	-	-	-
Pleuronichthys verticalis	hornyhead turbot	-	-	-	-
Cheilotrema saturnum	black croaker	-	-	-	-
Halichoeres semicinctus	rock wrasse	-	-	-	-
Menticirrhus undulatus	California corbina	-	-	-	-
Scorpaena guttata	California scorpionfish	-	-	-	-
Medialuna californiensis	halfmoon	-	-	-	-
Girella nigricans	opaleye	-	-	-	-
Anisotremus davidsonii	sargo	-	-	-	-
Heterostichus rostratus	giant kelpfish	-	-	-	-
Embiotoca jacksoni	black perch	-	-	-	-
Chromis punctipinnis	blacksmith	-	-	-	-
Rhacochilus vacca	pile perch	-	-	-	-
Umbrina roncador	yellowfin croaker	-	-	-	-
Sebastes auriculatus	brown rockfish	-	-	-	-
Paralabrax nebulifer	barred sand bass	-	-	-	-
Paralabrax clathratus	kelp bass	-	-	-	-
Rhinobatos productus	shovelnose guitarfish	-	-	-	-
Atherinopsis californiensis	jacksmelt	-	-	-	-
Leuresthes tenuis	California grunion	-	-	-	-
Platyrhinoidis triseriata	thornback	-	-	-	-
Leptocottus armatus	Pacific staghorn sculpin	-	-	-	-
Synodus lucioceps	California lizardfish	-	-	-	-
Pleuronichthys ritteri	spotted turbot	-	-	-	-
Paralabrax maculatofasciatus	spotted sand bass	-	-	-	-
Trachurus symmetricus	jack mackerel	-	-	-	-
Atherinops affinis	topsmelt	-	-	-	-
Hypsoblennius gilberti	rockpool blenny	-	-	-	-
Citharichthys stigmaeus	speckled sanddab	-	-	-	-
Atractoscion nobilis	white seabass	-	-	-	-
Scomber japonicus	chub mackerel	-	-	-	-
Xenistius californiensis	salema	-	-	-	-
Rhacochilus toxotes	rubberlip seaperch	-	-	-	-
Urolophus halleri	round stingray	-	-	-	-
Torpedo californica	Pacific electric ray	-	-	-	-
Ophichthus zophochir	yellow snake eel	-	-	-	-
Roncador stearnsii	spotfin croaker	-	-	-	-
Hypsopsetta guttulata	diamond turbot	-	-	-	-
Anchoa compressa	deepbody anchovy	-	-	-	-
Semicossyphus pulcher	California sheephead	-	-	-	-
Triakis semifasciata	leopard shark	-	-	-	-
Chilara taylori	spotted cusk eel	-	-	-	-
Syngnathus californiensis	kelp pipefish	-	-	-	-
Sebastes miniatus	vermilion rockfish	-	-	-	-
Ophidion scrippsae	basketweave cusk-eel	-	-	-	-
Odontopyxis trispinosa	pygmy poacher	-	-	-	-
Porichthys notatus	plainfin midshipman	-	-	-	-
	Survey Totals:	**19**	**0.329**	**3**	**0.039**

Fishes	8/12/2003 N.O. #3		8/22/2003 N.O. #4		8/26/2003 N.O. #5	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	-	-	-	-	4	0.077
white croaker	-	-	-	-	14	0.192
northern anchovy	-	-	-	-	1	0.011
white seaperch	-	-	-	-	-	-
shiner perch	1	0.010	-	-	5	0.057
walleye surfperch	-	-	-	-	-	-
California halibut	1	0.401	-	-	-	-
bat ray	-	-	-	-	2	1.589
specklefin midshipman	-	-	-	-	1	0.341
Pacific sardine	-	-	-	-	5	0.419
Pacific butterfish	-	-	-	-	2	0.019
hornyhead turbot	-	-	-	-	1	0.004
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**2**	**0.411**	**0**	**0.000**	**35**	**2.709**

Fishes	9/3/2003 N.O. #6		9/10/2003 N.O. #7		9/16/2003 N.O. #8	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	6	0.157	-	-	-	-
white croaker	1	0.011	-	-	-	-
northern anchovy	10	0.051	-	-	4	0.030
white seaperch	1	0.016	-	-	-	-
shiner perch	16	0.151	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	1	0.047	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	1	0.062	-	-	-	-
Pacific butterfish	6	0.079	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	2	0.354
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	1	1.200	-	-	-	-
Pacific staghorn sculpin	2	0.029	-	-	-	-
California lizardfish	1	0.020	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**46**	**1.823**	**0**	**0.000**	**6**	**0.384**

Fishes	9/23/2003 N.O. #9		9/30/2003 N.O. #10		10/7/2003 N.O. #11	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	7	0.132	-	-	4	0.021
white croaker	-	-	-	-	-	-
northern anchovy	37	0.343	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	10	0.093	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	1	0.001	-	-	-	-
Pacific sardine	-	-	-	-	1	0.012
Pacific butterfish	4	0.049	-	-	-	-
hornyhead turbot	1	0.023	-	-	1	0.010
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	2	0.287	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	1	0.017
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	1	0.115	-	-	-	-
spotted turbot	2	0.265	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**65**	**1.308**	**0**	**0.000**	**7**	**0.060**

Fishes	10/14/2003 N.O. #12		10/21/2003 N.O. #13		10/28/2003 N.O. #14	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	7	0.159	30	0.099	169	0.527
white croaker	-	-	-	-	-	-
northern anchovy	8	0.047	4	0.015	15	0.079
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	1	0.200	-	-
specklefin midshipman	1	0.004	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	1	0.004
black croaker	-	-	-	-	2	0.013
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	1	0.150	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	1	0.109	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	1	0.002	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	6	0.024
thornback	-	-	-	-	1	0.816
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	2	0.083	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	1	0.004	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	1	0.003	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**22**	**0.411**	**36**	**0.464**	**194**	**1.463**

Fishes	**11/4/2003 N.O. #15**		**11/11/2003 N.O. #16**		**11/20/2003 N.O. #17**	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	8	0.026	-	-	-	-
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	1	0.004
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**8**	**0.026**	**0**	**0.000**	**1**	**0.004**

Fishes	11/28/2003		12/2/2003		12/9/2003	
	N.O. #18		N.O. #19		N.O. #20	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	-	-	-	-	-	-
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	1	0.580	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**1**	**0.580**	**0**	**0.000**	**0**	**0.000**

Fishes	12/16/2003 N.O. #21		12/23/2003 N.O. #22		12/30/2003 N.O.#23	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	60	0.209	3	0.034	3	0.050
white croaker	-	-	-	-	-	-
northern anchovy	1	0.003	1	0.005	1	0.004
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	6	0.758	-	-	2	0.479
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	1	0.034	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	1	0.103
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	1	0.005
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	1	0.003
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	1	2.500	-	-	-	-
yellow snake eel	1	0.216	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**69**	**3.686**	**5**	**0.073**	**9**	**0.644**

Fishes	1/9/2004 N.O.#24		1/16/2004 N.O.#25		1/20/2004 N.O.#26	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	1	0.021	-	-	2	0.008
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	3	0.012
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**1**	**0.021**	**0**	**0.000**	**5**	**0.020**

Fishes	1/27/2004 N.O.#27		2/3/2004 N.O.#28		2/10/2004 N.O. #29	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	1304	7.252	2	0.013	4	0.018
white croaker	3	0.169	-	-	-	-
northern anchovy	18	0.090	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	2	0.053	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	1	0.014	-	-
Pacific butterfish	6	0.116	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	3	0.292	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	1	0.696	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	2	0.025	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	2	0.024	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	2	0.018	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	2	8.100	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	1	0.151	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**1346**	**16.986**	**3**	**0.027**	**4**	**0.018**

Fishes	2/18/2004 N.O. #30		2/24/2004 N.O. #31		3/2/2004 N.O. #32	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	1	0.006	3	0.059	5	0.079
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	4	0.028
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	1	0.017
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	1	0.017
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	1	0.052
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	1	0.006	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	1	0.054	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**2**	**0.012**	**4**	**0.113**	**12**	**0.193**

Fishes	3/9/2004 N.O. #33		3/16/2004 N.O. #34		3/23/2004 N.O. #35	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	1	0.007	2	0.011	14	0.051
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	17	0.092
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	1	0.019	-	-
Pacific butterfish	1	0.043	1	0.012	1	0.011
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	1	0.264	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**3**	**0.314**	**4**	**0.042**	**32**	**0.154**

Fishes	3/30/2004 N.O. #36		4/6/2004 N.O. #37		4/13/2004 N.O. #38	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	14	0.084	1	0.004	47	0.227
white croaker	-	-	-	-	10	0.042
northern anchovy	-	-	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	1	0.011
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	1	7.500	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	1	0.005
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	15	7.584	1	0.004	59	0.285

Fishes	4/20/2004 N.O. #39		4/27/2004 N.O. #40		5/4/2004 N.O. #41	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	21	0.100	4	0.017	40	0.261
white croaker	2	0.012	2	0.010	11	0.064
northern anchovy	-	-	1	0.004	-	-
white seaperch	-	-	-	-	7	0.019
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	2	0.321	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	1	0.118
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	1	0.018
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	1	0.298	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**25**	**0.433**	**8**	**0.329**	**60**	**0.480**

Fishes	5/11/2004 N.O. #42		5/18/2004 N.O. #43		5/25/2004 N.O. #44	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	1	0.003	-	-	-	-
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	4	1.300	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	1	0.350
Survey Totals:	**5**	**1.303**	**0**	**0.000**	**1**	**0.350**

Fishes	6/3/2004 N.O. #45		6/8/2004 N.O. #46		6/15/2004 N.O. #47	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	-	-	-	-	-	-
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	1	0.026
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**0**	**0.000**	**0**	**0.000**	**1**	**0.026**

Fishes	6/22/2004		6/29/2004		7/7/2004	
	N.O. #48		N.O. #49		N.O. #50	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	-	-	-	-	-	-
white croaker	-	-	-	-	-	-
northern anchovy	-	-	-	-	-	-
white seaperch	-	-	-	-	-	-
shiner perch	-	-	-	-	-	-
walleye surfperch	-	-	-	-	-	-
California halibut	-	-	-	-	-	-
bat ray	-	-	-	-	-	-
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	-	-
Pacific butterfish	-	-	-	-	-	-
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	-	-
rock wrasse	-	-	-	-	-	-
California corbina	-	-	-	-	-	-
California scorpionfish	-	-	-	-	-	-
halfmoon	-	-	-	-	-	-
opaleye	-	-	-	-	-	-
sargo	-	-	-	-	-	-
giant kelpfish	-	-	-	-	-	-
black perch	-	-	-	-	-	-
blacksmith	-	-	-	-	-	-
pile perch	-	-	-	-	-	-
yellowfin croaker	-	-	-	-	-	-
brown rockfish	-	-	-	-	-	-
barred sand bass	-	-	-	-	-	-
kelp bass	-	-	-	-	-	-
shovelnose guitarfish	-	-	-	-	-	-
jacksmelt	-	-	-	-	-	-
California grunion	-	-	-	-	-	-
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	1	0.484
Pacific electric ray	1	2.500	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**1**	**2.500**	**0**	**0.000**	**1**	**0.484**

Fishes	7/13/2004 N.O. #51		7/20/2004 N.O. #52		8/16/2003 H.T. #1	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	-	-	-	-	3200	116.908
white croaker	-	-	-	-	1192	21.196
northern anchovy	-	-	-	-	70	1.806
white seaperch	-	-	-	-	386	4.645
shiner perch	-	-	2	0.014	665	6.748
walleye surfperch	-	-	-	-	47	0.780
California halibut	-	-	-	-	2	2.210
bat ray	-	-	-	-	2	4.261
specklefin midshipman	-	-	-	-	-	-
Pacific sardine	-	-	-	-	2	0.086
Pacific butterfish	-	-	-	-	4	0.135
hornyhead turbot	-	-	-	-	-	-
black croaker	-	-	-	-	9	3.128
rock wrasse	-	-	-	-	1	0.366
California corbina	-	-	-	-	3	0.672
California scorpionfish	-	-	-	-	11	2.583
halfmoon	-	-	-	-	7	2.005
opaleye	-	-	-	-	4	2.400
sargo	-	-	-	-	5	1.207
giant kelpfish	-	-	-	-	1	0.125
black perch	-	-	-	-	1	0.135
blacksmith	-	-	-	-	1	0.031
pile perch	-	-	-	-	3	1.173
yellowfin croaker	-	-	-	-	1	0.184
brown rockfish	-	-	-	-	1	0.733
barred sand bass	-	-	-	-	12	2.930
kelp bass	-	-	-	-	45	22.677
shovelnose guitarfish	-	-	-	-	1	3.674
jacksmelt	-	-	-	-	20	1.365
California grunion	-	-	-	-	47	0.189
thornback	-	-	-	-	-	-
Pacific staghorn sculpin	-	-	-	-	-	-
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	-	-
spotted sand bass	-	-	-	-	-	-
jack mackerel	-	-	-	-	-	-
topsmelt	-	-	-	-	-	-
rockpool blenny	-	-	-	-	-	-
speckled sanddab	-	-	-	-	-	-
white seabass	-	-	-	-	-	-
chub mackerel	-	-	-	-	-	-
salema	-	-	-	-	-	-
rubberlip seaperch	-	-	-	-	-	-
round stingray	-	-	-	-	-	-
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	-	-
diamond turbot	-	-	-	-	-	-
deepbody anchovy	-	-	-	-	-	-
California sheephead	-	-	-	-	-	-
leopard shark	-	-	-	-	-	-
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	-	-	-	-
Survey Totals:	**0**	**0.000**	**2**	**0.014**	**5743**	**204.352**

Fishes	9/26/2003 H.T. #2		11/7/2003 H.T. #3		1/6/2004 H.T.#4	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	3548	104.300	4272	106.810	4529	88.728
white croaker	497	8.570	17	0.846	44	1.643
northern anchovy	643	3.317	167	1.100	482	3.084
white seaperch	102	2.530	86	2.452	64	2.526
shiner perch	2428	31.570	570	9.092	46	1.207
walleye surfperch	15	0.400	100	3.208	106	1.977
California halibut	1	1.050	2	0.688	-	-
bat ray	-	-	1	1.478	1	0.323
specklefin midshipman	-	-	-	-	1	0.006
Pacific sardine	17	1.400	4	0.298	-	-
Pacific butterfish	134	2.900	41	1.578	26	0.653
hornyhead turbot	-	-	-	-	1	0.144
black croaker	3	0.800	17	1.111	11	0.714
rock wrasse	2	0.550	1	0.475	-	-
California corbina	2	0.379	1	0.170	11	1.009
California scorpionfish	13	4.220	16	5.201	5	1.707
halfmoon	5	1.150	1	0.390	-	-
opaleye	2	1.200	-	-	-	-
sargo	-	-	8	0.174	4	0.053
giant kelpfish	1	0.140	1	0.050	6	0.393
black perch	5	1.500	9	2.544	3	0.140
blacksmith	13	1.000	12	0.446	8	0.303
pile perch	2	0.850	1	0.804	9	1.250
yellowfin croaker	5	1.750	-	-	-	-
brown rockfish	-	-	-	-	1	0.451
barred sand bass	20	3.670	20	2.533	3	0.168
kelp bass	28	9.870	46	2.700	4	0.919
shovelnose guitarfish	1	7.500	-	-	-	-
jacksmelt	5	0.226	18	1.026	22	1.826
California grunion	12	0.097	32	0.212	-	-
thornback	-	-	-	-	2	1.242
Pacific staghorn sculpin	-	-	-	-	3	0.103
California lizardfish	-	-	-	-	-	-
spotted turbot	-	-	-	-	4	0.007
spotted sand bass	1	0.900	-	-	-	-
jack mackerel	1	0.082	-	-	-	-
topsmelt	122	1.200	57	0.644	52	1.820
rockpool blenny	1	0.003	-	-	1	0.007
speckled sanddab	-	-	-	-	2	0.004
white seabass	-	-	8	1.000	21	1.667
chub mackerel	-	-	17	0.336	-	-
salema	-	-	3	0.120	17	0.111
rubberlip seaperch	-	-	1	0.620	-	-
round stingray	-	-	2	1.236	6	2.485
Pacific electric ray	-	-	-	-	-	-
yellow snake eel	-	-	-	-	-	-
spotfin croaker	-	-	-	-	28	0.616
diamond turbot	-	-	-	-	1	0.220
deepbody anchovy	-	-	-	-	2	0.011
California sheephead	-	-	-	-	1	0.359
leopard shark	-	-	-	-	2	0.812
spotted cusk eel	-	-	-	-	-	-
kelp pipefish	-	-	-	-	-	-
vermilion rockfish	-	-	-	-	-	-
basketweave cusk-eel	-	-	-	-	-	-
pygmy poacher	-	-	-	-	-	-
plainfin midshipman	-	-	1	0.003	-	-
Survey Totals:	**7629**	**193.124**	**5532**	**149.345**	**5529**	**118.688**

Fishes	2/22/2004 H.T. #5		5/30/2004 H.T. #6	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
queenfish	4204	52.445	5626	120.950
white croaker	10	0.252	2869	59.540
northern anchovy	4	0.021	3	0.015
white seaperch	61	2.215	90	4.220
shiner perch	1	0.035	120	1.161
walleye surfperch	55	2.790	123	6.100
California halibut	-	-	1	1.920
bat ray	-	-	1	1.205
specklefin midshipman	-	-	-	-
Pacific sardine	14	2.195	1	0.015
Pacific butterfish	146	3.530	119	5.030
hornyhead turbot	-	-	-	-
black croaker	1	0.365	3	0.564
rock wrasse	-	-	-	-
California corbina	14	0.576	2	0.298
California scorpionfish	2	0.515	28	6.840
halfmoon	-	-	-	-
opaleye	1	0.593	5	4.185
sargo	-	-	-	-
giant kelpfish	-	-	-	-
black perch	2	0.236	34	0.733
blacksmith	-	-	5	0.461
pile perch	2	0.241	2	0.411
yellowfin croaker	-	-	-	-
brown rockfish	-	-	-	-
barred sand bass	-	-	-	-
kelp bass	1	0.240	14	10.559
shovelnose guitarfish	-	-	-	-
jacksmelt	48	4.485	196	18.370
California grunion	-	-	-	-
thornback	-	-	-	-
Pacific staghorn sculpin	-	-	-	-
California lizardfish	-	-	-	-
spotted turbot	-	-	-	-
spotted sand bass	-	-	-	-
jack mackerel	-	-	1	0.171
topsmelt	-	-	-	-
rockpool blenny	-	-	1	0.006
speckled sanddab	7	0.050	-	-
white seabass	8	0.160	12	1.966
chub mackerel	-	-	-	-
salema	14	0.111	1	0.003
rubberlip seaperch	-	-	16	0.125
round stingray	2	1.220	38	17.390
Pacific electric ray	-	-	-	-
yellow snake eel	1	0.200	-	-
spotfin croaker	-	-	21	1.150
diamond turbot	-	-	1	0.138
deepbody anchovy	6	0.063	6	0.070
California sheephead	-	-	-	-
leopard shark	-	-	-	-
spotted cusk eel	7	0.128	-	-
kelp pipefish	2	0.007	-	-
vermilion rockfish	1	0.002	-	-
basketweave cusk-eel	-	-	1	0.011
pygmy poacher	1	0.005	-	-
plainfin midshipman	-	-	-	-
Survey Totals:	**4615**	**72.680**	**9340**	**263.607**

Macroinvertebrates Scientific Name	Common Name	7/29/2003 N.O. #1 No.	7/29/2003 N.O. #1 Wt. (kg)	8/5/2003 N.O. #2 No.	8/5/2003 N.O. #2 Wt. (kg)
Urechis caupo	innkeeper worm	1	0.091	-	-
Neotrypaea californiensis	bay ghost shrimp	1	0.005	-	-
Polyorchis penicillatus	jellyfish	-	-	1	0.002
Lysmata californica	red rock shrimp	-	-	1	0.002
Chrysaora colorata	purple-striped jelly	-	-	-	-
Salpidae	salp, unid.	-	-	-	-
Cancer antennarius	Pacific rock crab	-	-	-	-
Cancer anthonyi	yellow rock crab	-	-	-	-
Hemigrapsus oregonensis	yellow shore crab	-	-	-	-
Pachygrapsus crassipes	striped shore crab	-	-	-	-
Panulirus interruptus	California spiny lobster	-	-	-	-
Pisaster ochraceous	ochre starfish	-	-	-	-
Penaeus californiensis	yellowleg shrimp	-	-	-	-
Pyromaia tuberculata	tuberculate pear crab	-	-	-	-
Portunus xantusii	Xantus swimming crab	-	-	-	-
Heptacarpus palpator	intertidal coastal shrimp	-	-	-	-
Navanax inermis	California aglaja	-	-	-	-
Dendronotus frondosus	nudibranch	-	-	-	-
Hermissenda crassicornis	nudibranch	-	-	-	-
Pugettia producta	shield-backed kelp crab	-	-	-	-
Loligo opalescens	market squid	-	-	-	-
Ophiothrix spiculata	spiny brittlestar	-	-	-	-
Crangon nigromaculata	blackspotted bay shrimp	-	-	-	-
Cancer gracilis	graceful rock crab	-	-	-	-
Cancer productus	red rock crab	-	-	-	-
Pachycheles pubescens	pubescent porcelain crab	-	-	-	-
Cerebratulus californiensis	ribbon worm	-	-	-	-
Dendronotus subramosus	stubby dendronotus	-	-	-	-
Pisaster sp.	sea star (decomposed)	-	-	-	-
Flabellina iodinea	Spanish shawl	-	-	-	-
Parastichopus parvimensis	warty sea cucumber	-	-	-	-
Octopus bimac./bimac.	California two-spot octopus	-	-	-	-
Protothaca staminea	Pacific littleneck (shell debris)		1.240		-
Loxorhynchus crispatus	masking crab	-	-	-	-
Loxorhynchus grandis	sheep crab	-	-	-	-
Pachycheles rudis	thick-clawed porcelain crab	-	-	-	-
Petricola californiensis	California petricolid (debris)		-		-
	Survey Totals:	**2**	**1.336**	**2**	**0.004**

Macroinvertebrates	**8/12/2003**		**8/22/2003**		**8/26/2003**	
	N.O. #3		**N.O. #4**		**N.O. #5**	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	1	0.817	-	-	-	-
salp, unid.	-	-	2	0.012	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	-	-	-	-	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	1	0.190
Pacific littleneck (shell debris)		-		-		0.150
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		0.010
Survey Totals:	**1**	**0.817**	**2**	**0.012**	**1**	**0.350**

Macroinvertebrates	**9/3/2003 N.O. #6**		**9/10/2003 N.O. #7**		**9/16/2003 N.O. #8**	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	1	0.011
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	-	-	-	-	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	1	1.000	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	1	0.036	-	-	-	-
tuberculate pear crab	-	-	-	-	1	0.001
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		0.200		0.050		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**2**	**1.236**	**-**	**0.050**	**2**	**0.012**

Macroinvertebrates	9/23/2003 N.O. #9		9/30/2003 N.O. #10		10/7/2003 N.O. #11	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	2	0.032	1	0.018	1	0.014
red rock shrimp	1	0.001	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	1	0.005
yellow rock crab	-	-	1	0.002	-	-
yellow shore crab	-	-	1	0.001	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	1	0.870	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	1	0.005	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		0.900		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**5**	**1.808**	**3**	**0.021**	**2**	**0.019**

Macroinvertebrates	10/14/2003 N.O. #12		10/21/2003 N.O. #13		10/28/2003 N.O. #14	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	1	0.004
jellyfish	5	0.021	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	-	-	-	-	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		0.050		0.500
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**5**	**0.021**	**-**	**0.050**	**1**	**0.504**

Macroinvertebrates	11/4/2003 N.O. #15		11/11/2003 N.O. #16		11/20/2003 N.O. #17	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	1	0.001
yellow rock crab	2	0.003	-	-	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	1	0.002	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	8	0.006	-	-	-	-
Hermissenda crassicornis	8	0.005	-	-	-	-
shield-backed kelp crab	1	0.002	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		0.025		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**19**	**0.041**	**1**	**0.002**	**1**	**0.001**

Macroinvertebrates	11/28/2003 N.O. #18		12/2/2003 N.O. #19		12/9/2003 N.O. #20	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	1	0.002
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	-	-	-	-	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	500	0.450
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	1	0.001
market squid	1	0.060	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**1**	**0.060**	**-**	**0.000**	**502**	**0.453**

Macroinvertebrates	12/16/2003 N.O. #21		12/23/2003 N.O. #22		12/30/2003 N.O.#23	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	5	0.010	3	0.006	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	2	0.002	-	-	-	-
yellow rock crab	-	-	-	-	1	0.002
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	2	0.004
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	5	0.005	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	1	0.001	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	1	0.001	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**13**	**0.018**	**4**	**0.007**	**3**	**0.006**

Macroinvertebrates	1/9/2004 N.O.#24		1/16/2004 N.O.#25		1/20/2004 N.O.#26	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	17	0.119	-	-	-	-
red rock shrimp	1	0.001	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	1	0.004	-	-	-	-
yellow rock crab	91	0.104	-	-	1	0.001
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	1	0.001
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	1	0.002	-	-	2	0.003
graceful rock crab	1	0.003	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**112**	**0.233**	**-**	**0.000**	**4**	**0.005**

Macroinvertebrates	1/27/2004 N.O.#27		2/3/2004 N.O.#28		2/10/2004 N.O. #29	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	1	0.002	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	1	0.007	-	-	-	-
yellow rock crab	-	-	3	0.004	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	1	0.012	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	3	0.033	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**6**	**0.054**	**3**	**0.004**	**-**	**0.000**

Macroinvertebrates	2/18/2004 N.O. #30		2/24/2004 N.O. #31		3/2/2004 N.O. #32	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	2	0.028	-	-
yellow rock crab	-	-	-	-	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	1	0.004	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	1	0.016
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	30	0.015	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	7	0.007	-	-	2	0.007
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	1	0.150	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**37**	**0.022**	**4**	**0.182**	**3**	**0.023**

Macroinvertebrates	3/9/2004 N.O. #33		3/16/2004 N.O. #34		3/23/2004 N.O. #35	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	3	0.021	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	1	0.019	1	0.002	-	-
yellow rock crab	-	-	-	-	2	0.005
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	1	0.001	-	-	-	-
warty sea cucumber	-	-	1	0.064	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		0.083
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**5**	**0.041**	**2**	**0.066**	**2**	**0.088**

Macroinvertebrates	3/30/2004 N.O. #36		4/6/2004 N.O. #37		4/13/2004 N.O. #38	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	1	0.003
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	-	-	5	0.014	13	0.040
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	1	0.004	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	8400	1.680	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	2	0.006	-	-	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**8403**	**1.690**	**5**	**0.014**	**14**	**0.043**

Macroinvertebrates Common Name	**4/20/2004 N.O. #39 No.**	**Wt. (kg)**	**4/27/2004 N.O. #40 No.**	**Wt. (kg)**	**5/4/2004 N.O. #41 No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	3	0.010
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	4	0.008	-	-	5	0.036
yellow rock crab	6	0.013	4	0.010	52	0.088
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	1	0.004	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	1	0.001
Xantus swimming crab	-	-	-	-	2	0.016
intertidal coastal shrimp	-	-	-	-	1	0.001
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	41	0.062
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	3	0.004
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**10**	**0.021**	**5**	**0.014**	**108**	**0.218**

Macroinvertebrates	5/11/2004 N.O. #42		5/18/2004 N.O. #43		5/25/2004 N.O. #44	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	1	0.320	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	15	0.023	41	0.092	1	0.025
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	3	0.006	12	0.039
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	2	0.008
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	4	0.008	1	0.020
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	1	1.177	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**16**	**0.343**	**49**	**1.283**	**16**	**0.092**

Macroinvertebrates	6/3/2004 N.O. #45		6/8/2004 N.O. #46		6/15/2004 N.O. #47	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	28	0.724	-	-	-	-
yellow rock crab	130	2.447	-	-	4	0.004
yellow shore crab	-	-	-	-	-	-
striped shore crab	2	0.005	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	1	0.005	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	1	0.013	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	17	0.169	-	-	-	-
red rock crab	52	0.852	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	6	1.291	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	1	0.897
Pacific littleneck (shell debris)		-		-	-	-
masking crab	1	0.031	-	-	-	-
sheep crab			-	-	-	-
thick-clawed porcelain crab			-	-	-	-
California petricolid (debris)		-	-	-	-	-
Survey Totals:	**238**	**5.537**	**-**	**0.000**	**5**	**0.901**

Macroinvertebrates	6/22/2004 N.O. #48		6/29/2004 N.O. #49		7/7/2004 N.O. #50	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	-	-	-	-	-	-
purple-striped jelly	2	0.778	1	0.673	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	-	-	-	-	-	-
yellow rock crab	-	-	-	-	4	0.002
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	-	-
California spiny lobster	-	-	-	-	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	-	-	-	-	2	0.003
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	1	0.001	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	1	0.970	-	-	-	-
Pacific littleneck (shell debris)	-	-	-	-	-	0.070
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)	-	-	-	-	-	-
Survey Totals:	**3**	**1.748**	**2**	**0.674**	**6**	**0.075**

Macroinvertebrates	7/13/2004 N.O. #51		7/20/2004 N.O. #52		8/16/2003 H.T. #1	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	2	0.025
bay ghost shrimp	-	-	-	-	-	-
jellyfish	2	0.008	1	0.336	-	-
red rock shrimp	-	-	-	-	3	0.008
purple-striped jelly	2	0.190	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	2	0.028	92	0.392	1	0.056
yellow rock crab	-	-	16	0.284	-	-
yellow shore crab	-	-	-	-	-	-
striped shore crab	-	-	-	-	17	0.028
California spiny lobster	-	-	-	-	11	5.000
ochre starfish	-	-	-	-	3	1.103
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	4	0.004	59	0.070	-	-
Xantus swimming crab	-	-	-	-	-	-
intertidal coastal shrimp	-	-	-	-	-	-
California aglaja	-	-	-	-	-	-
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	-	-	-	-
shield-backed kelp crab	-	-	-	-	-	-
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	30	0.036	161	0.195	-	-
red rock crab	-	-	-	-	-	-
pubescent porcelain crab	-	-	-	-	-	-
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	-	-	-	-	12	0.047
Pacific littleneck (shell debris)		0.108		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**40**	**0.374**	**329**	**1.277**	**49**	**6.267**

Macroinvertebrates	9/26/2003 H.T. #2		11/7/2003 H.T. #3		1/6/2004 H.T.#4	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-	-	-
bay ghost shrimp	-	-	-	-	-	-
jellyfish	-	-	-	-	-	-
red rock shrimp	4	0.006	-	-	-	-
purple-striped jelly	-	-	-	-	-	-
salp, unid.	-	-	-	-	-	-
Pacific rock crab	13	0.008	2	0.010	-	-
yellow rock crab	-	-	-	-	21	0.037
yellow shore crab	-	-	-	-	-	-
striped shore crab	7	0.030	2	0.042	11	0.046
California spiny lobster	6	2.750	1	0.604	-	-
ochre starfish	-	-	-	-	-	-
yellowleg shrimp	-	-	-	-	-	-
tuberculate pear crab	9	0.006	1	0.002	27	0.028
Xantus swimming crab	-	-	-	-	11	0.019
intertidal coastal shrimp	2	0.001	-	-	14	0.005
California aglaja	3	0.005	-	-	4	0.015
Dendronotus frondosus	-	-	-	-	-	-
Hermissenda crassicornis	-	-	2	0.004	-	-
shield-backed kelp crab	-	-	-	-	1	0.054
market squid	-	-	-	-	-	-
spiny brittlestar	-	-	-	-	-	-
blackspotted bay shrimp	-	-	-	-	-	-
graceful rock crab	-	-	-	-	-	-
red rock crab	-	-	-	-	2	0.018
pubescent porcelain crab	-	-	-	-	1	0.001
ribbon worm	-	-	-	-	-	-
stubby dendronotus	-	-	-	-	-	-
sea star (decomposed)	-	-	-	-	-	-
Spanish shawl	-	-	-	-	-	-
warty sea cucumber	-	-	-	-	-	-
California two-spot octopus	14	0.041	2	0.030	-	-
Pacific littleneck (shell debris)		-		-		-
masking crab	-	-	-	-	-	-
sheep crab	-	-	-	-	-	-
thick-clawed porcelain crab	-	-	-	-	-	-
California petricolid (debris)		-		-		-
Survey Totals:	**58**	**2.847**	**10**	**0.692**	**92**	**0.223**

Macroinvertebrates	2/22/2004 H.T. #5		5/30/2004 H.T. #6	
Common Name	**No.**	**Wt. (kg)**	**No.**	**Wt. (kg)**
innkeeper worm	-	-	-	-
bay ghost shrimp	-	-	-	-
jellyfish	-	-	-	-
red rock shrimp	-	-	133	0.180
purple-striped jelly	-	-	-	-
salp, unid.	-	-	-	-
Pacific rock crab	-	-	52	1.105
yellow rock crab	20	0.035	110	1.270
yellow shore crab	-	-	-	-
striped shore crab	24	0.052	88	0.203
California spiny lobster	-	-	2	0.283
ochre starfish	-	-	-	-
yellowleg shrimp	-	-	-	-
tuberculate pear crab	-	-	349	0.346
Xantus swimming crab	4	0.020	1	0.016
intertidal coastal shrimp	4	0.004	11	0.008
California aglaja	8	0.018	-	-
Dendronotus frondosus	-	-	-	-
Hermissenda crassicornis	85	0.095	24	0.015
shield-backed kelp crab	1	0.015	9	0.130
market squid	-	-	-	-
spiny brittlestar	-	-	14	0.007
blackspotted bay shrimp	2	0.004	-	-
graceful rock crab	-	-	11	0.079
red rock crab	-	-	23	0.147
pubescent porcelain crab	-	-	-	-
ribbon worm	-	-	-	-
stubby dendronotus	14	0.028	-	-
sea star (decomposed)	-	-	-	-
Spanish shawl	-	-	-	-
warty sea cucumber	-	-	-	-
California two-spot octopus	1	1.556	5	0.800
Pacific littleneck (shell debris)		-		-
masking crab	-	-	-	-
sheep crab	-	-	1	0.657
thick-clawed porcelain crab	-	-	1	0.001
California petricolid (debris)		-		-
Survey Totals:	**163**	**1.827**	**834**	**5.247**

ATTACHMENT 3

Restoration Plan

AES HUNTINGTON BEACH GENERATING STATION

CLEAN WATER ACT SECTION 316(b) RESTORATION PLAN

Prepared by
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Tenera Environmental, Inc.

for

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21730 Newland Street
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November 14, 2007

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1.0 INTRODUCTION

AES Huntington Beach proposes to comply with Section 316(b) of the Clean Water Act in part through the use of restoration measures. A yearlong entrainment and impingement mortality study was conducted at the AES Huntington Beach Generating Station (HBGS) in 2003-4 as part of a California Energy Commission (CEC) relicensing condition. Data collected during this study were used to determine appropriate mitigation (restoration) for the retooling of Units 3&4 at the HBGS. The CEC staff determined the most appropriate restoration site was the Huntington Beach Wetlands (HBW), located adjacent to the HBGS. Conceptual restoration plans were already drafted for the HBW in April 2006. AES Huntington Beach contributed $5.5 million to the Huntington Beach Wetlands Conservancy to initiate restoration activities in December 2006.

The 316(b) Phase II regulations required the Restoration Plan to include:

1. A demonstration that design and construction technologies and/or operational measures have been evaluated and an explanation of how it was determined that restoration would be more feasible, more cost-effective, or more environmentally desirable. This is provided in the HBGS Comprehensive Cost Evaluation Study and discussed further in this section.
2. A narrative description of the design and operation of all restoration measures (existing and proposed) that are in place or will be used to produce fish and shellfish. This information is presented in Section 1.2.
3. Quantification of the ecological benefits of the proposed restoration measures. This must include a discussion of the nature and magnitude of uncertainty associated with the performance of the restoration measures, and a discussion of the time frame within which the ecological benefits are expected to accrue. This is provided in Section 2.
4. Design calculations, drawings, and estimates to document that the proposed restoration measures in combination with design and construction technologies and/or operational measures, or alone, will meet the requirements of Sec. 125.94(c)(2). If the restoration measures address the same fish and shellfish species identified in the IM&E Characterization Study, it must be demonstrated that the restoration measures will produce a level of fish and shellfish substantially similar to that which would result from meeting applicable performance standards in 125.94(b), or they would satisfy site-specific requirements established pursuant to 125.94(a)(5). If the restoration measures address fish and shellfish species different from those identified in the IM&E Characterization Study (out-of-kind restoration), it must be demonstrated that the restoration measures produce ecological benefits substantially greater than those that would be realized through in-kind restoration. Such a demonstration should be based on a watershed approach to restoration planning and consider applicable multi-agency watershed restoration plans, site specific peer-reviewed ecological studies, and or consultation with appropriate Federal, State, and Tribal fish and wildlife management agencies. This information is provided in Section 3.
5. An adapative management plan for implementing, maintaining, and demonstrating the efficacy of the restoration measures selected and for determining the extent to which the restoration measures (along with any design and construction technologies and/or operational measures) have met the applicable requirements of Section 125.94(c)(2). The adaptive management plan must include:
    a. A monitoring plan that includes: parameters to be monitored, monitoring frequency, and success criteria for each parameter;

   b. A list of activities to be undertaken to ensure the efficacy of the restoration measures, a description of the linkages between these activities and the items in (a), and an implementation schedule;
   c. A process for revising the Restoration Plan as new information, including monitoring data, becomes available, if the applicable requirements of 125.94(c)(2) are not being met. This information is provided in Section 4.
6. A summary of any past or ongoing consultation with appropriate Federal, State, and Tribal fish and wildlife management agencies on your use of restoration measures. This information is provided in Section 5.
7. If requested by the Director, a peer review of the Restoration Plan. You must choose the peer reviewers in consultation with the Director.
8. Information to be submitted in a biannual status report to the Director. This information is provided in Section 4.

Restoration in lieu of technology changes was originally deemed more desirable by the California Energy Commission in their review of the AES Huntington Beach retool project. AES Huntington Beach and the authors of this plan believe the restoration project is more environmentally desirable in that it not only compensates for entrainment losses, but provides added ecological benefits as described in Section 3. The restoration project is also more cost effective when compared to the costs estimated in the Comprehensive Cost Evaluation.

The purpose of this restoration plan is to provide the Santa Ana Regional Water Quality Control Board (SARWQCB) with sufficient information as described above to implement the HBW restoration project as described above.

1.1 PROJECT SELECTION

This section summarizes the timeline leading to preparation of this restoration plan. In 2000, AES Huntington Beach submitted the Application for Certification (AFC) for the HBGS Retool Project to the CEC, and several months later the CEC approved the Retool Project with Conditions of Certification. One of the Conditions of Certificaiton required AES Huntington Beach to perform a one-year entrainment and impingement study. If the the one-year study determined that entrainment and/or impingement losses were significant, then AES was required to perform restoration to offset those losses. The Retool Project began in 2001, and by summer 2003 both Units 3&4 were commercially operational. The one-year entrainment and impingement study was performed from summer 2003 through summer 2004. Data reports were submitted quarterly during the study, and the final report was submitted in April 2005 (MBC and Tenera 2005).

In March 2006, CEC staff issued their findings of significance, indicating that restoration of 104 acres of wetlands would fully mitigate for cooling water system impacts (CEC Staff 2006a). This estimate was based on maximum cooling water flows at Units 3&4. In August 2006, the National Pollutant Discharge Elimination System (NPDES) permit for the HBGS was renewed, and it specified restoration as a 316(b) compliance option. In September 2006, it was agreed that AES Huntington Beach would fund the restoration of 66.8 acres of the Huntington Beach Wetlands to fully mitigate cooling water system impacts at Units 3&4. This was based on the actual operations of the cooling water system at the HBGS.

Lastly, in December 2006 AES Huntington Beach fulfilled its obligation to provide funding to the Huntington Beach Wetlands Conservancy (HBWC) for the restoration of 66.8 acres (0.270 km^2) at the HBW complex.

CEC staff considered several methods to reduce entrainment impacts at the HBGS (CEC Staff 2006b). These included:

- Cooling water flow reductions;
- Tidal wetlands restoration; and
- Creation of artificial reefs.

CEC staff determined that tidal wetland restoration would be most appropriate, and that restoration at the adjacent Huntington Beach Wetlands would be the best project.

1.2 PROJECT DESCRIPTION

The Conceptual Restoration Plan for the Huntington Beach Wetlands was prepared in April 2006 (Moffatt & Nichol 2006). The Conceptual Restoration Plan described the proposed project at the HBW complex in sufficient detail to perform environmental review and secure permits to begin the next steps in the restoration process.

The Huntington Beach Wetlands occupy approximately 191 acres (0.773 km^2) of relic salt marsh habitat associated with the Santa Ana River in Huntington Beach, California (Figure 1). The entire HBW complex was once the lower Santa Ana River mouth wetland area. The wetlands currently consist of four recognized marshes:

Marsh	Area (Acres)	Area (km^2)
Talbert Marsh	27	0.109
Brookhurst Marsh	67	0.271
Magnolia Marsh	43	0.174
Newland Marsh	54	0.219
Total	**191**	**0.773**

The four marshes are hydraulically connected but separated by roads. Talbert Marsh was restored in 1990 by the HBWC, and resulted in increased tidal flushing and circulation, establishment of sensitive salt marsh habitat, and improved flood control. Besides Talbert Marsh, the other marshes are relict salt marshes isolated from tides by flood control levees along their northern boundaries and other infrastructure. The sites have degraded over time and serve as seasonal wetlands during the rainy season only. The marshes are habitat for the state-listed endangered Belding's savannah sparrow (*Passerculus sandwichensis beldingi*) and other coastal wetland species.

Figure 1. Location of each of the Huntington Beach Wetlands. Modified from Moffat & Nichol (2006).

1.2.1 Talbert Marsh

The restoration of Talbert Marsh includes:

- Construction of a large sediment trap (60,000 cubic yards) to control sedimentation;
- Construction of a smaller sediment trap in the inlet channel. Maintenance of this trap would be less environmentally disturbing than maintenance on the main trap within the marsh;
- Construction of a small shoal removal area to manage sedimentation from propagating upstream toward other marshes as the restored tidal prism is increased; and
- Modification of elevations to enhance tidal influence.

An oil boom will be stored near the inlet so that if an offshore oil spill occurred, it could be deployed at the entrance and protect all marshes from contamination. Infrastructure for maintenance dredging would also be maintained at the inlet, including (1) a launch ramp for small, hydraulic dredges, (2) a storage and launch facility for a permanent small barge and mounted pump, and (3) a platform for operation of a crane and dragline type of dredge. Public access and interpretive aids will remain the same as exists.

The tidal range of Talbert Marsh will increase due to removal of sand shoals. The spring tide range will be 7.6 ft, with elevations between –0.2 and +7.4 ft North American Vertical Datum (NAVD). The same types of habitat that occur at Talbert Marsh at present will occur after restoration, although subtidal habitat will increase with the creation of the sediment trap near PCH. The sediment trap will help prevent sedimentation (including creation of sand bars that currently exist in Talbert Marsh), which restricts tidal circulation. The preferred restoration concept for Talbert Marsh is presented in Figure 2.

Figure 2. Proposed configuration of Talbert Marsh. Source: Moffat & Nichol (2006).

1.2.2 Brookhurst Marsh

The restoration of Brookhurst Marsh includes:

- Modification of elevations to enhance tidal influence;
- Lowering the Huntington Beach Channel levee to allow tidal inundation during high tides (+4.6 to +6 ft NAVD);
- Lowering internal channels by about two to three feet;
- Lowering banks along the main channel to create mudflat habitat;
- Constructing a low dike along Magnolia Avenue for flood protection;
- Removal of contaminated sediments near Magnolia and Pacific Coast Highway (PCH); and
- Constructing an earthen dike around an oil seep near the Brookhurst Street bridge.

Tidal conveyance will occur via one open channel, with a spring tide range of 6.6 ft (+0.8 ft to +7.4 ft NAVD). The tidal prism after restoration will be approximately 136 acre-feet as most of the site will become new wetland area.

Restoration will also include establishment of a primary public access point at PCH and Brookhurst Street, which will serve as the focal point for interpretive activities. This will include construction of environmentally-sensitive pathway systems through the marsh. The preferred restoration concept for Brookhurst Marsh is presented in Figure 3.

Figure 3. Proposed configuration of Brookhurst Marsh. Source: Moffat & Nichol (2006).

1.2.3 Magnolia Marsh

The restoration of Magnolia Marsh includes:

- Modification of elevations to enhance tidal influence;
- Lowering internal channels to create mudflat habitat;
- Constructing a flood levee near the HBGS for flood protection;
- Constructing a flood levee along Magnolia Avenue to prevent flooding, and installing a stormdrain line with a flag gate to allow Magnolia Street to drain without receiving high waters from the marsh;
- Removal of the flood control levee along the Huntington Beach Channel to supplement tidal influence; and
- Removal of contaminated sediments.

Tidal conveyance will occur via one open channel and near complete levee overtopping, with a spring tide range of 5.4 ft (+2.0 ft to +7.4 ft NAVD). The tidal prism after restoration will be approximately 94 acre-feet as most of the site will become new wetland area. This site will be substantially converted to subtidal and low marsh habitat. The vegetation at the existing site is primarily non-tidal pickleweed and salt panne, but will consist of open water, mudflat, and cordgrass after restoration.

The majority of the public outreach and interpretative activities will likely occur at this marsh, since it is closes to the Wetlands and Wildlife Care Center. The preferred restoration concept for Magnolia Marsh is presented in Figures 4 and 5.

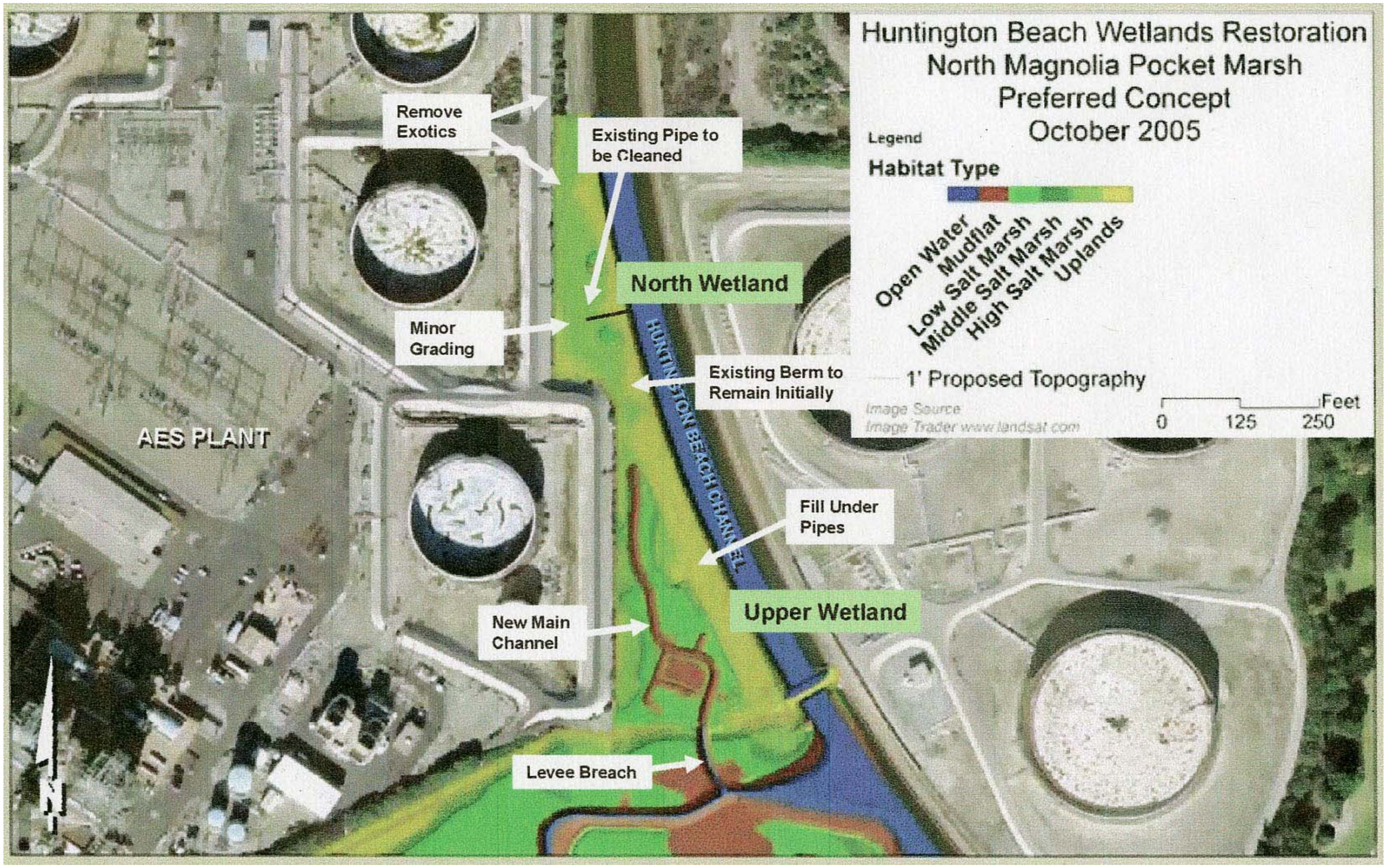


Figure 4. Proposed configuration of North Magnolia Marsh (upper marshes adjacent to the HBGS). Source: Moffat & Nichol (2006).

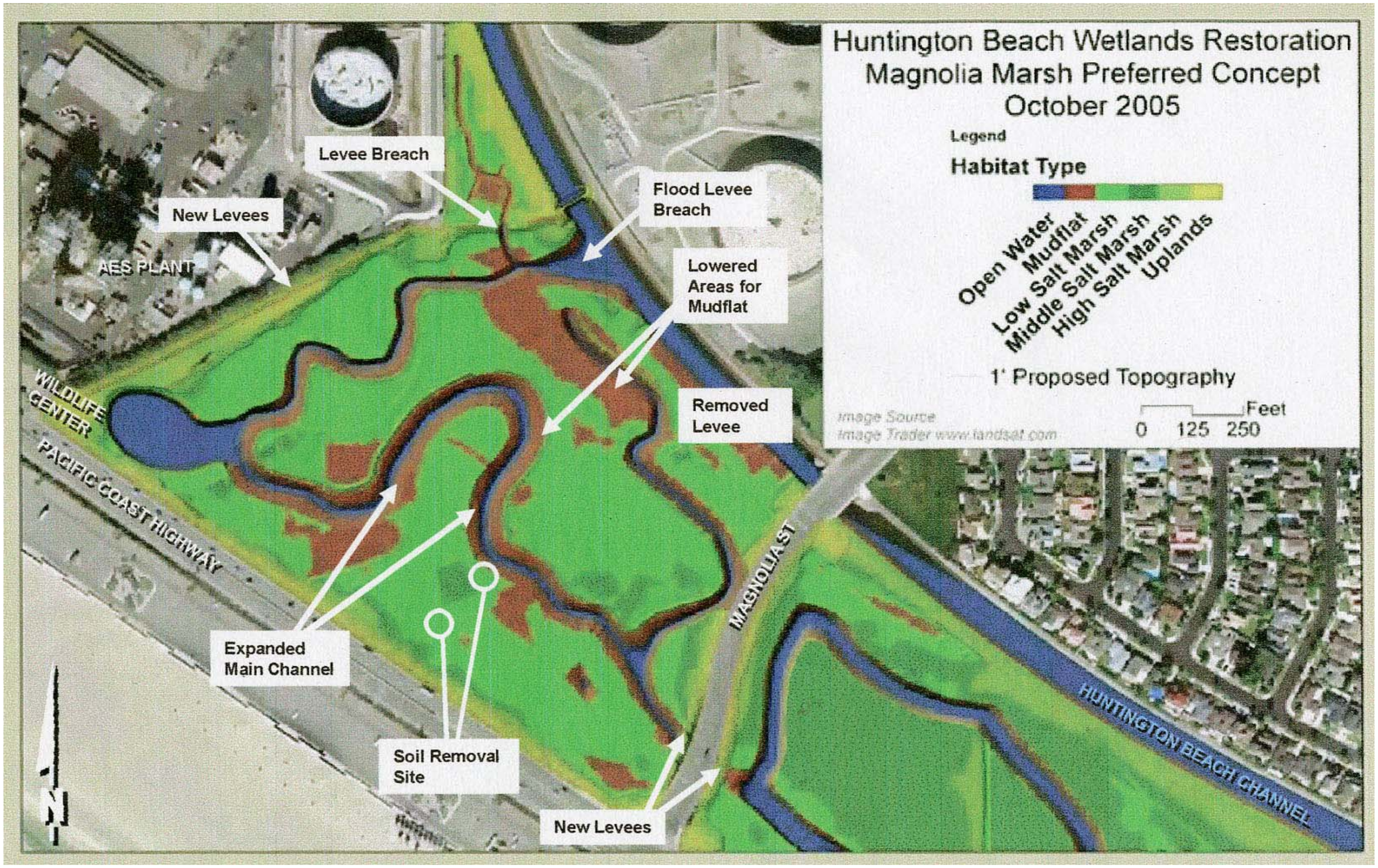


Figure 5. Proposed configuration of Magnolia Marsh. Source: Moffat & Nichol (2006).

1.2.4 Newland Marsh

Newland Marsh is divided into the Newland West, Newland East, and Newland North Marshes. The West and East Marshes are connected to the Huntington Beach Channel through a single, three-foot diameter culvert at each marsh, while the North Marsh will be connected with a one-feet diameter culvert. Thus, tidal prisms will vary between the marshes. All Newland Marshes will be converted into intertidal salt marsh habitat under muted tidal conditions (ranging between about +2 and +5 ft NAVD). Public access would be available along at least two boundaries of all three marshes.

The restoration of Newland West includes installation of a culvert through the Huntington Beach Channel to provide tidal connection with the ocean, enlarging three to six tributary channels through the marsh, installing perimeter channels along Beach Boulevard and PCH to discourage access, and installing new perimeter levees. The spring tide range will be 2.8 ft (+2.1 ft to +4.9 ft NAVD). The tidal prism for the restored marsh will be approximately 60 acre-feet.

The restoration of Newland East includes installation of a culvert through the Huntington Beach Channel to provide tidal connection with the ocean, enlarging two tributary channels through the marsh, lowering the sides of the tributaries to create marsh area, and installing new perimeter levees. The spring tide range will be 3.0 ft (+2.2 ft to +5.2 ft NAVD). The tidal prism for the restored marsh will be approximately 47 acre-feet. A small educational/interactive marsh would be installed at the east end of this marsh.

The restoration of Newland North includes installation of a culvert through the Huntington Beach Channel to provide tidal connection with the ocean, creation of a tributary channel, lowering the sides of the tributaries to create marsh area, installing new perimeter levees, and potentially constructing a pedestrian bridge over the Huntington Beach Channel to provide public access. The spring tide range will be 3.1 ft (+2.1 ft to +5.2 ft NAVD). The tidal prism for the restored marsh will be approximately 6 acre-feet. The preferred restoration concept for Newland Marsh is presented in Figure 6.

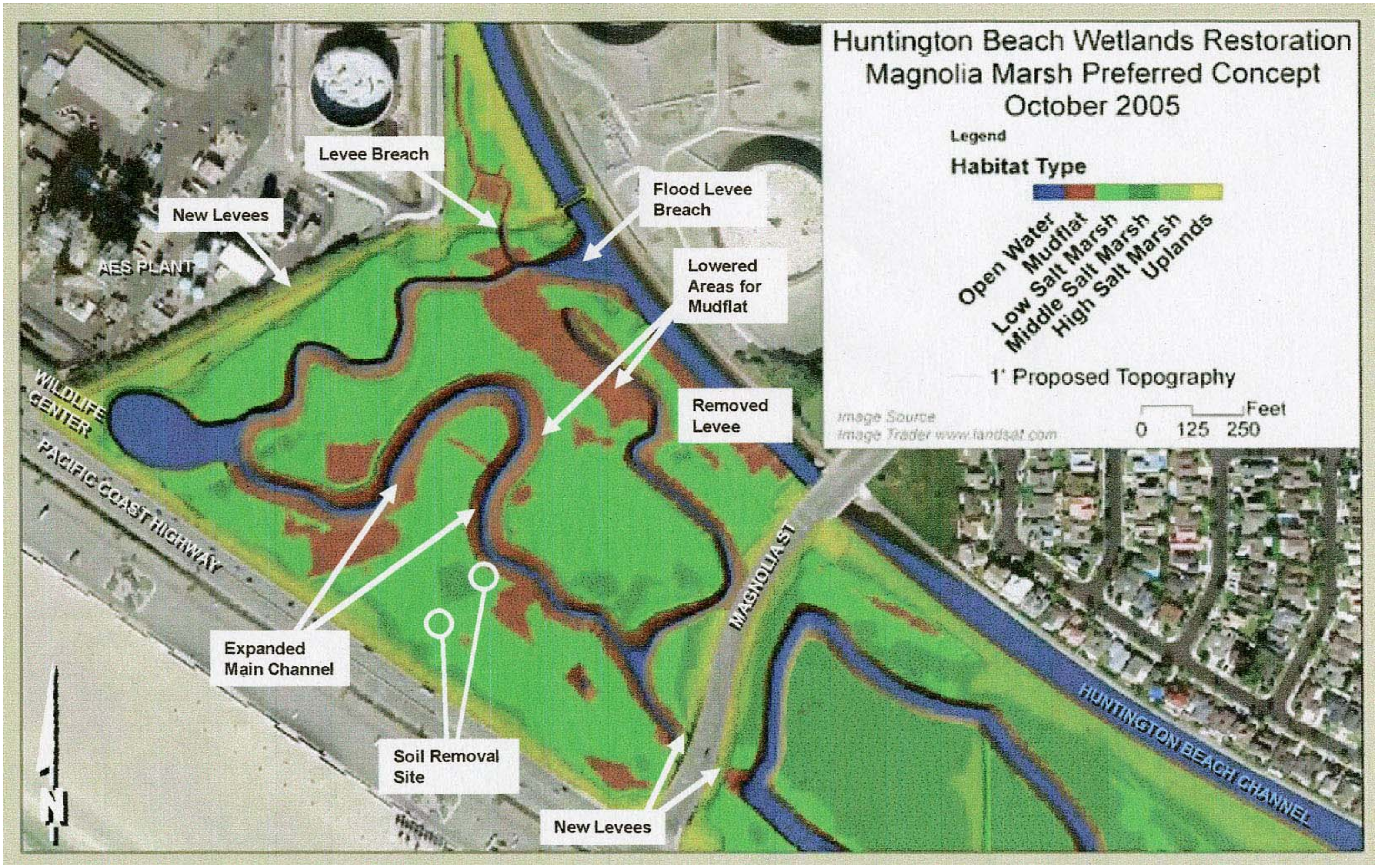


Figure 6. Proposed configuration of Magnolia Marsh. Source: Moffat & Nichol (2006).

2.0 PROJECT IMPLEMENTATION

The Conceptual Restoration Plan set forth a proposed implementation timeline that is phased to ensure that some marsh habitat is available during construction. This phased approach is designed to avoid site flooding or modification of vegetation during the avian nesting season within the marshes (April through September). Construction is scheduled to begin in September 15, 2008 (G. Gorman, pers. comm.). This is contingent on obtaining permits/approvals from the following agencies in the following approximate timeframes:

December 2007: City of Huntington Beach, U.S. Army Corps of Engineers, California Dept. of Fish and Game.

Feb./March 2008: California Coastal Commission.

After California Coastal Commission approval, the HBWC will request bids for the construction of the restoration projects. The phased approach to construction consists of the following elements:

1. Implementation of Upper Marsh North Wetland Restoration. This would take approximately 6-9 months including permitting, approvals, and all site construction.

2. Implementation of Talbert and Magnolia Marshes including the remaining Upper Wetland Restoration. This would take approximately 21-24 months including permitting, approvals, and all site construction, and could occur concurrently with Phase 1 (above). Before proceeding with Phase 3 (below), 3-5 years should elapse to enable habitat establishment for use by Belding's savannah sparrows during restoration of Brookhurst Marsh.

3. Implementation of Brookhurst Marsh Restoration. This would take approximately 6-9 months for site construction, and assumes all permits/approvals were secured as part of the Talbert/Magnolia effort (above).

4. Implementation of Newland Marsh Restoration. This would take approximately 9-12 months for site construction, and assumes all permits/approvals were secured as part of the Talbert/Magnolia effort (above). The timing of this phase is less certain due to land ownership issues.

With construction set to begin in September 2008, implementation of the first two phases (Upper Marsh North, Talbert, and Magnolia marshes) would continue through June to September 2010. Phase 3 (Brookhurst Marsh) would begin between late 2013 and late 2015. As restoration activities occur, ecological benefits will begin to accrue. For some aspects the benefits will be immediate (such as the availability of restored terrestrial habitat) whereas for others (such as the establishment of a benthic community in new subtidal areas), it may take many months or years for a climax community to become established.

3.0 RESTORATION SCALING

Upon submittal of the final entrainment and impingement study to the CEC (MBC and Tenera 2005), the CEC staff determined that entrainment losses represented a significant impact requiring mitigation (CEC Staff 2006a). (AES Huntington Beach and its consultants disputed this determination). The determination of the amount of wetland acreage to be restored was made using results from the 2003-4 entrainment study (MBC and Tenera 2005). The collection of monthly source water samples during the year-long study off the HBGS enabled use of the Empirical Transport Model (*ETM*), which was used to calculate the probability of mortality (P_M) of entrainment for susceptible larvae. An estimate of the area of larval production lost due to entrainment (area of production foregone, or APF) was calculated by multiplying the P_M estimates (for each species analyzed) by the alongshore source water length and the width of the source water sampled (approximately five kilometers). This is similar to the approach used at the Moss Landing Power Plant.

Several estimates of the amount of restoration sufficient to offset entrainment losses were calculated. Ultimately, however, the final amount was determined based on the following:

- Actual cooling water flow volumes, not maximum cooling water flow volumes;
- Probability of mortality estimates for taxa with nearshore distributions that were effectively characterized during source water sampling.

Based on maximum cooling water flow at the HBGS, the P_M estimates for each of the target taxa analyzed ranged between 0.10 and 2.36 km^2 (25.4 and 584 acres), with an average of 0.84 km^2 (206.4 acres) (Tenera 2006) (Table 1).

Table 1. Probability of mortality and area of production foregone (APF) estimates for the HBGS assuming maximum flow at all units (from Tenera 2006).

Taxon	P_M Alongshore (from 2005 report)	Alongshore Displacement (km)	APF (km^2)	APF (acres)
Estuarine taxon				
Unid. gobies	0.0090	3,397.78	0.12	30.68
Nearshore taxa				
spotfin croaker	0.0029	16.94	0.22	54.77
queenfish	0.0063	84.88	2.36	584.3
white croaker	0.0071	47.84	1.51	374
black croaker	0.0012	19.42	0.10	25.42
blennies	0.0077	12.82	0.44	108.26
diamond turbot	0.0058	16.93	0.44	107.62
Calif. halibut	0.0025	30.91	0.34	84.97
Cancer megalops	0.0107	26.50	1.26	311.81
Nearshore Average			**0.84**	**206.39**

The estimates from Table 1 were refined to take into account (1) only the operation of Units 3&4, and (2) projected operations for Units 3&4 between 2006 and 2011 (Stone and Kramer 2006). The projected operations of Units 3&4, calculated by AES Huntington Beach, estimated 25% operation during the first quarter of each year, 50% during the second, 80% during the third, and 45% during the fourth quarter. This estimate (50% operation during the year) was considered conservative by AES Huntington Beach. Recalculating the *APF* based on these estimates resulted in a restoration estimate of 66.8 acres. The CEC calculated the estimated restoration costs at the HBW complex ($5,511,000) based on information provided by the HBWC. The costs were based on $4,987,288 for restoration ($74,600 per acre) plus an additional $523,712 for maintenance ($784 per acre per year for 10 years). The cost for restorating each acre of wetland at the HBW complex was calculated by dividing the total estimated project cost ($14.26 million) by the size of the wetlands (191 acres). Maintenance costs were estimated in a similar matter ($149,767 per year for 191 acres).

In California, more than 90% of the coastal wetlands have been lost due to human activity, and there are state and federal efforts underway to accelerate the pace of coastal wetland restoration. In addition to increasing the net production of fish and shellfish by enhancing existing habitat or creating new habitat, restoration of coastal wetlands has multiple benefits. These include: improvements in water quality by trapping pollutants before they enter coastal waters; providing foraging, resting, and nesting habitat for seabirds and shorebirds, including sensitive species; physical improvements in terrestrial and avian habitats; improved aesthetics; added recreational and/or viewing opportunities and so on (CEC Staff 2006b). Tidal wetlands provide nursery habitat for many nearshore fish species, and also export organic matter that enhances coastal food chains. These added benefits were not quantified as part of the scaling process.

4.0 ADAPTIVE MANAGEMENT PLAN

A draft comprehensive verification monitoring plan was prepared by Merkel & Associates (2007). The goal of the monitoring plan is to document the physical and biological status of the HBW complex prior to and following initiation of restoration activities. Pre-restoration monitoring was intiated in 2007 and is scheduled to continue through summer 2008, just prior to initiation of restoration. Post-restoration monitoring is proposed to occur for 10 years following restoration.

Proposed monitoring parameters and monitoring frequencies are summarized in Table 2.

Table 2. Proposed monitoring parameters and frequencies at the HBW complex (from Merkel & Associates [2007]).

Parameter	Method	Pre-Restoration Frequency	Post-Restoration Frequency
Bathymetry	Vessel-based fathometer	January & July 2008	Immediate post-construction, annually for 5 years following, and again 7- and 10-years post-construction
Tidal monitoring	Tide gauges	30-day deployements quarterly	30-day deployments quarterly for at least 5 years
Water quality	Hydrolab multi-parameter datasondes	14-day deployments quarterly	14-day deployments quarterly for at least 5 years, and again 7- and 10-years post-construction
Birds	Field surveys	Quarterly	Quarterly for 5 years following, and again 7- and 10-years post-construction
Belding's savannah sparrow	Field survyes	April 2008 (breeding season)	Annually following post-construction for 10 years
Fish	Otter trawl and beach seine	Quarterly	Quarterly for 5 years following, and again 7- and 10-years post-construction
Infauna	15-cm core, 1.0-mm sieve at +1-ft and -2-ft elevations	Twice per year	Twice per year for 5 years following, and again 7- and 10-years post-construction
Vegetation	High-resolution aerial photography, digitization in GIS, field transects	Annually (September)	Photography annually (September) following post-construction for 10 years, transects annually for 5 years following, and again 7- and 10-years post-construction

It is recognized that maintenance will need to occur on a regular basis for the site to remain high in habitat quality (Moffatt & Nichol 2006). The verification monitoring of the Huntington Beach Wetlands Complex will support an adaptive management strategy by allowing the continuous evaluation of physical and biological parameters before, during, and after restoration activities. Quarterly and annual reports will be submitted to the HBWC, and will include not only a summary of monitoring results, but a discussion on potential maintenance action needs to ensure the success of the project, and the subsequent response to any corrective actions already implemented. There have been some recent, successful wetlands restoration projects in southern California that provide an acceptable level of certainty that this project will succeed (CEC Staff 2006b).

To evaluate the success of the restoration project, AES Huntington Beach will evaluate the quarterly and annual reports as they are submitted, and on a biannual basis will provide the SARWQCB with progress reports that summarize the reports prepared for the HBWC. As part of the Memorandum of Understanding (2006), AES Huntington Beach will be provided copies of the HBWC annual reports that include descriptions of the projects implemented and a schedule and description of future projects. The success of the restoration project will be based on the physical restoration of the affected habitats as proposed by the HBWC (Moffatt & Nichol 2006). That is, the restoration will be considered successful if the proposed area of each habitat type proposed by HBWC is indeed modified as expected. Specific items to be addressed in the biannual status report include (1) physical restoration activities undertaken since the last reporting period, and (2) a summary of physical monitoring results since the last reporting period.

5.0 AGENCY CORRESPONDENCE

The AES HBGS entrainement and impingement study final report was submitted in April 2005, after which time the CEC and participating agencies submitted their comments on the significance of impacts due to operation of the once-through cooling water system at the HBGS. Condition of Certification Bio-5 required AES Huntington Beach to provide funds for mitigation/compensation for impacts to Southern California Bight fish populations "*if the entrainment and impingement study determine(d) that significant impacts to one or more species of coastal fish is occurring…*" In March 2006 the CEC Staff released their preliminary staff assessment indicating that they had determined the losses to be significant and in need of mitigation. Representatives from the California Coastal Commission, California Department of Fish and Game, National Marine Fisheries Service, and the SARWQCB also agreed with the CEC staff and supported mitigation to offset entrainment and impingement losses (CEC Staff 2006b). There has been no recent correspondence with state or federal fish/wildlife agencies with respect to this restoration project.

6.0 LITERATURE CITED

CEC Staff. 2006a. Huntington Beach Units 3&4 Entrainment and Impingement Results and Mitigation Option. Dr. Noel Davis, Rick York, and Joanna Reinhardt. March 17, 2006. 21 p.

CEC Staff. 2006b. Huntington Beach Units 3&4 Entrainment and Impingement Study Results, Mitigation Options, Staff and Working Group Recommendations, and AES's Response and Objections to the Recommendation. Dr. Noel Davis, Dr. Pete Raimondi, Rick York, and Joanna Reinhardt. Sept. 14, 2006. 45 p.

Gorman, G. 2007. HBWC. Personal communication with S. Beck (MBC), August 30, 2007.

MBC Applied Environmental Sciences and Tenera Environmental. 2005. AES Huntington Beach L.L.C. Generating Station Entrainment and Impingement Study: Final Report. Prepared for AES Huntington Beach L.L.C. and the Calif. Energy Comm. April 2005.

Memorandum of Understanding. 2006. MOU between AES Huntington Beach, LLC, the Huntington Beach Wetlands Conservancy, and the California Energy Commission.

Merkel & Associates. 2007. Draft Pre- and Post-Restoration Monitoring Plan for the Huntington Beach Wetlands Restoration Project. Prepared for the Huntington Beach Wetlands Conservancy. April 2007. 24 p.

Moffatt & Nichol. 2006. Huntington Beach Wetlands Conceptual Restoration Plan: Revised Final Report. Prepared for the Huntington Beach Wetlands Conservancy and the California Coastal Conservancy for the Wetlands Recovery Project. Prepared in association with Merkel & Associates, New West Land, Geosyntec Consultants, and Kleinfelder. Apr. 10, 2006. 57 p. plus appendices.

Stone, D. and P. Kramer. 2006. Memo to California Energy Commissioners and Interested Parties. Subject: AES HBGS Retool Project (00-AFC-13C) Report of September 25 Staff Workshop. Sept. 26, 2006.

Tenera Environmental. 2006. Huntington Beach Generating Station Empirical Transport Model estimates for Area of Production Foregone using seasonal flow reduction. Prepared for Mr. Paul Hurt, AES Southland. Aug. 14, 2006. 3 p.

ATTACHMENT 4

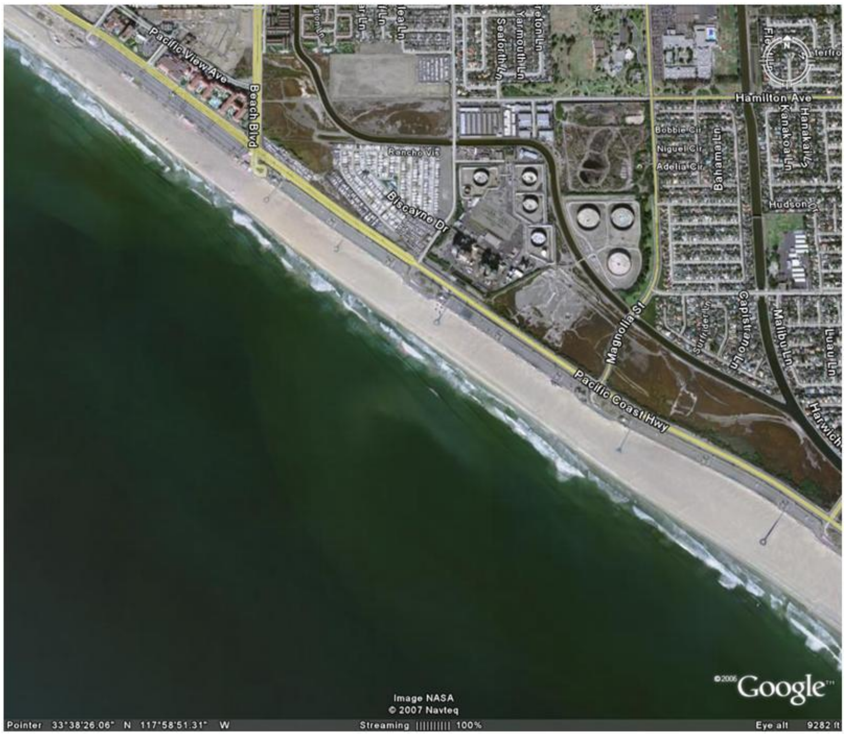
Comprehensive Cost Evaluation Study

ALDEN

Solving flow problems since 1894

ATTACHMENT 4

COMPREHENSIVE COST EVALUATION FOR THE HUNTINGTON BEACH GENERATING STATION



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1.0 Introduction

The Huntington Beach Generating Station (HBGS) is located on the Pacific Ocean in the City of Huntington Beach, CA. Units 1 & 2 share a common intake with Units 3 & 4. Units 3 & 4 are currently using restoration measures for compliance with entrainment reduction standards for those Units consistent with the HBGS NPDES permit. AES Huntington Beach (AES) conducted an evaluation of alternative intake technologies and operational measures for compliance for Units 1 & 2 and for the difference between the impingement mortality reduction achieved by the offshore velocity cap and the 95% reduction necessary to comply with the permit. Based on that evaluation, AES selected use of a site-specific determination of BTA as specified in Section: Special Provision VI.C.2(a)(5) of the permit. Use of this option requires submittal of a number of CDS documents one of which is a Comprehensive Cost Evaluation Study. The requirements for this CDS documents are specified at §125.95(b)(6) of the Federal Phase II Rule and require that the following information be provided:

> (A) Engineering cost estimates in sufficient detail to document the costs of implementing design and construction technologies, operational measures, and/or restoration measures at your facility that would be needed to meet the applicable performance standards of § 125.94(b);
>
> (B) A demonstration that the costs documented in paragraph (b)(6)(i)(A) of this section significantly exceed either those considered by the Administrator for a facility like yours in establishing the applicable performance standards or the benefits of meeting the applicable performance standards at your facility; and
>
> (C) Engineering cost estimates in sufficient detail to document the costs of implementing the design and construction technologies, operational measures, and/or restoration measures in your Site-Specific Technology Plan developed in accordance with paragraph (b)(6)(iii) of this section.

The information required by (A) above is provided in Sections 2, 3 and 5 of this study. The information required by (B) is found in Section 4 of the study and the information required by (C) is provided in Section 4 of the study and Attachment 6.

2.0 Discussion of Technologies Selected for Detailed Evaluation

Alden Research Laboratory, Inc. (Alden) conducted an assessment of alternative technologies and operational measures that have potential to meet the performance standards required in the Federal Rule. This initial assessment looked at the full range of available options, their estimated effectiveness, and the monetary impact associated with both implementation and operation at HBGS (Appendix A).

The technologies selected for further review are summarized below and have been updated to reflect the current state-of-knowledge and present-day costs. In addition to this assessment, additional considerations were requested. Because HBGS is required to meet both the impingement mortality reduction and entrainment reduction standards and any entrainment reduction technology and operational measures would also make up the 13% impingement mortality reduction shortfall required by the permit, only entrainment reduction options were evaluated in this study.

The options considered for permit compliance with the impingement and entrainment standards are:

- Fine-mesh modified traveling screens
- Modular Inclined Screens
- Offshore narrow-slot cylindrical wedgewire screens
- Relocation of the intake further offshore to a point below the thermocline
- Use of reclaimed water
- Reduced circulating pump flow using variable frequency drives
- Closed-cycle cooling

Site-specific information was used to determine the applicability and optimal layout of each technology. In addition, Alden has included recent IM&E information to support the technology selection.

Estimates of biological efficacy have been developed for each technology or operational option based on the species and lifestage of the organisms entrained, Table 1. These estimates are designed to provide the basis for determining the benefits associated with each option. When determining benefits, the effects of entrainment-reducing technologies on impingeable-size organisms have also been included. A detailed discussion of the methodology used to determine exclusion and survival of aquatic organisms is included in Appendix E.

2.1 Fine-mesh Modified Traveling Screens

In the technology assessment, Alden assumed that the screenhouse would need to be expanded to reduce the screen approach velocity to 0.5 ft/sec. Estimates of retention based upon the size of organisms typically entrained at HBGS indicate that few would be prevented from being entrained with 0.5 mm screens. In addition, the survival of the impinged ichthyoplankton that were previously entrained, but would become impinged on 0.5 mm screens, is expected to be low for some species. Therefore, there is expected to be no benefit associated with expanding the intake. Fine-mesh screens (0.5 mm mesh) at HBGS would decrease the entrainment of some larval fish through the circulating water system (CWS). The effectiveness of a fine-mesh screening system is measured in two ways: exclusion/retention and survival. Fine-mesh screens prevent the entrainment of some organisms; however, the number is dependent upon the size of the organisms exposed to the system and the mesh size considered. The survival of organisms removed from the screens is highly variable and depends on species, intake velocity, and the return system.

With this option, fish and debris removed from the screens would have to be transported back to the ocean. The discharge location would have to be carefully selected in order to increase the likelihood of survival. Transporting the fish back to the ocean at HBGS would be exceptionally difficult as the fish return line would need to be routed under the Pacific Coast Highway, across a public beach and out beyond the surf zone.

Although the finer mesh may result in an increased rate of biofouling of the screen mesh, this should not be an issue if HBGS continues to use the same cleaning method currently used to reduce biofouling of the existing screens.

Conclusion

Fine-mesh traveling screens are technically an “exclusion technology”. However, unlike narrow-slot wedgewire screens that depend on an air-burst cleaning system coupled with ambient currents to “carry” impinged fish and debris away from the CWIS, this technology uses a “collection/transfer” concept. As discussed in Appendix E, organisms previously entrained will now be impinged. Although the system is designed to minimize stress to aquatic organisms, the process of collection and transfer will impart a stress to the organism that would not be experienced if they were not impinged. This is especially true for the earliest lifestages (e.g. yolk-sac larvae). Generally, survival will increase as a fish grows. For those fish that do come in contact with the screen, collecting them on a fine-mesh screen and returning them to the ocean rather than allowing them to be entrained should result in some reduction in losses.

For the species and lifestages entrained at HBGS the reduction in entrainment is expected to be very low as shown in Table 1. Therefore, fine-mesh screens are not expected to meet the 90% reduction as required in the permit or the 60% reduction as required by the Federal Rule.

2.2 Narrow-slot Cylindrical Wedgewire Screens

Initially, Alden estimated that 24, stainless steel, T-84 (7 ft. diameter) screens with 0.5 mm slot opening would be required to screen the total facility flow. This option was dismissed because of the distance of the intake offshore and the limitations of a shore-based, air backwash system. However, Alden has re-evaluated this option with a new design, as discussed in detail in Appendix B.

The final design includes 20, T-120 (10 ft. diameter) screens with 0.5 mm slot openings. Twenty screens are used to reduce the through-slot velocity to about 0.35 ft/sec; which is similar to the minimum ambient current in the area. In addition, this design would allow a screen to be out of service without increasing the through-slot velocity above 0.5 ft/sec (manufacturer's design velocity for wedgewire screens). To reduce the effects of biofouling, a 70-30 copper-nickel alloy would be used. The screens would be mounted to four intake pipes located beneath a large offshore work platform. The platform would provide: housing for compressors for the air backwash system; a mechanical cleaning system; and, a work deck from which to remove and maintain the screens. Each of the intake pipes would include an emergency bypass to allow uninterrupted water flow to HBGS during extreme fouling events. These gates would also allow continued use of the existing heat treatments to prevent biofouling in the intake pipes.

Since there are no biological efficacy data available for wedgewire screens and the species entrained at HBGS, head capsule depth data developed for the fine-mesh screen option above were used to estimate the physical exclusion that could be achieved with narrow-slot wedgewire screens. Several species entrained at HBGS are relatively small; therefore, the estimated exclusion of 0.5 mm screens is low for some species (Table 1).

Observations of fish eggs and larvae in the laboratory indicate that those organisms that are not entrained are carried away by the ambient currents and do not typically impinge. Therefore, these screens are not "handling" the organisms in the same way that fine-mesh traveling screens do and thus there is no post-impingement survival component to estimating the efficacy. Additionally, hydraulic conditions near the wedgewire screens may stimulate rheotactic responses in the larvae, causing them to swim away from the screens. Species-specific behavior may also affect the likelihood of entrainment.

Given the very low through-slot velocity (0.35 ft/sec.), the screens should effectively eliminate impingement of juvenile and adult fish. To date there have been no large-scale offshore deployments in a marine environment. Therefore, AES should conduct a pilot study to see if the screens can be maintained at HBGS.

Conclusion

Narrow-slot wedgewire screens should be effective at excluding the majority of early lifestages of ichthyoplankton at HBGS. The ultimate efficacy is dictated by species-specific lifestages and abundance of those lifestages in the entrained population.

Overall, the reduction in entrainment associated with narrow-slot wedgewire screens is expected to meet the requirements of the Federal Rule. Based on the species and lifestages present at HBGS this reduction in entrainment is not expected to meet the 90% reduction as specified in the permit.

2.3 Modular Inclined Screens (MIS)

Originally, the MIS was considered as a technology to reduce impingement mortality by virtue of a 2 mm slot size (the only size for which data are available). However, in reconsidering entrainment reduction alternatives, Alden proposed consideration of the MIS for protecting larger entrainable organisms. Results of species-specific survival from pilot studies of both the fine-mesh traveling screens and the MIS were compared to develop overall system efficacy.

All the ancillary issues associated with fine-mesh modified traveling screens, such as transport to a safe location in the source waterbody, apply to the MIS. Biofouling of the screen mesh may also be an issue; however, the existing heat treatment or a copper-nickel alloy could be used to reduce the effects of biofouling.

Based on the organisms collected during the IM&E characterization study, Alden now believes that survival of the earliest and most dominant stages of fish entrained at HBGS would be negligible. If AES wants to consider this technology further Alden recommends that pilot studies be conducted.

Conclusion

Due to the size of the species entrained at HBGS the projected efficacy of this technology would be less than that for both narrow-slot wedgewire screens and fine-mesh traveling screens. Therefore, a MIS is not expected to meet the minimum requirements of the Federal Rule.

2.4 Reducing Cooling Water Pump Flow

The potential use of this option is contingent upon the diel and seasonal densities of entrainable life stages which would dictate when operation of cooling water pumps (CWP) could be reduced. Seasonal variations in densities of entrained organisms from the 2003-2004 studies demonstrate an increase through the summer months. Diel variation in abundance occurs at HBGS with greater abundances typically found at night. The ability to target flow reductions during periods of high entrainment is mitigated by the fact that the period of most effect is the period of maximum generation demand.

Reduction in cooling water flow by curtailing use of one or more existing pumps on a diel or seasonal basis is currently practiced at HBGS. When generation demand is low one pump is taken out of service. The CWP's are operated in a manner similar to all other equipment onsite, i.e., safely and as cost-efficiently as possible. The pumps provide, boiler-cycle cooling as well as bearing and machinery cooling. Running equipment within proper temperature ranges is necessary to protect and extend the life of equipment. Running the pumps entails a large electrical energy cost, and the pumps are always run as little as necessary.

One pump must run at all times, even when no generator units are operating. This pump maintains the equipment operating temperatures that must stay operative, such as air compressors, and ready to bring a unit online if/when called. To initiate start-up, for any of the units, both CWP's need to be operating. When a unit is shut down, both CWP's must run for a typical lag time of 24 hours after the unit is off-line to keep equipment from overheating. This time is required to get the equipment/housings cooled in order to reduce any hazard for maintenance and re-start checks/preparations. After 24 hrs (assuming the unit does not re-start) one CWP can be shut off.

Any additional flow reductions would be relatively small or require a substantial reduction in generation. During cooler periods when meeting the thermal limits is not an issue, variable frequency drives (VFD) could be used to reduce the intake flow without impacting generation. As most of the entrainment occurs during the summer, reducing flow during cooler periods would not have a large impact on entrainment rates.

Conclusion

The current flow reduction procedures achieve some level of entrainment reduction. Typically, flow reductions need to be discussed with Corporate Power Supply. Assessment of general trends in load demand can predict periods when running at reduced loads or placing a unit(s) on stand-by would not affect the reliability of the plant. During periods of high demand and high water temperatures, reducing flow would result in the need to de-rate the unit(s) to maintain thermal discharge limits.

However, due to power demands and intake water temperatures, additional flow reductions beyond what is currently practiced are unlikely to meet the 90% reduction standard in the permit. If this alternative is to be considered further a detailed assessment of in-plant components associated with the condensers would be required.

2.5 Extend the Intake Tunnel 5 Miles Offshore

Extending the intake tunnel to a location five miles offshore was proposed by Dr. Irwin Haydock at the AES first quarterly stakeholder's meeting. At this location, the intake would be in about 100 ft of water and below the thermocline in cold, nutrient-rich water. Dr. Haydock expects that, at this location, entrainment would be significantly reduced and the quantity of cooling water somewhat reduced. He also expects that this will result in a reduction in impingement as well. To address Dr. Haydock's comments and concerns, this option is investigated further and is detailed in Appendix C.

At this location, there is potential for the intake flow to entrap some of the effluent from the Orange County Sanitation District (OCSD) wastewater outfall. The water leaving the outfall has received only secondary treatment, which is not safe for human contact. If the effluent is entrained through the HBGS cooling system the water would only be discharged approximately 1200 feet from shore. Releasing the effluent this close to shore would exacerbate the potential for the treated water to contaminate Huntington Beach. To determine if this is indeed an issue a physical or numerical model would be required.

Extension of the cooling water intake tunnel to a location further offshore would not eliminate either impingement or entrainment of biota. Rather, a new assemblage would be affected. The magnitude and direction of change cannot be predicted at this time. Additionally, tunnel cleanliness is maintained by routine thermal treatment. The ability to maintain the required elevated temperature (approximately 105°F) for effective bio-fouling control is also unknown.

Conclusion

There are too many uncertainties associated with the susceptibility of deep water biota to determine efficacy estimates for this option. In addition, the potential entrapment of the OCSD effluent could also be a major problem. Since cost was similar to closed-cycle cooling and the benefits are not clear, this option was dropped from further evaluation.

2.6 Use Reclaimed Water to Reduce the Amount of Seawater Needed.

An additional option considered was to assess the use of treated water from the OCSD to supplement existing cooling water needs. OCSD discharges about 240 MGD (371.3 cfs) of water to the Pacific Ocean. This water is a 50/50 mix of secondary- and primary-treated sanitary wastewater. By 2012, all water discharged by OCSD will have received secondary treatment. 70 MGD of this water has been allotted for other re-use and reclamation projects leaving approximatly170 MGD (263 cfs) available for potential use at HBGS. Connecting the circulating water system to the OCSD discharge would require the installation of two pipes, one for the intake and one for the discharge. The need for two pipes is that OCSD is currently permitted to discharge the pollutants contained in this water while HBGS is not.

It was determined this option is not feasible for a number of reasons as follows:

1. The OCSD discharge flow is not constant and fluctuates throughout the day. On a typical day during the dry season, the OCSD discharge flow can be as low as 30 MGD (53 cfs) during the early morning, assuming that previously allotted water has already been removed from the system.

   Based on the available flow information, AES would be able to operate one unit on mostly reclaimed water. Units 1 or 2 would be able to operate on solely reclaimed water for most of the day.

2. Using recycled wastewater can cause operating issues due to the chemical make-up of the water. This may require modifications to the existing condenser and circulating water piping to limit corrosion. Prior to moving forward with this concept a detailed chemical analysis for the treated water would need to be conducted.

3. Heating of the treated wastewater could result in environmental issues when the wastewater is discharged back to the ocean. Additional study would be required to evaluate environmental issues associated with heated wastewater that are beyond what could be accommodated for the CDS submittal.

Conclusion

Using reclaimed water at HBGS is not feasible due an inadequate reliable supply of condenser cooling water to support one Unit as well as concerns for materials damage and potential environmental issues. These drawbacks and appraisal-level costs for using reclaimed water are discussed in detail in Appendix D.

2.7 Closed-cycle Cooling

Retrofitting HBGS with closed-cycle cooling would automatically meet the performance standards of the Federal Rule and comply with the NPDES permit. This option has been investigated for HBGS as part of a study to determine the costs of retrofitting all of California's once-through cooling facilities with closed-cycle cooling. That report has been submitted to the State Water Resources Control Board and the cost estimate for HBGS from that document is provided in Appendix F. In addition to providing cost estimates this study took a qualitative look at adverse environmental and social impacts associated with closed-cycle cooling. Appendix F provides site-specific retrofit costs for HBGS. These issues would include:

- Human health impacts from fine-particulate emissions
- Salt drift effects on nearby residences and nearby salt marshes being restored
- Fogging
- Noise
- Visual impacts to community and nearby beaches

The cost estimates for wet and dry cooling provided in the Comprehensive Cost Analysis are based on these costs.

Conclusion

Closed-cycle cooling could be used to meet both the impingement mortality and entrainment reduction performance standards at HBGS. However, as discussed in the next Section this option has the highest cost and the most significant adverse environmental and social impacts to the local area. These issues would have to be addressed in order to obtain the necessary permits for implementation of this option.

3.0 Estimated Technology Costs

Based on the screening of intake technologies discussed in Section 2, four alternatives using intake technologies for fish protection were selected for their potential for effective application at HBGS. The alternatives selected for cost estimates are:

Alternative 1– Fine-mesh modified traveling screens

Alternative 2– Narrow-slot cylindrical wedgewire screens (0.5 mm slot width)

Alternative 3– Modular inclined screens

Alternative 4– Closed-cycle cooling

Costs for these technologies are provided to allow a valid comparison to be made between the different options and their potential benefits. Costs for narrow-slot wedgewire screens are based on detailed cost estimates provided in Appendix B. The closed-cycle cooling costs presented here are taken from the EPRI study (Appendix F).

The impacts of capital and O&M costs of these alternatives are summarized in Table 2. These costs include estimated annual O&M costs, estimated annual energy required for operating the equipment, and the estimated plant outage time necessary for construction/installation for each option.

Capital costs for the intake alternatives to reduce entrainment range from $27,183,000 to install an MIS to $69,946,000 to add fine-mesh screens. These costs include construction-related shutdowns. Retrofitting Units 1&2 with cooling towers would have a capital cost of approximately $76,398,000.

Alden included an estimate of existing annual O&M costs to allow the incremental costs of selected technologies to be calculated. Incremental costs provide a better estimate of the additional cost associated with each technology. The same assumptions were used in calculating all O&M costs. The incremental costs are used in the cost-benefit test as part of Compliance Alternative 5.

4.0 Discussion of Economic Benefits

The Phase II Rule includes two conditions under which a facility may be allowed a site-specific determination of its relevant standards. One of the conditions, referred to in the rule as the cost-benefit test (EPA 2004a, p. 41,593), involves determining that the costs of meeting the standards are "significantly greater" than the associated economic benefits. Making and supporting such a determination requires conducting a sound benefit-cost analysis. It also entails identifying what constitutes costs of IM&E reductions being significantly greater than the corresponding benefits. This report contains a benefit-cost analysis and significantly greater evaluation for Huntington Beach Generating Station. The Benefit Valuation Study (BVS) for HBGS is provided as Attachment 5.

The benefit estimates in this assessment reflect the current IM&E estimates provided by MBC and Tenera (2007). The organisms analyzed by MBC and Tenera are limited to those that were sufficiently abundant to provide a reasonable assessment of impacts. Specifically, the I&E estimates reflect the most abundant fish taxa that together comprised 90 percent of all larvae entrained and/or juveniles and adults impinged at HBGS. Moreover, the benefit estimates reflect the benefits of complying with the performance standards. As previously explained, compliance with the impingement mortality standard requires a 13 percent in impingement for all units at HBGS. Compliance with the entrainment standard requires a 90 percent reduction in entrainment for Units 1 and 2 at HBGS.

Based on a scientific evaluation of uncertainty (see BVS, Section 6), the expected annual benefits associated with IM&E reductions range from \$750 to \$27,000 with a mean estimate of \$8,000. The 20-year discounted value of that benefit stream ranges from \$14,850 to \$543,400 with a mean estimate of \$163,400. This distribution of expected benefits is conditional upon the presumption that I&E leads to changes in fish populations and corresponding changes in expected catch and recreational benefits. Any changes to this assumption will lead to corresponding changes in benefits. In addition, this distribution of expected benefits recognizes that nonuse benefits do not need to be quantified because HBGS's I&E does not cause "substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function" in the coastal waters near HBGS (EPA 2004a, p. 41,648). Additional details on the benefit estimates are provided in the attached BVS.

This section presents the statistical evaluations that Veritas conducted for the benefit-cost comparisons and the cost-effectiveness evaluations. Each comparison uses a well-established statistical interpretation of "significantly greater" to make the determinations, which is described below.

4.1 Interpretation of Significantly Greater

As part of the Phase II Rule, EPA has included two conditions under which a facility may be allowed a site-specific determination of its relevant standards. One condition is that the costs of meeting the standards are "significantly greater" than the associated economic benefits. In developing the Phase II Rule, EPA has not provided specific guidance on the exact nature of this comparison, the determination of "significantly greater," and the role of uncertainty in this determination. Nevertheless, the EPA's extensive efforts to measure economic benefits indicate support for conclusions that are based on economic theory. Moreover, the EPA's requirement of sensitivity analysis of the BVS, as well as its phrasing of "significantly greater," support decision-making based on statistical criteria.

Statistical significance of an estimate reflects a specific level of confidence that the value being estimated is indeed different from zero (or some other parameter of interest). For example, a statistical determination might be that there is a 95-percent probability that the estimated quantity is significantly greater than zero. Such an outcome indicates that the likelihood that the estimated quantity is below zero is less than 5 percent, giving the analyst a great deal of confidence that the actual (not estimated) quantity is indeed larger than zero. Evaluating statistical significance of benefit-cost differences in this manner requires determining both a level at which costs are determined to be "significantly greater" than benefits and a methodology for appropriately capturing the uncertainty in cost and benefit estimates.

Decision theory, based on the work of Neyman and Pearson (1933) provides a framework for this evaluation. H_0 and H_1 are alternatives to one another in that they never specify the same conclusion, but taken jointly they specify all relevant conclusions. For benefit-cost comparisons, the null and alternative hypotheses are stated:

H_0: Benefits – Costs > 0

H_1: Benefits – Costs <= 0

Note that for any particular decision, there are three possible outcomes:

- A correct decision was made.
- A true hypothesis was rejected.
- A false hypothesis was accepted.

Errors under this paradigm are termed Type I and Type II and described as follows:

- Type I error: Reject H_0 when H_0 is true (a true hypothesis is rejected).
- Type II error: Accept H_0 when H_1 is true (a false hypothesis is accepted).

Decisions to reject or accept H_0 depend on the true value of parameters, the sample data, and the methodologies used to calculate benefits and costs. The power of the Neyman and

Pearson approach is its ability to recognize that Type I and Type II errors are not necessarily of equal importance. In some instances, society may be better off rejecting a true hypothesis. In other instances, society may be better off accepting a false hypothesis.

Applying Neyman and Pearson's (1933) decision theoretic approach to identification of "significantly greater" in the 316(b) context explicitly provides additional capabilities to benefit-cost decision-making. For example, with this framework, it is possible to minimize the probability that a meaningful impact is not mitigated or conversely to minimize the probability that funds are spent over-mitigating minor impacts.

In our assessment, the determination of "significantly greater" is based on economic concepts and statistical methods with the understanding that protection of the environment is preferred. The determination will be based on a calculation of net benefits (benefits of compliance minus lowest costs of compliance) with simultaneous consideration of costs, benefits, and uncertainty in a Monte Carlo simulation. The result is a distribution of net benefits, and the determination of "significantly greater" is based on the proportion of the estimated range of net benefits that crosses zero.

4.2 Benefit-Cost Comparisons

The benefits in each of these evaluations reflect the effectiveness associated with the technology. Table 4 below contains the detailed comparisons of benefits to costs.

To make the significantly greater determination, we compared these expected costs to the expected benefits. The benefit estimates include uncertainty, as instructed by the EPA rule (see Section 6 of the BVS for additional details). Specifically, we conduct a Monte Carlo analysis that makes one draw from the distribution of benefits and subtracts from it the point estimate of costs to develop a single estimate of net benefits. Our analysis repeats this Monte Carlo process 1,000 times to develop a distribution of net benefits (benefits minus costs).

In all cases, the benefit-cost comparisons reveal that the costs of achieving compliance are significantly greater than the benefits, indicating that a site-specific determination of BTA (Alternative 5) is appropriate for Units 1 and 2 of the HBGS.

5.0 Summary and Conclusions

A benefit-cost based submission under Alternative 5 must include a demonstration that the costs of strict compliance with percentage reduction standards are "significantly greater" than the associated benefits. In this case, the facility can comply with alternative standards. These alternative standards are associated with coming as "close as is practicable" to meeting the standards without resulting in costs that are "significantly greater" than the benefits of compliance. This Comprehensive Cost Evaluation includes a Benefits Valuation Study that uses an integrated mathematical simulation model to identify the economic benefits of compliance. This study indicates that the net present value of compliance by reducing entrainment at units 1 and 2 by 90% and impingement at 1 and 2 by 13% ranges from $4,719 to $12,700.

To facilitate the identification of appropriate technology solutions, the costs of potential technologies are compared to economic benefits. By comparison with compliance benefits, the costs of installing and maintaining IM and E reduction technologies are quite large. Incorporating technology efficiency in the mathematical simulation model allows cost-effectiveness and cost-benefit comparisons by technology. Technology effectiveness is incorporated at the species level for impingement and entrainment. For example, narrow-slot wedgewire screens are specified to eliminate 100% of impingement and 64% of entrainment at Units 1 and 2 for queenfish. This approach indicates that the costs of each evaluated technology are significantly greater than its economic benefit. The least expensive option studied, installation and operation of variable frequency drives, has the most favorable cost-benefit outcome, with a negative annualized net benefit of between $108,000 and $159,000.

Table 1 Predicted Reduction in Entrainment that could be Achieved with the Alternative Intake Technologies Being Proposed at HBGS.

Species	Proportion of Total Estimated Entrainment	Fine-mesh screens: Retention	Fine-mesh screens: Survival	Fine-mesh screens: Percent Reduction in Entrainment	Fine-mesh screens: Percent Contribution to Total Reduction	Narrow-slot Wedgewire: Percent Reduction in Entrainment	Narrow-slot Wedgewire: Percent Contribution to Total Reduction
Gobiidae	0.325	46.9	0.0	0.0	0.0	64.1	20.8
northern anchovy	0.153	71.7	10.0	7.2	1.1	71.7	11.0
croaker [1]	0.349	58.8	18.0	10.6	3.7	58.8	20.5
combtooth blennies [2]	0.020	21.8	0.0	0.0	0.0	21.8	0.4
diamond turbot	0.015	11.3	79.5	9.0	0.1	11.3	0.2
Totals	**0.862**				**4.9**		**52.9**
Relative to Total Entrainment					**5.7**		**61.4**

Species	Proportion of Total Estimated Entrainment	Modular Inclined Screens: Retention	Modular Inclined Screens: Survival	Modular Inclined Screens: Percent Reduction in Entrainment	Modular Inclined Screens: Percent Contribution to Total Reduction	Closed-cycle Cooling: Percent Reduction in Entrainment	Closed-cycle Cooling: Percent Contribution to Total Reduction
Gobiidae	0.325	0.6	0	0	0	92.0	29.9
northern anchovy	0.153	0.6	10	0.1	<0.1	92.0	14.1
croaker [1]	0.349	0.05	18	<0.1	<0.1	92.0	32.1
combtooth blennies [2]	0.020	0.8	0	0	0	92.0	1.8
diamond turbot	0.015	0	79.5	0	0	92.0	1.4
Totals	**0.862**				**<0.1**		**79.3**
Relative to Total Entrainment					**<0.1**		**92.0**

[1] Includes white, black, and spotfin croakers, queenfish and salema as all have similar larval morphology and sizes.

[2] Blenny survival unknown; used same value as Gobiidae

Table 2 Alden's Costs of Evaluated Alternatives

Alternative	Construction Costs (2007 $)	Replacement Power During Shutdown (MWh)	Total Capital Cost (2007)[1]	O&M Costs (2007 $)	Lost Generation (MWh)[2]	Annualized Capital Costs (2007 $)[3]	Incremental Annualized O&M Costs (2007$)[1, 2]	Total Incremental Annualized Costs (2007 $)
Fine-mesh Modified Traveling Screens	$6,348,000	1,271,952	$69,946,000	$357,000	2,102	$6,029,000	$364,000	$6,393,000
Narrow-slot Cylindrical Wedgewire Screens[4]	$36,003,000	423,984	$57,202,000	$676,000	1,097	$6,834,000	$633,000	$7,467,000
Modular Inclined Screens	$5,984,000	423,984	$27,183,000	$133,000	1,050	$2,560,000	$88,000	$2,648,000
Closed-cycle Cooling (wet cooling)[5,6,7]	$76,398,000	0	$76,398,000	$2,291,940	16,574	$10,877,000	$3,023,000	$13,900,000

1. Based on a cost for lost generation of $50 per MWh
2. As a result of any power penalties associated with the technology
3. Alden assumed a discount rate of 7% and an amortization rate of 10 years for the capital costs and 30 years for the pilot study and down-time costs
4. Costs are based on the detailed quantity take-offs in Appendix B
5. Cooling tower costs are based on the costs to upgrade Units 1&2 at HBGS as provided in the EPRI study for cooling tower retrofit analysis for several California power plants.
6. Duration of shutdown not provided in the EPRI report. Alden estimated a that adding closed-cycle cooling would not require any shutdowns beyond the existing maintenance shutdowns.
7. O&M costs are based on a 2% reduction in generation as a result of, power requirement to operate the cooling towers and losses due to increased turbine backpressure.

Table 3 Estimates of Net Benefits and Significantly Greater Determination with Benefit-Cost Comparisons

Technology Alternative	Total Annualized Costs	Range of Annualized Benefits	Range of Annualized Net Benefits	Costs Are Significantly Greater
Fine-mesh modified traveling screens	$6,393,000	$4,400 - $11,400	- $6.381M to -$6.384M	Yes
Narrow-slot cylindrical wedgewire screens	$7,467,000	$7,200 - $18,500	-$7.460M to -$7.448M	Yes
Modular inclined screens	$2,648,000	$100 - $800	-$2.648M to -$2.648M	Yes
Closed-cycle cooling (wet cooling)	$13,900,000	$4,800 - $13,200	-$13.887M to -$13.895M	Yes

Table 4 – Velocity Calculation for the Velocity Cap

Data:

Flow (Q): 794.5 cfs

Opening height: 5.0 ft

Cap Width: 28.0 ft

Cap Length: 33.0 ft

Formulas Used

$$V(velocity) = \frac{Q(flow)}{A(area)}$$

Calculations

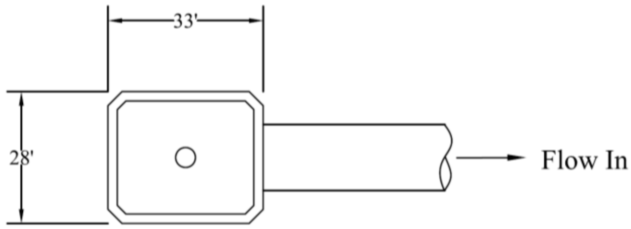
$$Open area = 5\,ft \times [(28\,ft \times 2) + (33\,ft \times 2)] = 610\,ft^2$$

$$V(velocity cap) = \frac{794.5 cfs}{610\,ft^2} = 1.3\,ft/\sec$$

Table 5 Entrapment Densities for Total Fishes at HBGS

Year	Velocity Cap Present	Time	Entrapment Density (kg/hr)	Effectiveness
1979	No	Day/Night 18-hr	20.45	
1979	Yes	Day/Night 18-hr	1.97	90%
1979	No	Night	32.93	
1979	Yes	Night	15.53	53%
			Average:	72%
1980	No	Day	47.2	
1980	Yes	Day	0.65	99%
1980	No	Night	52.99	
1980	Yes	Night	6.78	87%
			Average:	93%
			Overall:	82%

Figure 1 Aerial Photograph of HBGS (Google)



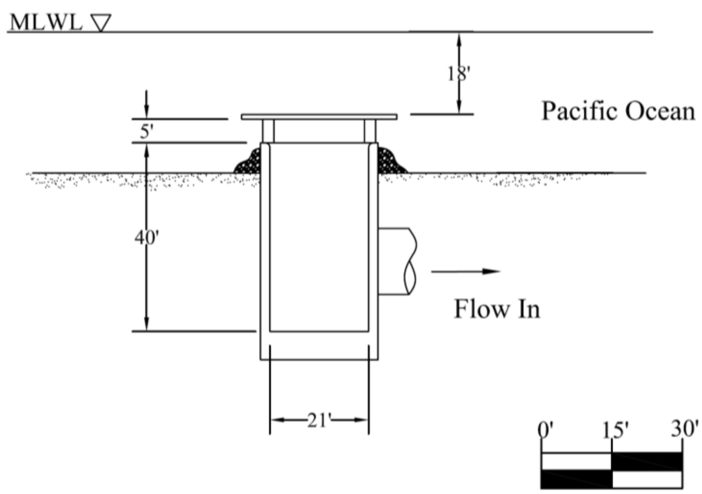


Figure 2 Existing Velocity Cap

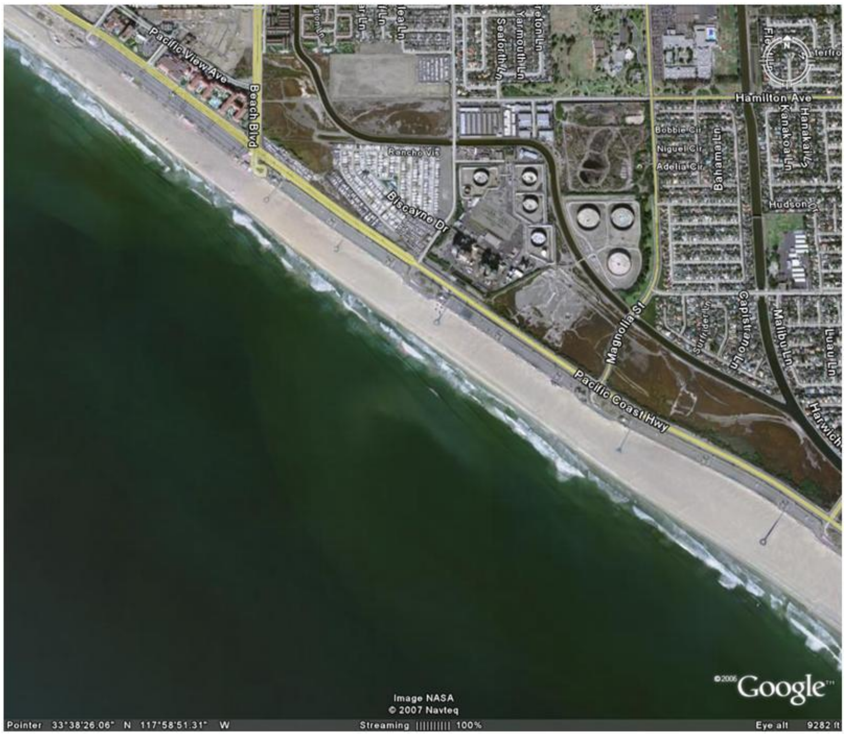
6.0 References

Alden Research Laboratory (Alden). 2004. Evaluation of the Huntington Beach Generating Station with Respect to the Environmental Protection Agency's 316(B) Rules For Existing Facilities. Report Number 295-04/E400F. October 2004.

Google. 2007. Google Earth Professional.

U.S. Environmental Protection Agency. 2004a. National pollutant discharge elimination system—final regulations to establish requirements for cooling water intake structures at Phase II existing facilities; final rule. Federal Register Vol. 69, No. 131 (Friday, July 9):41,576–41,693.

APPENDIX A
PRELIMINARY
ALTERNATIVE INTAKE ANALYSIS
FOR THE
HUNTINGTON BEACH GENERATING STATION



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EXECUTIVE SUMMARY

In response to §316(b) of the United States Environmental Protection Agency's (USEPA) Clean Water Act for existing Phase II facilities (Rule), the Electric Power Research Institute (EPRI) and Alden Research Laboratory, Inc., (Alden) collectively referred to as "the Team", conducted a strategic assessment for AES Huntington Beach (AES) for the Huntington Beach Generating Station (HBGS). This assessment evaluated the impact of the Rule on HBGS, including potential cost-effective compliance alternatives, additional information collection needs, and relative budget impacts as a result of studies and compliance alternatives.

The major component of this analysis was an evaluation of alternative fish protection technologies to meet the applicable performance standards for HBGS and discussion of approximate costs for the feasible alternatives. As part of this alternatives analysis, the Team reviewed operational options for meeting the applicable performance standards.

This report addresses technologies, and operational changes, that AES could implement to meet the Rule. USEPA's favored approach was to reduce total fish losses, which did not address adverse environmental impacts (AEI) at the population and ecosystem levels. Therefore, the Team did not address traditional measures of population and ecosystem health, such as species diversity and richness. Further, USEPA did not consider factors that influence populations such as compensatory mechanisms, species fecundity, and natural mortality. Therefore, these factors were not evaluated.

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Section 1
INTRODUCTION

Alden Research Laboratory, Inc. (Alden) has conducted an assessment of the permit requirements for AES Huntington Beach (AES) for the Huntington Beach Generating Station (HBGS), relative to the Rule. Since HBGS withdraws water from the Pacific Ocean both the impingement mortality (IM) and entrainment (E) reduction standards would apply. This assessment identifies fish protection technologies or operational changes that have potential to meet the IM&E standards required by the USEPA Rule. Order-of-magnitude costs associated with the potential alternative fish protection measures at HBGS are also presented in this assessment.

Section 2 presents a summary of existing engineering and biological information for HBGS and an assessment of the potential that the existing design and operations will meet USEPA's IM&E performance standards. Fish protection technologies that have potential application at HBGS are identified in Section 3. Preliminary engineering information is provided in Section 4. Potential compliance costs, including permitting, technology, and USEPA costs, are provided in Section 5. The conclusions of this study are presented in Section 6.

Section 2
DESCRIPTION OF EXISTING POWER GENERATION FACILITY

2.1 Facility Features

HBGS uses a once-through cooling water system. The plant is located on the shore of the Pacific Ocean in the City of Huntington Beach, California (see Figure 2-1 and Figure 2-2). HBGS has four gas/oil steam turbine units (Units 1–4) and one jet fuel/natural gas combustion turbine peaking unit (Unit 5) for a total generating capacity of 1,020 MW. Table 2-1 presents a summary of pertinent plant data.

The cooling water intake structure (CWIS) at HBGS serves Units 1–4. The CWIS includes a single offshore intake pipe with velocity cap, as shown on Figure 2-3, and a single screenwell structure with trash racks and four traveling water screens that are used to keep fish and debris out of the cooling water system (CWS). Circulating water pumps, located downstream of the screens, supply ocean water to the steam-turbine condensers and the closed-loop cooling system that serves the auxiliary equipment.

2.2 Intake Structure

The intake structure, a velocity cap, is located approximately 1,500 ft offshore of Huntington Beach at an elevation of El. -23.3 ft (all elevations refer to mean sea level). The velocity cap is 33 ft by 28 ft with the top cap located at El. -17.5 ft approximately 5 ft above the intake opening. The velocity cap (Figure 2-4) redirects the intake flow from a vertical direction to a horizontal direction, which Alden believes to be easier for fish to sense and avoid. Water flows through the velocity cap, down a 21 ft vertical riser pipe, into a 14 ft diameter intake pipe that conveys the water to the onshore screen structure. Both pipes and the velocity cap are made out of concrete. Mammal barriers are mounted on risers around the velocity cap to help prevent aquatic mammals, large fish, or turtles from entering the intake. The barrier consists of bars spaced approximately 18 in. on center.

The intake pipe is connected to a single onshore screening structure. Water entering the rectangular forebay (13 ft x 50 ft) is redirected three ways by guiding vanes to three wider screenbays (Figure 2-5). The three screenbays then merge into two trash rack bays. Each trash rack bay is 20 ft wide and 18 ft deep. The trash racks are vertical steel bars with 3 in. slot openings.

Downstream from the trash racks, the intake channel expands slightly and splits into four 11 ft wide channels, each containing a stationary screen and a traveling water screen. The stationary screens consist of flat, angle bars with 3 in. openings. The traveling screens are located 19.5 ft downstream of the trash racks. A plan and section of the screenwell appear on Figure 2-5 and Figure 2-6, respectively. Each screen is washed by six internal and external spray nozzles that spray the descending screen panels. Debris is deposited into a screenwash trough that leads to a trash basket located on the east side of the screenwell structure. The traveling screens are removed for maintenance and cleaned twice a year.

Immediately downstream of the traveling screens, the flow combines before entering a box culvert that is 14 ft wide and 11 ft high. The culvert is 236 ft long and slopes down slightly toward the circulating pump intake structure. The increased size of the pump intake structure decreases the velocity of the water before it enters the suction of the eight circulating pumps. Stoplog slots in each pump bay allow the pumps to be dewatered. Units 1–4 each require two circulating water pumps. The six pumps for Units 1–3 are rated at 98 cfs, while the two pumps for Unit 4 are rated at 103.2 cfs. This total system flow for HBGS is 794.4 cfs. Condenser flow accounts for 756.2 cfs, while the remaining water (38.2 cfs) is used for the auxiliary flow. Unit 5 does not use any cooling water. The City of Huntington Beach supplies additional water that is used as potable and makeup water. A section and plan view of the pumphouse structure is provided on Figure 2-7 and Figure 2-8, respectively.

Cooling water is discharged through a 14 ft diameter concrete pipe that is located parallel to the intake pipe. The discharge location is about 1,200 ft offshore, slightly to the south of the intake, and at a depth of 21.3 ft. The transit time between intake and discharge is 21.5 minutes. The NPDES permit for Huntington Beach allows a maximum delta T of 30° F.

2.3 Existing Hydraulic Conditions

The HBGS CWIS is located within the near-shore zone of the Pacific Ocean (defined as the zone between the shoreline and 1,000 ft from shore or the 30-foot depth contour, whichever is farther). Tides in the region are semi-diurnal, with two high and two low tides of unequal heights during each 25-hour tidal period. Flood tides flow up-coast while ebb tides flow down-coast. The extreme low water level El. -4.0 ft, while the mean tidal range is approximately 3.7 feet (all elevations refer to Mean Sea Level, El. 0.0 ft). Ocean currents in the near-shore region vary widely and are affected by wind, weather, tides, and the nearby Channel Islands. One predominant current is the California Current, which flows southeast. The Channel Islands divert and modify this flow. Currents in the near-shore region generally flow up and down the coastline.

The horizontal velocity in the velocity cap opening is approximately 2 ft/sec. Velocities in both the intake and discharge pipes are estimated at 5.2 ft/sec. Velocities immediately upstream from the traveling screens at HBGS were calculated in a study performed in 1978. The mean screen approach velocities ranged from 0.80 to 1.04 ft/sec at an assumed design flow of 795 cfs. The velocity calculated by Alden at this design flow and mean low water level (El. 0.0 ft) is 1.04 ft/sec in each bay, which is consistent with the 1978 study.

Bacterial growth is controlled by the injection of a sodium hypochlorite solution through the suction of each circulating pump. Chlorination is performed at 12-hour intervals for approximately 30 minutes. A heat treatment process also controls excessive marine growth, with mussels as a primary target. Heat treatment is performed every six weeks by partially recycling the circulating water flow, which increases the circulating water discharge to about 105° F.

2.4 Biological Characterization

The selection of technologies for the protection of aquatic organisms to meet applicable performance standards is based, in part, upon the species and life stages of aquatic life in the vicinity of the intake, their temporal and spatial abundance, and there relative hardiness. Since USEPA bases the performance standards upon a reduction over a calculation baseline, some understanding of current fish and shellfish populations is required to make predictions about the efficacy of potential technological options.

2.4.1 Impingement and Entrainment Characterization

The most recent impingement and entrainment data available for Huntington Beach was collected in 2003-04 (MBC and Tenera 2005). Below is a summary of the results with the emphasis on determining which species were numerically dominant. Since the performance of fish protection technologies is species-specific, the most abundant species were used to estimate the effectiveness of the technologies being considered for application to reduce IM&E.

Entrainment

The composition and abundance of ichthyoplankton was sampled in the immediate proximity of the cooling water intake twice monthly during September and October 2003, weekly from November 2003 through July 2004, and twice during August 2004. Each sampling event consisted of two replicate tows at the entrainment station four times per 24-hr period (i.e., once every six hours). The four discrete samples in each 24-hr sampling block were initiated at approximately 1200 hr, 1800 hr, 2400 hr, and 0600 hr. The second and fourth cycles were initiated to correspond with sunset and sunrise, respectively.

Samples were collected offshore near the submerged intake (within 100 m) using a wheeled, bongo frame fitted with plankton nets. Samples consisted of oblique tows from near the bottom to the surface. Two replicate tows were used to sample between 30 to 40 m^3 per net. Ichthyoplankton samples were returned to the laboratory, preserved, and processed. Fish larvae and targeted invertebrate larvae were separated from debris and other zooplankton. Larvae were identified to the lowest practical taxonomic level (species for most larvae) and enumerated. Fish eggs were not sorted nor identified.

Larvae were measured (notochord/standard lengths) to determine their size length ranges in the entrainment samples. A representative number of individual larvae of the most abundant taxa, or species with recreational or commercial fishery importance were measured.

A total of 6,950 fish larvae were collected during the September 2003 through August 2004 period. The 10 most abundant taxa that accounted for 90% of the entrained fish are shown in Table 2-2. The measured larval densities during each survey were multiplied by a total daily maximum intake flow of 1,919,204 m^3 (507 mgd) and extrapolated for an estimated annual cooling water volume of 702,428,664 m^3. Approximately 350 million fish larvae were estimated to have been entrained during the study. Descriptions of the patterns in entrainment by species are presented in Table 2-3. There were five target invertebrate taxa included in the study. Only mole crab and cancer crabs were found in the entrainment samples (Table 2-4). Mole crab zoeae comprised almost 99% of the entrained target invertebrates.

Impingement

To understand the total impact associated with impingement, two impingement sampling methods were undertaken. First, samples collected under normal operating conditions were used to determine the day-to-day impingement impacts from plant operations. Second, samples were collected during heat treatments (used to control biofouling), which were conducted at approximately eight -week intervals. The results of the two sampling methods were used to estimate the annual impingement losses of juvenile and adult fish at Huntington Beach.

Normal operations samples were collected weekly from July 2003 to July 2004. Prior to sampling, the screens were cleared of organisms and debris. During sampling, the screen was not rotated. At the end of the 24-hour sampling period, the screens were rotated for 10 minutes. Collected fish and macroinvertebrates were identified to species (or lowest practical taxon), enumerated, and batch-weighed. The standard length of up to 200 individual fish of each species was measured. Results from each weekly 24-hr impingement sample were extrapolated to a weekly impingement total using cooling water flow for the 7-day period. During heat treatments, traveling screens were run until no more fish were impinged on the traveling screens. Fish and macroinvertebrates collected during heat treatments were processed in the same manner as those collected during normal operations.

The most abundant species collected during impingement monitoring are presented in Table 2-5. An estimated 12,694 fish were impinged during 52 weeks of normal operations surveys. The highest normal operations abundance occurred in January. Aside from this impingement event, there were slight seasonal peaks of abundance in September-October 2003 (predominantly queenfish and northern anchovy) and in April-May 2004 (predominantly queenfish and white croaker). The most abundant species were queenfish (83%), northern anchovy (7%), white croaker (2%), and shiner perch (2%). Sampling during normal operations accounted for 25% of total impingement (normal + heat treatment).

An estimated 38,388 fish were impinged during six heat treatment surveys (Table 2-5). The most abundant species were queenfish (66%), white croaker (12%), shiner perch (10%), and northern anchovy (4%). Peaks in abundance during heat treatments occurred in May 2004 (predominantly queenfish and white croaker) and in September 2003 (predominantly queenfish and shiner perch).

2.5 Evaluation of Existing Information

The current facility configuration plays an important role in determining which performance standards will apply to HBGS. If this configuration is not consistent with the "calculation baseline," then there may be potential to receive credit toward these standards.

2.5.1 Applicability of the Rule at HBGS

The Rule requires all Phase II Existing Facilities to meet specific national performance standards, achieve an environmental benefit that is substantially similar to what it would achieve if a facility were to comply with the national performance standards, or, under certain circumstances, meet alternative, less restrictive, performance standards. The defining criteria for a Phase II Existing Facility are listed in Table 2-6. Since HBGS meets all the criteria for a Phase II facility, USEPA will require it to meet the applicable performance standards based on waterbody type and plant flow. The criteria used to determine which performance standards USEPA requires for the CWIS appear in Table 2-7. USEPA would not require a facility that answers “yes” to any of the criteria listed in Table 2-7 to meet the entrainment reduction standard. Since none of the criteria apply to HBGS, both the IM&E standards will apply.

2.5.2 Baseline Characterization

HBGS’s CWIS is not configured and/or operated in a manner consistent with USEPA’s “calculation baseline” (Table 2-8). Consistent with “baseline” configuration, HBGS’s cooling system is designed as a once-through cooling system and uses a standard 3/8 in. mesh traveling water screen. Unlike the “baseline” CWIS, HBGS’s intakes are located offshore rather than on the shoreline. In addition, HBGS does not generate at 100% capacity (another assumption of the “calculation baseline”). If HBGS’s periods of peak generation do not coincide with periods of peak impingement and/or entrainment, then a credit toward meeting the IM&E standards may be appropriate.

AES will need to determine whether the benefit of demonstrating that the current configuration and operation of the CWIS decreases IM&E is worth the costs associated with the additional biological studies (beyond the IM&E Study) that may be required to prove such an assertion. If the facility anticipates that the reductions in IM&E as a result of HBGS’s CWIS configuration and operation will be minimal and/or difficult to demonstrate, then additional studies may not be worth their cost.

Table 2-1 Pertinent Project Data — HBGS

Location	
21730 Newland Street Huntington Beach, California	
	Latitude: N 33° 38’
	Longitude: W117° 58’
Waterbody: Pacific Ocean	
Waterbody: ocean (near-shore zone)	
NPDES permit expiration date: June 1, 2005	
Estimated project intake flow	
	Plant design: 794.5 cfs (356,600 gpm)
Intake velocities	
	Horizontal current at cap: 2.0 ft/sec
	Intake pipe: 5.2 ft/sec
	Mean velocities upstream of traveling screens
	Calculated by Alden: 1.04 ft/sec
	Screen 1 (North): 0.80 ft/sec
	Screen 2: 0.96 ft/sec
	Screen 3: 1.04 ft/sec
	Screen 4 (South): 0.98 ft/sec
Water Level	
Elevations	
	Extreme low: El. -4.0 ft
	Mean low water: El. 0.0 ft
	Mean tidal range: El. 3.7 ft
Water depths: (around offshore intake)	
	Maximum: approx 37 ft
	Minimum: approx 29 ft
	Normal: approx 33 ft
Other info: all elevations refer to mean sea level	
Project Structures	
Offshore intake structure	
	Type: offshore intake
	Location: 1,500 ft offshore (near-shore zone)
	Top of cap: El. -17.5
	Cap height above intake: 5 ft
	Cap size: 28 ft x 33 ft (approx.)
	Intake invert: El. -23.3 ft
	Intake pipe material: concrete
	Intake pipe diameter: 14 ft (inside diameter)
	Pipe invert: El. -47.5 ft inlet
	Recirculation: gates located in intake pipe
	Mammal exclusion barrier: bars at approx 18 in. with velocity cap
Onshore intake structure	
	Length: 112 ft
	Guide vanes: 2 vanes split flow three ways prior to entering forebay
	Forebay: 13 ft x 50 ft
	Invert: El. -17.0 ft inlet

Table 2-1(Continued)

Trash racks
- Location: end of forebay
- Sections: 2 (20 ft wide 18 ft deep)
- Invert: El. -17.0 ft
- Top: El. 1.0 ft
- Material: steel
- Bar spacing: 3 in. openings
- Debris loading: pick and clean twice per year

Stationary screens
- Location: in traveling water screen bays upstream of traveling screens
- Mesh size: 3 in. openings

Traveling water screens
- Location: 19.5 ft downstream of trash racks
- Number: 4
- Bay width: 11 ft
- Invert: El. -17.0 ft
- Top: El 17.0 ft
- Rotation speeds: 1.2 rpm (approx. 1ft/sec)
- Width: 10 ft (approx from bay width)
- Mesh size and geometry:1/2 in^2 openings (estimated by plant personnel)
- Spray nozzle configuration: inside spray nozzles spray front and back (6 nozzles/screen)
- Volume: 1,000 gpm
- Operation: twice per shift for 20 minutes
- Fish return (trough/ pipes): debris trough discharges into trash basket
- Trough configuration: single trough leading to Units 1 & 2 discharge pipe

Culvert
- Culvert: 14 ft x 11 ft box culvert
- Length: 236 ft
- Invert entrance: El. -14.5 ft
- Invert exit: El -15.0 ft

Circulating water pump structure
- Location: end of culvert downstream of traveling water screens
- Length: 112.0 ft
- Guide vanes: two vanes split flow three ways prior to entering pump structure
- Invert entrance: El. -15.0 ft
- Invert pumps: El. -12.3 ft
- Pump bays: 8
- Bay width: 9.2 ft
- Design: 2 symmetrical halves (4 bays per half)
- Bay offset: 10.6 ft back 7.2 ft over

Circulating water pumps
- Number of pumps: 8
- Type of pumps:
  - Units 1 & 2: vertical, mixed flow
  - Unit 3 & 4: vertical wet pit
- Inlet elevation: -12 ft

Table 2-1 (Continued)

Flow per pump:
- Units 1–3: 98.0 cfs (44,000 gpm)
- Unit 4: 103.2 cfs (46,300 gpm)

Total flow
- Condensers: 756.2 cfs (339,400 gpm)
- Auxiliary: 38.3 cfs (17,200 gpm)
- Total: 794.5 cfs (356,600 gpm)

Other water: City of Huntington Beach

Cooling water discharge
- Location: 1,200 ft offshore south of intake
- Depth: 21.3 ft
- Discharge pipe: 14 ft (inside diameter)
- Type: open pipe
- Transit time: 21.5 minutes (intake to discharge)

Power Generation

Fuel Type:
- Units 1–4: gas/oil
- Unit 5: jet fuel/natural gas
- Plant output: (net)
  - Units 1 & 2: 215 MW
  - Units 3 & 4: 225 MW
  - Total: 880 MW (Units 1-4)
  - Unit 5: 150 MW (peaking unit)
  - Plant design total: 1,020 MW
  - 2004 total: 904 MW

Operating mode: baseloaded (Units 1–4 are steam turbines); peaking (Unit 5, gas turbine)

Plant capacity factor: 26% (expected for 2004)

Average annual energy: 2,058,950 MWh (based on 904 MW)

Other data: Units 3 & 4 were shut down in 1995. Both were repowered: Unit 3 came online on July 31, 2002, and Unit 4 on August 7, 2003.

Table 2-2 Most Abundant Larval Fishes Collected at Huntington Beach, September 2003 - August 2004.

Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (no./1000 m^3)	Total Estimated Entrainment
Gobiidae	gobies	2,484	36.95	36.95	151.56	113,166,834
Roncador stearnsii	spotfin croaker	912	13.57	50.52	53.07	69,701,589
Engraulidae	anchovies	1,209	17.98	68.50	74.46	54,349,017
Seriphus politus	queenfish	306	4.55	73.05	18.17	17,809,864
Genyonemus lineatus	white croaker	446	6.63	79.68	28.14	17,625,263
Xenistius californiensis	salema	153	2.28	81.96	7.70	11,698,960
Sciaenidae	croaker	244	3.63	85.59	14.73	10,534,802
Hypsoblennius spp.	combtooth blennies	166	2.47	88.06	10.28	7,165,513
Cheilotrema saturnum	black croaker	96	1.43	89.49	5.41	7,128,127
Pleuronichthys guttulatus	diamond turbot	87	1.29	90.78	5.28	5,443,118

Table 2-3 Observed Trends in Entrainment of the Numerically Dominant Fish Taxa at Huntington Beach, September 2003 – August 2004

Common Names	Entrainment Trends
gobies	Most abundant taxon collected (37% of total). Most larvae 2-3 mm length (mean 3.8 mm). Most abundant in July.
spotfin croaker	Numbers driven by single sampling event (Aug 2004 - 1,800/1000 m^3). Limited length range entrained (1.3 - 2.5 mm).
anchovies	Greater than 95% northern anchovy (*Engraulis mordax*). High variability in density (~0-400/1000 m^3). Greatest abundance in May and June. Bimodal length distribution - 20% 2-3 mm; large number 8-16 mm.
queenfish	Collected May through August with peak abundance in August (>300/1000 m^3). Length ranged from 1.5 - 20.4 mm (mean = 5.0 mm).
white croaker	High variability in entrainment densities (0-135/1000 m^3). Peak entrainment occurred in May. Lengths ranged from 1.5 - 8.6 mm (mean = 3.4 mm).
salema	Collected in substantial numbers only in August. Narrow length range - 1.7 - 2.6 mm (mean = 2.0 mm).
combtooth blennies	Present year-round, but entrainment peaked in summer (June-August). Length ranged from 1.6-13.0 mm (mean = 2.3 mm). Majority were between 2.0 - 5.0 mm.
black croaker	Collected April - September with peak density in August. Highest entrainment density - 160/1000 m^3. Lengths ranged from 1.5 - 11.5 mm (mean = 2.1 mm)
diamond turbot	Mean entrainment was variable (0 - 100/1000m^3). Entrainment peaked in August. Length ranged from 1.3 - 4.7 mm (mean = 2.3 mm).

Table 2-4 Invertebrate Larvae (Select Taxa) Collected at Huntington Beach September 2003 - August 2004.

Taxon	Common Name	Sample Count	Percent of Total	Cumulative Percent	Mean Density (no./ 1000 m^3)	Total Estimated Entrainment
Emerita analoga (zoea)	mole crabs - larvae	10,399	98.73	98.73	658.95	91,912,298
Cancer anthonyi (megalops)	yellow crab	77	0.73	99.46	4.68	1,320,180
Cancer gracilis (megalops)	slender crab	31	0.29	99.75	1.97	311,450
Cancer antennarius (megalops)	brown rock crab	18	0.17	99.92	1.15	202,088
Cancer productus (megalops)	red rock crab	3	0.03	99.95	0.18	53,672
Emerita analoga (megalops)	mole crabs	2	0.02	99.97	0.17	54,061
Cancer spp. (megalops)	cancer crabs	2	0.02	99.99	0.11	34,834
Cancer spp.	cancer crabs	1	0.01	100.00	0.06	27,126

Table 2-5 Fish Impingement Totals from 52 Normal Operation and Six Heat Treatment Surveys. Species Limited to Those that Accounted for More Than 0.1 Percent of the Total Number Impinged.

		Normal Operations		Heat Treatment Total		Impingement Total		Percent of Total	
Species	Common Name	No.	Wt (kg)	No.	Wt. (kg)	No.	Wt. (kg)	No.	Wt.
Seriphus politus	queenfish	10,468	58.015	25,379	590.141	35,847	648.156	70.2	50.2
Genyonemus lineatus	white croaker	274	3.374	4,629	92.047	4,903	95.421	9.6	7.4
Cymatogaster aggregata	shiner perch	215	2.014	3,830	49.813	4,045	51.827	7.9	4.0
Engraulis mordax	northern anchovy	824	5.513	1,369	9.343	2,193	14.856	4.3	1.2
Phanerodon furcatus	white seaperch	80	0.485	789	18.588	869	19.073	1.7	1.5
Peprilus simillimus	Pacific pompano	131	2.096	470	13.826	601	15.922	1.2	1.2
Hyperprosopon argenteum	walleye surfperch	30	0.498	446	15.255	476	15.753	0.9	1.2
Atherinopsis californiensis	jacksmelt	23	2.370	309	27.298	332	29.668	0.7	2.3
Atherinops affinis	topsmelt	-	-	231	3.664	231	3.664	0.5	0.3
Leuresthes tenuis	California grunion	49	0.211	91	0.498	140	0.709	0.3	0.1
Paralabrax clathratus	kelp bass	-	-	138	46.965	138	46.965	0.3	3.6
Scorpaena guttata	California scorpionfish	35	5.528	75	21.066	110	26.594	0.2	2.1
Sardinops sagax	Pacific sardine	69	3.322	38	3.994	107	7.316	0.2	0.6
Urobatis halleri	round stingray	52	17.322	48	22.331	100	39.653	0.2	3.1
Porichthys myriaster	specklefin midshipman	99	10.249	1	0.006	100	10.255	0.2	0.8

Table 2-6 USEPA Definition of "Phase II Existing Facility"

Rule Criteria	Applicable to HBGS?
point source that commenced construction before January 17, 2002	yes
generates electric power primarily for transmission or sale	yes
designed to withdraw ≥ 50 MGD[a] of water, at least 25% of which is used for cooling water	yes

[a] MGD = millions of gallons per day

Table 2-7 Criteria for Eliminating the Entrainment Reduction Standard at HBGS

Rule Criteria	Applicable to HBGS?
Facility is on a lake (other than the Great Lakes)	no
Facility withdraws 5% or less of the mean annual flow of a freshwater river or stream	no
Facility has a capacity utilization rate less than 15%	no

Table 2-8 Criteria for "Calculation Baseline"

Rule Criteria	Applicable to HBGS?
The cooling water system has been designed as a once-through system	yes
The face of the CWIS is located the shoreline and oriented parallel to the shoreline	no
The cooling water intake structure has standard 3/8-inch mesh	no
Traveling screen is oriented parallel to the shoreline near the surface of the source waterbody	no
The cooling water intake structure has no modifications that would reduce IM&E (Ristroph screens, fish return)	no
The facility has no operating controls to reduce IM&E (seasonal shutdown, flow or velocity reduction)	no

Figure 2-1 Vicinity Map of HBGS

Figure 2-2 Aerial Photograph of HBGS (USGS)

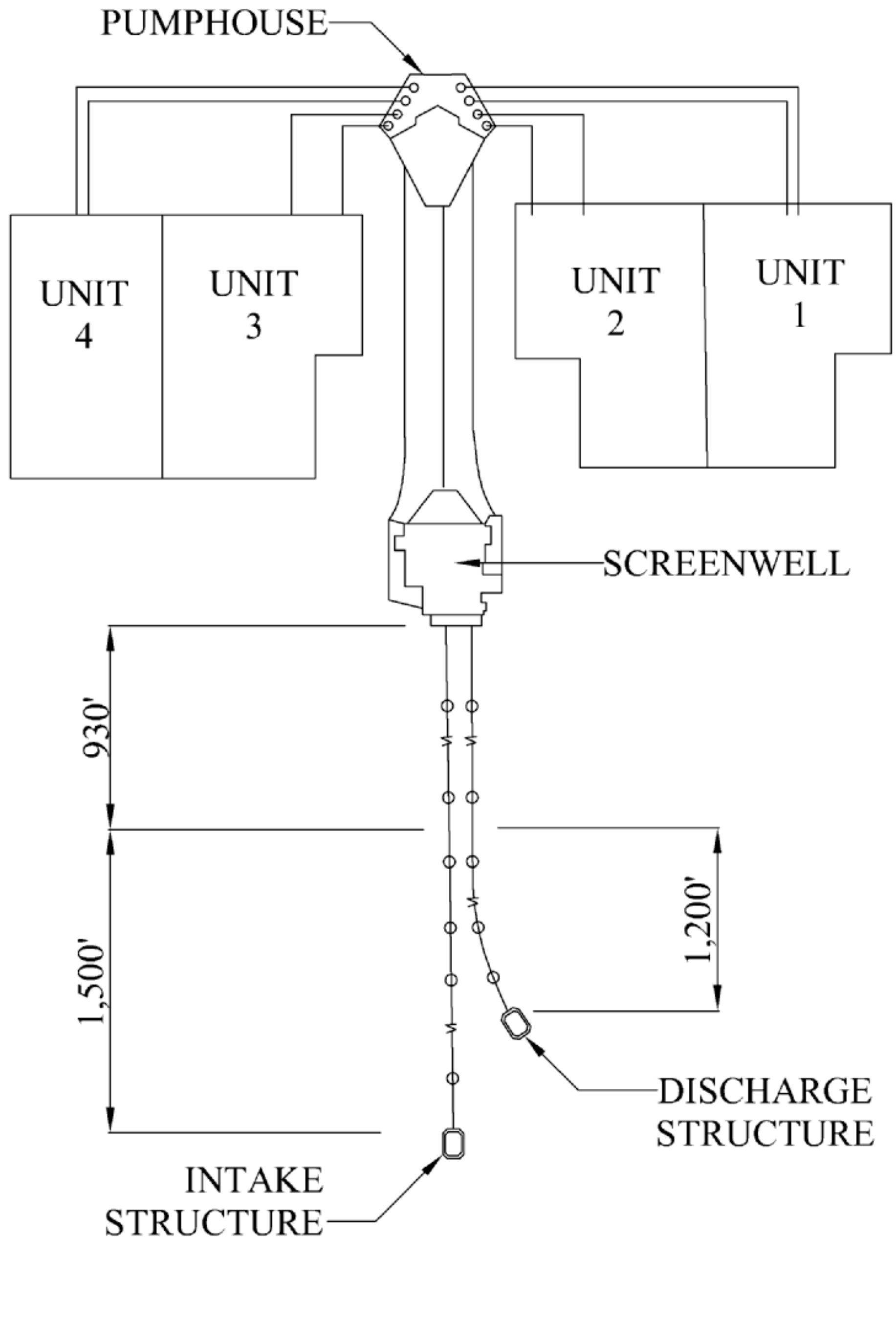
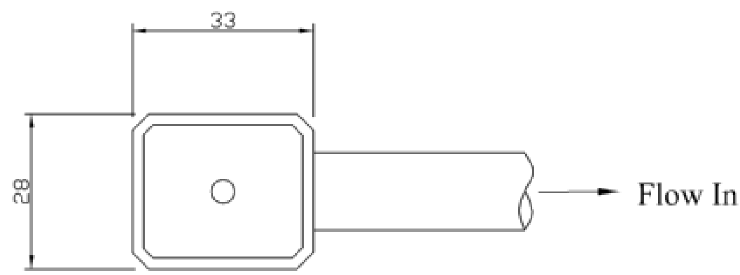


Figure 2-3 HBGS Circulating System



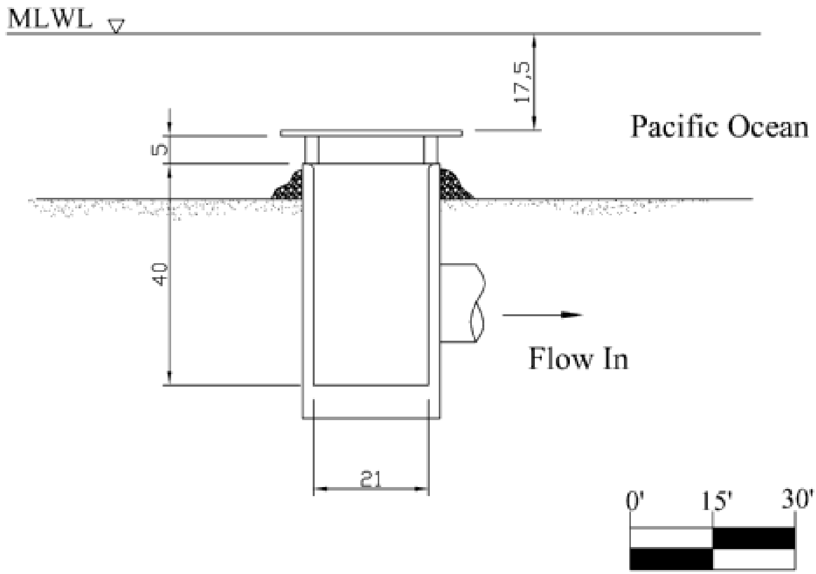


Figure 2-4 Velocity Cap

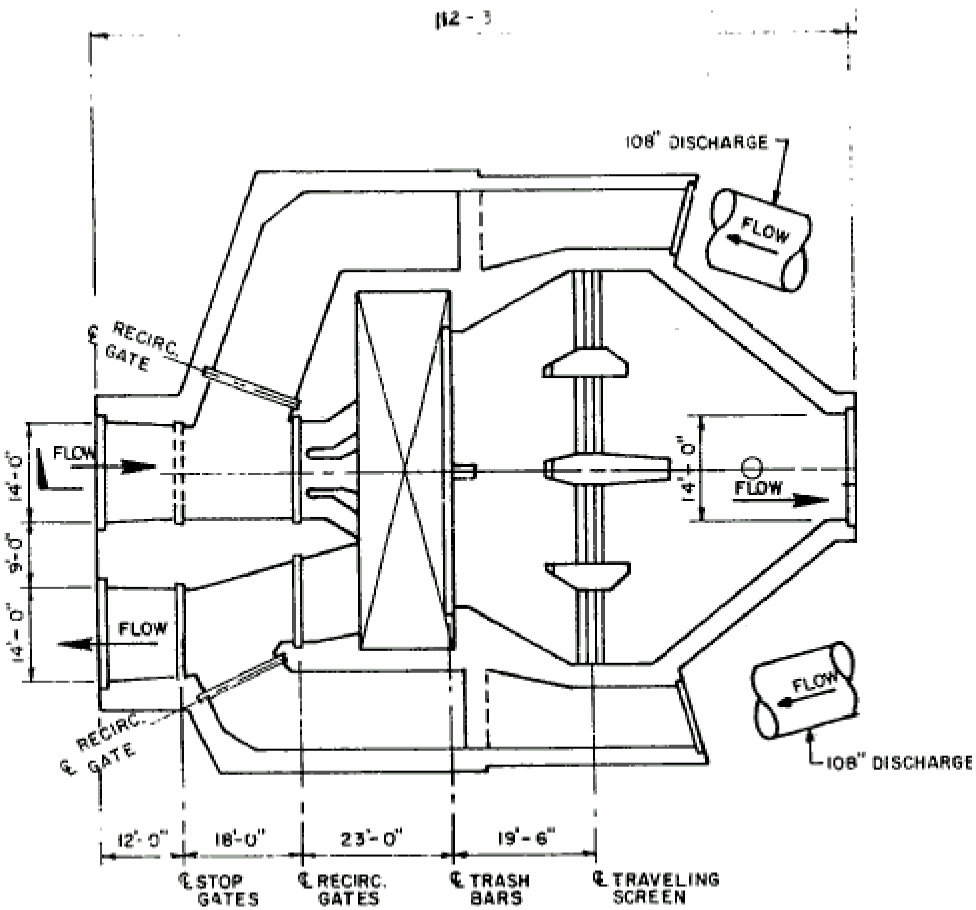


Figure 2-5 HBGS Screenwell Structure Plan View

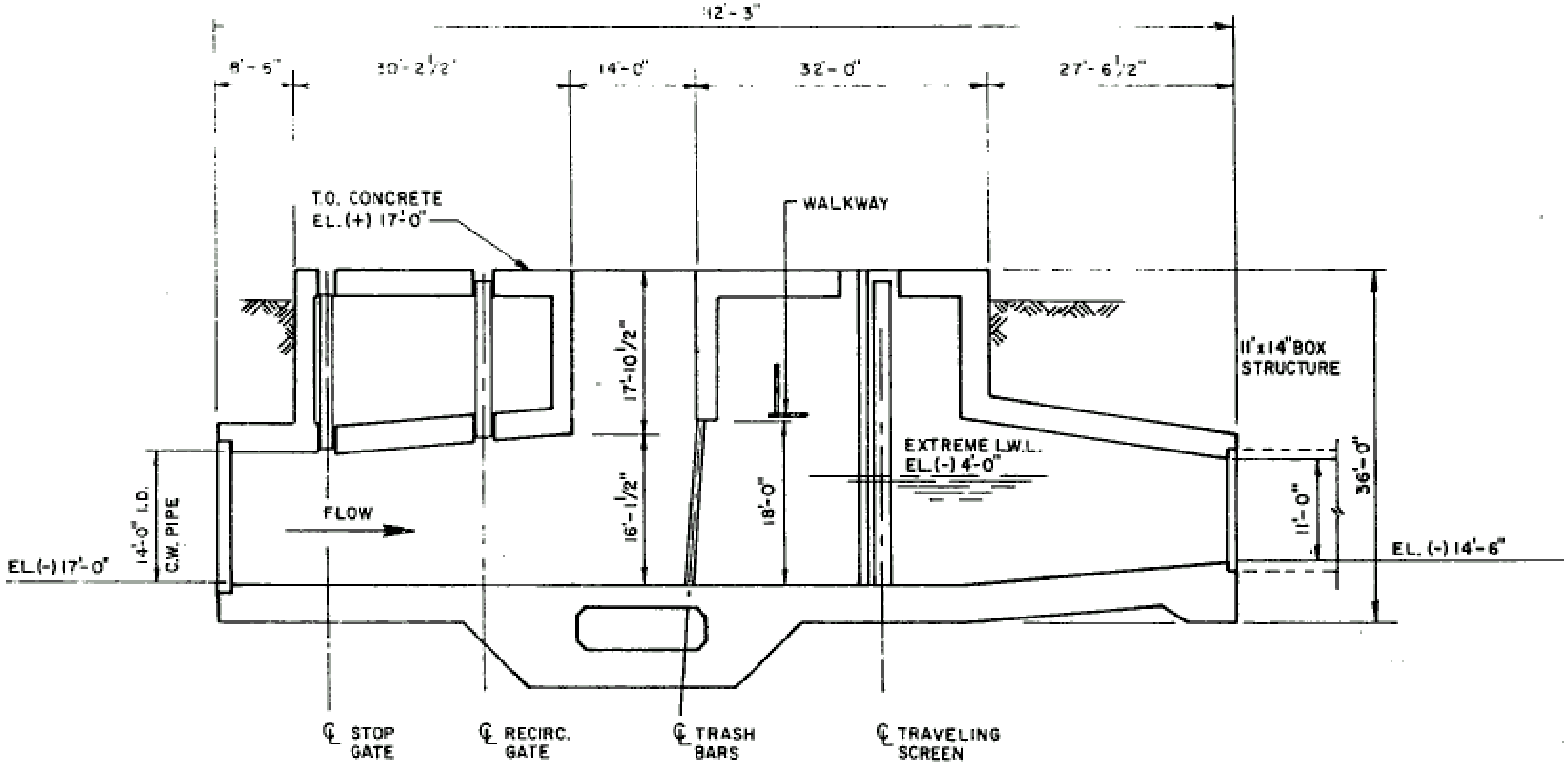


Figure 2-6 HBGS Screenwell Structure Section View

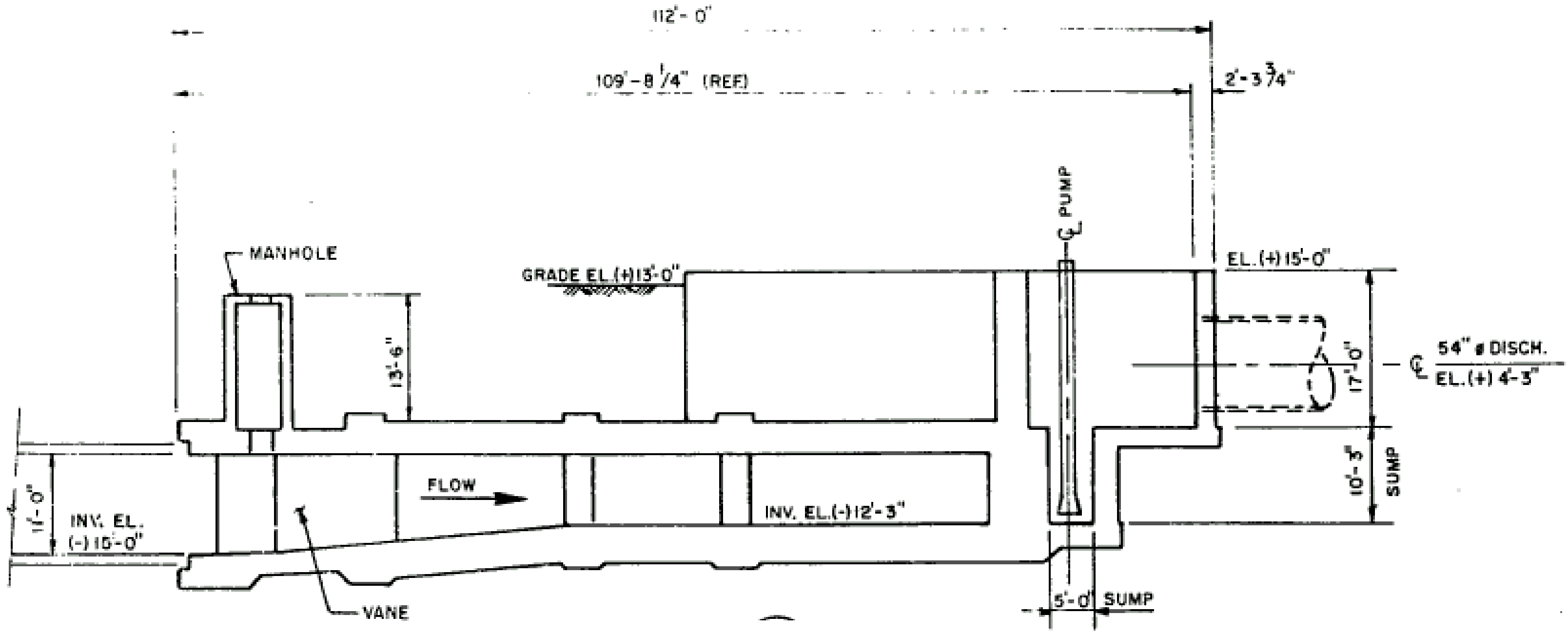


Figure 2-7 HBGS Pumphouse Structure Section View

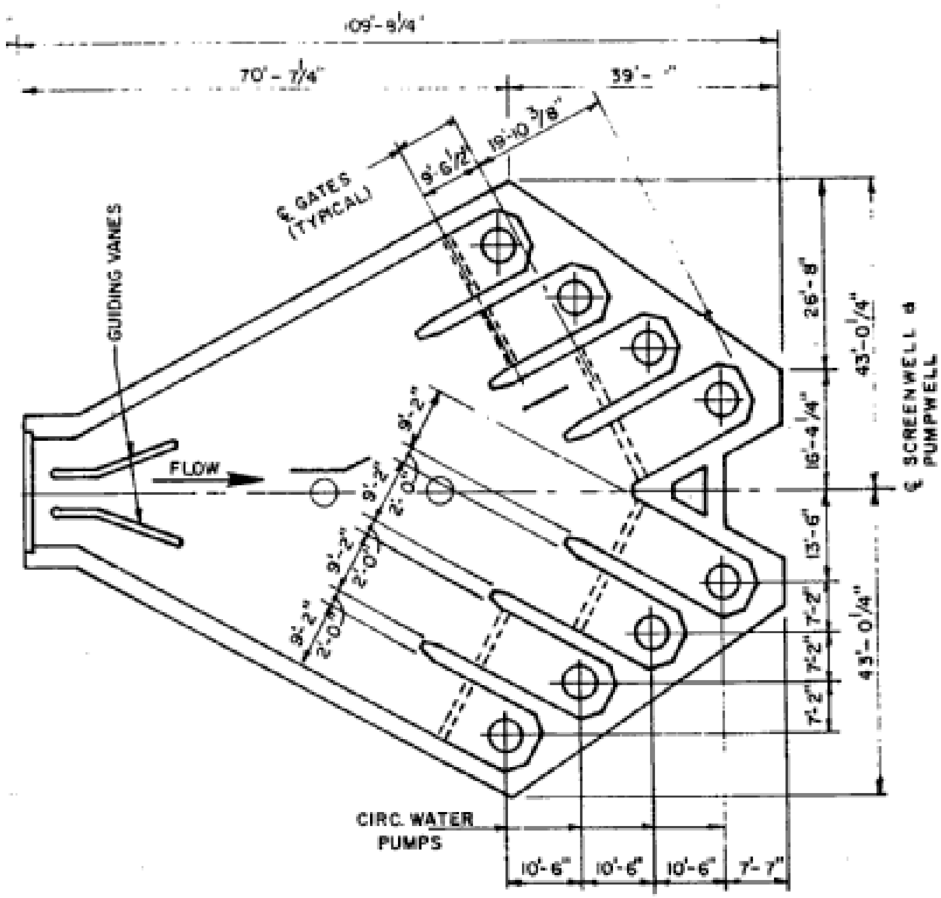


Figure 2-8 HBGS Pumpwell Structure Plan

Section 3
ASSESSMENT OF FISH PROTECTION TECHNOLOGIES

3.1 Evaluation Criteria

USEPA supports the adoption of national standards for existing CWISs (80-95% reduction in impingement mortality and 60-90% reduction in entrainment). Therefore, the primary criterion for evaluating alternative technologies is their ability to meet the performance standards. At HBGS, both impingement mortality and entrainment reduction technologies were evaluated.

Criteria used to evaluate alternatives that may be appropriate for application at HBGS are defined in this section. The screening process used for selecting alternatives for preliminary evaluation is presented in Section 3.2 for intake technologies and Section 3.3 for reduced flow options.

The following general considerations were used to develop conceptual designs of alternative fish protection technologies. The criteria were used to evaluate the relative advantages and disadvantages of each fish protection alternative and to select for more detailed development those alternatives that have the greatest potential to effectively protect fish. The criteria represent key aspects to any ultimately successful protection strategy and are not listed in order of priority.

- Alternatives should be designed to reduce impingement mortality of impingeable[1] fish by 80–95% from the "calculation baseline."
- Alternatives should be designed to reduce entrainment by 60–90% from the "calculation baseline."
- Alternatives should provide protection for species present in the ocean that are potentially susceptible to IM&E.
- The period of protection is year-round for impingement and May through August for entrainment.
- Alternatives should take into consideration current project design features, as summarized in Table 2-1.
- Alternative designs should have suitable conditions for fish protection over the full range of intake flows and water depths at the CWIS.
- Alternatives should provide effective protection throughout the entire water column such that they are effective with all species potentially susceptible to IM&E.

[1] USEPA defines an entrainable organism as one that will fit through a 3/8 in. mesh. By extension, any organism that is too large to be entrained through a 3/8 in. mesh would be considered "impingeable."

- Alternatives should function under expected debris loading and hydraulic conditions in the ocean (i.e., reasonable cleaning techniques are available and demonstrated).
- Alternatives should preserve, to the extent possible, the existing civil/structural features.
- Alternatives should meet worker and public safety requirements.
- Alternatives should not adversely impact navigation.
- Alternatives should be compatible with the other aesthetic and recreational features of the region.

3.2 Identification of Intake Alternatives with Potential for Application

The available fish protection technologies were subjected to a screening process to determine which technologies offered the greatest potential for practical application at HBGS. The screening consisted of the identification of those technologies that have potential for application, as presented below, and development of alternatives for proper installation of the technologies at the site. The criteria used to screen the technologies are discussed above in Section 3.1.

Table 3-1 summarizes results of the preliminary screening of the fish protection technologies. A technology was considered to have potential for application at HBGS if:

1. the technology has proven biological effectiveness,
2. the technology is available and does not require further engineering development, and
3. the technology has engineering and/or biological advantages over the other technologies evaluated.

The screening process was as objective as possible. However, in assessing the potential for application of fish protection schemes under physical, hydraulic, and environmental conditions in which they may never before have been applied, Alden had to use best professional judgment based on experience.

A technology was deemed to have proven biological effectiveness if test data (preferably from full-scale application) were available documenting that the technology had been effective for one or more of the targeted species when used at other sites. If engineering data existed in sufficient detail to develop a conceptual design and/or if the technology had been constructed at another site, it was judged to be an available technology. Each technology was qualitatively assessed to identify whether it had biological and/or engineering advantages over the other alternatives. For example, an intake technology that has been proven effective at reducing losses for many species and under a variety of intake conditions has a biological advantage over one that has been proven effective with a few species or under limited intake conditions. From an engineering perspective, one technology may hold an advantage over another if the civil/structural requirements for its installation are substantially less.

Based on the team's experience with intake technologies, the following concepts are considered to have limited or no proven biological effectiveness (i.e., they have not substantially reduced entrainment or impingement in past applications as indicated in Table 3-1):

- Infrasound
- Mercury lights
- Chemicals
- Electric screens
- Water jet curtains
- Hanging chains
- Visual keys
- Inclined plane screens
- Submerged traveling water screens

Behavioral barriers to protect juvenile and adult fish have been the subject of extensive research. The use of strobe lights to elicit a behavioral response is supported by the results of laboratory and cage test studies that have demonstrated strong avoidance by several fish species. Strobe lights have been evaluated for repelling or guiding juvenile and adult fish away from water intakes (EPRI 1999) and, in many cases, toward bypasses for transport to a safe release location. There is some evidence that combining strobe lights with an air bubble curtain can provide effective fish deterrence. However, results have been species- and site-specific.

The focus of recent studies involving underwater sound technologies has been on the use of low- and high-frequency acoustic systems that were not available for commercial use until the 1990s. High-frequency (120 kHz) sound has been shown to effectively and repeatedly repel members of the genus *Alosa* (American shad, alewife, and blueback herring) at sites throughout the U. S. (Ploskey et al. 1995; Dunning 1995; Consolidated Edison 1994). Other studies have not shown sound to be consistently effective in repelling species such as largemouth bass, smallmouth bass, yellow perch, walleye, rainbow trout (EPRI 1998), gizzard shad, Atlantic herring, and bay anchovy (Consolidated Edison 1994).

Based on the results of behavioral barrier studies conducted over the past 30 years, a hybrid barrier consisting of light, sound, and air bubbles would be most effective on Alosids. Given that Alosids are not impinged at HBGS, a hybrid barrier would likely not reduce impingement to a level that meets the impingement mortality reduction standard, and thus these types of barriers have been eliminated from further consideration at HBGS.

The existing intakes at HBGS could be modified for installation of Ristroph screens. Ristroph screens are very similar to conventional traveling water screens except that they are designed with extra features to collect and transport impinged organisms safely back to the waterbody. Fine-mesh Ristroph screens have the potential to meet both standards, while coarse-mesh Ristroph screens may meet only the impingement morality standard. In addition, Ristroph screens are designed for continuous operation to minimize impingement duration. Continuous rotation along with spraywash systems provides an automatic screen-cleaning feature. This gives them an engineering advantage over fixed-screens, barrier nets, and bar rack barriers, all of which would require an additional cleaning system. Fine-mesh Ristroph screens are considered to be a viable alternative for reducing both impingement and entrainment mortality at HBGS. Coarse-mesh screens have also been evaluated, since HBGS may choose to meet the entrainment reduction standard through other compliance alternatives.

Modification of the screenhouse to incorporate physical barriers or diversion systems, such as angled screens to prevent impingement, would be difficult. Traveling water screens have an engineering advantage over other physical barriers (angled fixed-screen, rotary drum screen, barrier net, bar rack barrier, infiltration intakes, and porous dikes; Table 3-1). Installation of rotary drum screens and porous dikes would require a much larger area than conventional traveling screens because of the lower design velocity. Rotary drum screens are typically installed in channels where water elevations are relatively constant and water depths are less than 12 ft, which is not the case at HBGS. Bar rack barriers are typically designed to have spacing greater than 1 in. and would not prevent the entrainment of early life stages. They may, however, effectively reduce impingement. The Team has not included any of these options in this evaluation because they do not have significant advantages over other impingement mortality reducing technologies included in this report.

The Modular Inclined Screen (MIS) has a biological and engineering advantage over louvers, angled bar racks, and angled screens in preventing impingement. Both screens offer the potential to effectively divert most species by using smaller structures than the other screen concepts. The MIS, for example, is designed to operate at velocities up to 10 ft/sec. The MIS could replace a section of the intake pipe downstream of the screen structure, and has been evaluated as an option to reduce impingement at HBGS.

Achievement of a 0.5 ft/sec through-screen intake velocity at HBGS would satisfy USEPA's Compliance Alternative 1 (BTA for impingement mortality). The required velocity could be attained through flow reduction, intake expansion, or installation of wedgewire screens. Intake expansion would require the addition of 14 new screenbays, while flow adjustment would require a 77% reduction in total plant flow. However, these two options have been eliminated in this evaluation because the Team does not consider them to be as cost-effective as other alternatives that have potential to meet both the IM&E standards. Narrow-slot wedgewire screens, however, present a feasible means of meeting both the IM&E standards.

Cylindrical wedgewire screens have an engineering advantage over the porous dike, infiltration intake, and bar rack barriers (Table 3-1). Wedgewire screens are designed for a through-screen velocity of 0.5 ft/sec, therefore automatically meeting the impingement mortality standard. Wedgewire screens have cleaning features that make them easier to clean than other fixed-screens and barrier nets. This cleaning feature requires the presence of a sweeping current to be effective. Ambient nearshore currents that are increased during periods of tidal change could potentially provide this sweeping current. Cylindrical wedgewire screens have a biological advantage in that they can exclude more life stages from intake water than conventional screens and bar racks. For this reason, the team has included wedgewire screens in the preliminary evaluation for HBGS.

Aquatic filter barriers (AFB) could prevent the entrainment of early life stages of fish. The AFB has an engineering advantage over barrier nets relative to cleaning (Table 3-1). An AFB has two layers of material, with an air purge system installed between the layers to permit automatic cleaning of accumulated silt and debris. This cleaning system can also free impinged fish larvae and other non-motile life stages. This technology requires low through-material velocities resulting in an extremely large surface area and may affect navigation in the vicinity of the intake. Securing and maintaining an AFB deployment in the open ocean, may be extremely difficult if even possible, because of the hydrodynamics associated with storm events. As a result, there may not be a cost-effective means of securing and maintaining an AFB in the open ocean. Due to the level of uncertainty in this option the team does not believe that an AFB would be a viable option for HBGS.

Fine-mesh barrier nets (<0.5mm) are easily fouled by silt and algae, require labor-intensive cleaning, and are considered experimental for reducing entrainment at this time. However, coarse-mesh nets could reduce impingement if they were installed in a low velocity zone and periodically cleaned to remove debris accumulation and biofouling growth. Barrier nets require less surface area than AFBs, although they may also hinder navigation and recreation at HBGS. For the same reasoning as with the AFB the Team has eliminated a barrier net from further consideration.

The preliminary screening of intake technologies available for fish protection (Table 3-1) indicates that two intake alternatives have the greatest potential for application to reduce fish impingement mortality and entrainment at HBGS:

- Expanded intake with fine-mesh[2] Ristroph screens
- Wedgewire screens with 0.5 mm openings

Three additional intake alternatives that would act to reduce fish impingement only have also been identified:

- Installing coarse-mesh Ristroph screens in existing intake
- Wedgewire screens with 9.5 mm openings
- Installing modular inclined screen (MIS) in intake

While AES will need to evaluate both impingement and entrainment technologies for HBGS under the Rule, technologies that would reduce impingement mortality only have been included in the event that AES is able to meet the entrainment reduction at HBGS through other compliance measures.

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[2] The term "fine mesh," as used in this document, refers to 0.5 mm (0.02 in.) square woven mesh.

The selected alternative technologies have proven biological effectiveness and have advantages over other concepts, as presented in Table 3-1. All of these concepts have been previously developed to a level such that a conceptual design could be prepared for possible application of the technology at HBGS subsequent to this study. Therefore, the team has carried forward these alternatives to a preliminary evaluation, as presented in Section 4. In addition, flow reduction options that are considered to have the potential for application at HBGS to reduce entrainment are discussed in Section 3.3.

3.3 Reduced Flow Alternatives Selected

Two flow reduction options to reduce IM&E at HBGS's intake structure have been identified. These options are:

- Reduced circulating water pump operation
- Installing a closed-cycle cooling system

Current plant operating procedures dictate operation of all pumps per unit to maintain the plant discharge within the permitted thermal limits when generating at full-capacity. However, when generation demand is reduced it is current practice to shut-down one pump per unit, as appropriate. To maintain the plant discharge within the permitted thermal limits, reduced pump flow would require a reduction in plant output.

Closed-cycle cooling could greatly reduce both IM&E at HBGS. Mechanical or natural draft wet towers would require less modification to the existing circulating water system piping and less real estate than dry cooling towers. The costs for construction of a wet mechanical cooling tower are about 60% less than the natural wet cooling tower. Wet cooling towers require less energy to operate and have lower annual costs then a mechanical draft tower. However, wet mechanical draft towers generally have less aesthetic and air quality impacts than natural draft wet towers. HBGS is surrounded by residential, recreational, and state parks, therefore aesthetics and air quality issues would probably rule out the use of natural draft towers. For these reasons, wet mechanical draft towers were chosen as the closed-cycle cooling system option for preliminary evaluation.

Table 3-1 Initial Screening of Fish Protection Alternatives at HBGS

Concept	Biological Effectiveness Proven	Engineering Alternative Available	Advantages over Other Concepts	Potential for Application at HBGS
Behavioral Barriers				
Sound	yes	yes	no	no
Infrasound	no	yes	yes	no
Strobe lights	yes	yes	no	no
Mercury lights	no	yes	yes	no
Chemicals	no	no	no	no
Electric screens	no	yes	no	no
Air bubble curtain	yes	yes	no	no
Water jet curtain	no	yes	no	no
Hanging chains	no	yes	no	no
Visual keys	no	yes	no	no
Hybrid barriers (e.g., strobe light / air bubble curtain)	no	no	no	no
Physical Barriers				
Fixed screens	yes	yes	no	no
Traveling water screens	yes	yes	no	no
Rotary drum screens	yes	yes	no	no
Barrier net	yes	no	yes	no
Bar rack barrier	yes	yes	no	no
Infiltration intakes	yes	yes	no	no
Porous dike	yes	yes	no	no
Aquatic filter barrier	yes	no	yes	no
Cylindrical wedgewire screen intakes	**yes**	**yes**	**yes**	**yes**

Table 4-1 (continued)

Concept	Biological Effectiveness Proven	Engineering Alternative Available	Advantages over Other Concepts	Potential for Application at HBGS
Collection Systems				
Modified traveling (Ristroph) screens	**yes**	**yes**	**yes**	**yes**
Fish pumps	yes	yes	no	no
Diversion Systems				
Louvers / angled bar racks	yes	yes	no	no
Angled screens (fixed or traveling)	yes	yes	no	no
Angled rotary drum screens	yes	yes	no	no
Inclined plane screens	no	yes	no	no
Eicher screen	yes	yes	no	no
Modular inclined screens	**yes**	**yes**	**yes**	**yes**
Submerged traveling screens	no	yes	no	no
Modifications to Reduce Intake Flow				
Modified pump operation	**yes**	**yes**	**yes**	**yes**
Install variable frequency drives	yes	yes	no	no
Install closed-cycle cooling system (mechanical & natural draft and dry cooling towers)	**yes**	**yes**	**yes**	**yes**

Section 4
PRELIMINARY EVALUATION OF ALTERNATIVES

Based on the screening of intake technologies and flow reduction options presented in Section 3, five alternatives using intake technologies for fish protection and two flow reduction options were selected as having potential for effective application at HBGS. The alternatives selected for more detailed evaluation are:

Alternative 1: Fine-mesh Ristroph screens with expanded intake

Alternative 2: Cylindrical wedgewire screens with 0.5 mm slot width

Alternative 3: Coarse-mesh Ristroph screens in existing intake

Alternative 4: Cylindrical wedgewire screens with 9.5 mm slot width

Alternative 5: MIS in existing intake

Alternative 6: Reduced circulating water pump operation

Alternative 7: Closed-cycle cooling with wet mechanical draft towers

Preliminary conceptual designs were prepared for each of these alternatives to serve as a basis for evaluation and cost estimates. The following sections present for each option: (1) the technical considerations associated with the design, installation, operation, and maintenance, (2) estimated construction, and operations and maintenance (O&M) costs including replacement power, and (3) estimated reductions of organism losses that can be expected.

4.1 Expand Intake and Install Fine-mesh Ristroph Screens

AES could replace the existing traveling water screens for all four units or modify them with new, state-of-the-art, fine-mesh Ristroph screens. Typically, fine-mesh screens are designed with an approach velocity of 0.5 ft/sec to increase the survival of fish eggs and larvae. To achieve a screen approach velocity of 0.5 ft/sec (about 1 ft/sec through-screen) at plant design flow, HBGS would need to expand the screenhouse. Lowering the velocity and installing new Ristroph screens would reduce year-round IM&E. The facility could add a total of four, 10 ft wide screens to achieve an approach velocity of 0.6 ft/sec. Adding a fifth new screen to reduce the velocity to 0.5 ft/sec was determined to be impractical due to space limitations associated with the screenhouse location. A velocity of 0.6 ft/sec should be adequate to reduce entrainment while ensuring some entrainment survival, although AES may wish to perform a pilot study to verify this. New fish return and debris troughs would be added. A plan of the expanded CWIS appears on Figure 4-1.

The existing screenbays would require modification for installation of the new fine-mesh screens. The existing traveling water screens would be removed and completely replaced with new screens. The existing support frames, backwash headers, nozzles, and control systems may be compatible with the new screens and would likely not have to be replaced. The new screen baskets would have a mesh size of 0.5 mm and each screen basket would have a fish bucket to hold collected organisms in about 2 in. of water while they were lifted to the fish recovery system. A section of the Ristroph traveling water screen is shown on Figure 4-2. A low-pressure spray (10 psi) would be used to gently remove the fish from the fish holding buckets into a fish sluice. A conventional high-pressure wash would then remove debris into a debris sluice. Both troughs would be located on the back side of the screens.

The four new screens would be located adjacent to the existing screens and connected to the new fish and debris troughs and return system as the screens in the existing screenbays. There would be no need for additional trash racks or circulating water pumps, since the expanded screenbay structure would entrain the entire cooling water flow into a common pump structure. Guide vanes may be necessary to provide an even distribution of flow to the outside screenbays. If spatial constraints do not allow expansion of the existing structure to include all four new screens, an alternative would be to rebuild the entire screenbay structure in a new location where there may be enough area to accommodate the required number of screens.

Expansion of the existing screenbay structure would require new fish and debris troughs to be mounted above deck level on the downstream side of the screens. The new troughs would discharge at the south end of the intake structure into a discharge pipe leading to the Pacific Ocean. The existing high-pressure screenwash pumps would provide flow to the high-pressure spraywash headers for the new fine-mesh Ristroph screens located in the existing screenbays. New screenwash pumps would be installed for the high-pressure spraywash headers for the new screens in the expanded screenbays. New screenwash pumps would need to be installed for the low-pressure spraywash headers for all the screens.

Removal of the existing traveling water screens, installation of the new Ristroph screens, and completion of mechanical and electrical work would require about 2 weeks per screen. The expansion of the screenbay structure would require one construction season to complete. Units 1–4 would be required to shut down during this period. An additional month of shutdown would be required to connect the new screens.

Maintenance of the CWIS with Ristroph screens would be similar to the CWIS with the existing screens. Total power requirements to continuously operate the screens year-round would be about 2,100 MWh per year.

Fine-mesh screens at HBGS would decrease the entrainment of larval fish through the CWS. The effectiveness of a fine-mesh screening system is measured in two ways: exclusion/retention and survival. Fine-mesh screens will prevent the entrainment of some organisms; however, the number is dependent upon the size of the organisms exposed to the system and the mesh size considered.

Retention (or exclusion) that can be achieved with a given mesh-size can be estimated by the body depth of an organism. Since larval fish are soft bodied and can be compressed, the deepest non-compressible portion of the body (head capsule) was used to predict exclusion. Exclusion is species-specific, because there is substantial variation in the morphometric characteristics among species. Therefore, species-specific estimates were generated for several of the commonly entrained species at HBGS. Because the size distribution of entrained organisms at HBGS tends to be fairly small, retention is for some species is low (Table 4-1).

The second measurement of effectiveness is the survival of organisms impinged on the fine-mesh screens that would previously have been entrained. The survival of impinged organisms is dependent upon their biology (life stage, relative hardiness, etc.) and the screen operating characteristics (rotation speed, spraywash pressure, etc.).

Survival estimates were derived from available data from other sites with modified traveling screens or other evaluations (e.g., laboratory and pilot-scale studies). Estimates of larval survival are presented in Table 4-1 Estimates of juvenile and adult fish post-impingement survival are presented in Section 4.3.

4.2 Cylindrical Wedgewire Screens with 0.5 mm Slot Width

AES could install cylindrical wedgewire screen intakes at HBGS to reduce fish entrainment and impingement. The design 0.5 ft/sec through-screen velocity will allow AES to meet the impingement mortality standard through Compliance Alternative 1. Wedgewire screens would not satisfy Compliance Alternative 4 (USEPA-approved technology), because this alternative only applies to facilities located on a freshwater river or stream.

Cooling water would be conveyed through submerged, cylindrical wedgewire screens mounted on a new 12 ft diameter pipe attached to the existing intake pipe at a 90-degree angle (forming a T shape). The wedgewire screen structure would replace the existing velocity cap, which would be removed. The existing trash racks and traveling water screens would also be removed from the screen structure, as they would no longer be necessary.

The new pipe would be at a right angle with the existing intake pipe (approximately parallel to the shoreline). Both the existing intake pipe and the new pipe would be buried in the ocean bottom. The minimum water depth at the screens is estimated to be approximately 29.5 ft during extreme low water levels. If the actual water depth in the vicinity of the screens is less than 14 ft during low water levels, then smaller wedgewire screens would be needed. Indicator buoys would be installed to alert boats about the presence of the submerged, wedgewire screens.

The screens would have a 0.5 mm screen slot size and would be designed for a maximum slot velocity of 0.5 ft/sec. Twenty-four T-84 screens would be required to accommodate the total facility flow. Each screen would be 7 ft in diameter and T-shaped, with an overall length of about 23 ft. Two screen sections, each about 7 ft long, would be located on each side of an 8 ft long T section. The outlet pipe would be 5 ft in diameter and located in the middle of the T section. The outlet of the T would be flanged for connection to the new 12 ft diameter pipe. Both ends of the screen cylinders would be tapered to deflect submerged floating debris. A typical section of a wedgewire screen appears on Figure 4-3.

The orientation of the screens relative to the new pipe will depend on the currents in the area. The screens should be positioned parallel to the predominant current for minimum debris buildup. The spacing between screens and the length of the new pipe will depend on the screen orientation. Figure 4-4 shows a plan view of the wedgewire screen design with the screens positioned parallel to the shoreline. This would be an optimal configuration if up-coast and down-coast currents are stronger than tidal currents.

An air backwash system, complete with necessary air compressors and controls, would be installed to clean the wedgewire screens. The air compressor and controls would be located in a new shelter near the existing screenbay structure. The air piping to each wedgewire screen would be installed along the top of the intake pipe. The air backwash system could be an effective method for maintaining the wedgewire screens at HBGS in a clean condition. Local currents, as a result of tides and up and down coast currents in the area, should be sufficient to transport debris and organisms away from the screens. Periodic manual cleaning for removal of biofouling agents would likely be necessary.

Approach velocities at the wedgewire screens would be similar to tidal or other ambient currents. The maximum through-slot velocity would not exceed 0.5 ft/sec. Head losses through the screens should not exceed 1 ft (assuming biofouling would not be a significant problem). Except for the slightly lower water level, flow characteristics in the intake pipe leading to the screenbay would not be any different than the existing intake. Flow patterns to the pumps would not change from the existing conditions.

The circulating pumps for all four units would have to be shutdown for approximately 1 month to remove the existing trash racks and screens and to connect the new wedgewire structure to the existing intake.

Installation of the cylindrical wedgewire screens would eliminate the need for operation and maintenance of the existing traveling water screens. Maintenance requirements for the circulating water pumps with the wedgewire screens in place would not change. Additional operation and maintenance efforts associated with the wedgewire screens would entail approximately 660 MWh per year. Plant personnel would be required to operate the air compressors and monitor backwashing operation to maintain the air supply equipment. An annual inspection by divers would be necessary to identify any damage or debris build up that could affect facility operations and to verify effective cleaning by the air backwash system. This inspection would take approximately 2 weeks using a three-man diving crew working from a workboat.

Implementation of this alternative would involve environmental impacts associated with installation of the new 12 ft diameter pipe, dredging of bottom material, and disposing of dredge spoil. If analytical results of the dredged materials were to indicate excessive contamination by priority pollutants, disposal of the spoil could be a difficult problem. Disposal of the dredge spoil would have to comply with all applicable laws and regulations. Dredging would have to be performed in a manner to minimize adverse impact to the marine environment.

Wedgewire screens designed with slot openings of 0.5 mm and slot velocities of 0.5 ft/sec or less should successfully exclude from entrainment most white croaker and northern anchovy eggs (similar to fine-mesh screens discussed above), however a slotted wedgewire design is more conducive to fish passage than a woven mesh of the same nominal opening size and some eggs may be entrained.

The head capsule method used to calculate retention on fine-mesh screens can also be used to estimate exclusion of larvae by narrow-slot wedgewire screens. The estimated reduction in entrainment using narrow-slot wedgewire screens is presented in Table 4-2.

4.3 Coarse-mesh Ristroph Screens

If the entrainment reduction standard is met through other compliance measures, then coarse-mesh Ristroph screens could be a viable alternative at HBGS to meet the impingement standard. The existing traveling water screens in the CWIS could be replaced with new, state-of-the-art coarse-mesh (9.5 mm) Ristroph screens to reduce impingement mortality. The mean screen approach velocity in the existing screenbay structure is 1.1 ft/sec. This is slightly higher than the design value of 1.0 ft/sec, but impingement survival may meet the performance standards such that expansion of the existing screenbay would not be necessary. AES may wish to perform a pilot study to further verify that there is no need for expansion. A section of a typical Ristroph screen appears on Figure 4-2.

New screens would be installed in the existing screenbays. These screens are very similar to the fine-mesh Ristroph screen alternative with the exception of a screen mesh size of 3/8 in. The existing screenwell structure would require only minor modification for installation of new coarse-mesh Ristroph traveling screens. The existing traveling water screens would be modified with new baskets, debris and fish troughs, backwash headers, and nozzles. The existing traveling water screens are not designed for continuous operation and the control systems and support frames would need to be replaced. Each screen basket would have a fish bucket to hold collected fish in about 2 in. of water while being lifted to the fish recovery system. A low-pressure spray (10 psig) would be used to gently remove the fish from the fish holding buckets into a separate fish trough. A conventional high-pressure wash would then remove debris into a separate debris trough, as for the fine-mesh screens. Removal of the existing screens and installation of the new screens should take approximately 8 weeks, during which Units 1–4 would be shut down.

Coarse-mesh Ristroph screens do not reduce the number of fish impinged but do increase the survival of impinged fish. Therefore, these screens are beneficial from an organism protection viewpoint only if impingement survival for important species and life stages is relatively high. In general, post-impingement survival of juvenile and adult fish off Ristroph screens is moderate to high. Survival is very species-specific, with hardy species surviving better than fragile ones. Extended survivals are typically reported for fish held for 48 to 96 hours following removal from screens to assess the potential for long-term damage.

Estimates of post-impingement survival by species based on existing literature for juvenile and adult fish are presented in

	Fine-mesh screens		
Species	**Retention**	**Survival**	**Overall Effectiveness (Reduction in Entrainment Losses)**
Gobiidae	64.1	0.0	0.0
spotfin croaker	7.5	18.0	1.4
northern anchovy	71.7	10.0	7.2

queenfish	85.8	18.0	15.4
white croaker	58.9	18.0	10.6
salema [1]	0.8	18.0	0.1
black croaker	9.6	18.0	1.7
combtooth blennies [2]	21.8	0.0	0.0
diamond turbot	11.3	79.5	9.0

Table 4-2 Estimated Reduction in Entrainment with the Use of Narrow-slot (0.5 mm) Wedgewire Screens at Huntington Beach Generating Station.

Species	Narrow-slot Wedgewire Percent Reduction in Entrainment
Gobiidae	64.1
spotfin croaker	7.5
northern anchovy	71.7
queenfish	85.8
white croaker	58.9
salema [1]	0.8
black croaker	9.6
combtooth blennies [2]	21.8
diamond turbot	11.3

Table 4-3.

4.4 Cylindrical Wedgewire Screens with 9.5 mm Slot Width

Cylindrical wedgewire screen intakes could also be installed to reduce fish impingement year-round. Cooling water could be conveyed through submerged, cylindrical wedgewire screens mounted on a new 12 ft diameter pipe attached at a 90-degree angle to the end of the existing intake pipe. The layout and design would be similar to the alternative described in Section 4.2 with the exception of slot width and fewer screens. A plan and section of the cylindrical wedgewire screens appear on Figure 4-4 and Figure 4-3.

The screens would have a 9.5 mm screen slot size and would be designed for a maximum slot velocity of 0.5 ft/sec. Seven T-84 screens would be required to accommodate the total facility flow. The arrangement of the screens, air backwash, screen size and the new pipe design would be similar to that discussed in Section 5.2 except the length of the new pipe would be 180 ft for the fewer screens.

Approach velocities at the wedgewire screens would be similar to the ambient currents. The maximum through-screen velocity would not exceed 0.5 ft/sec. Head losses through the screens should not exceed 1 ft (assuming biofouling would not be a significant problem). Except for the slightly lower water level, flow characteristics in the intake pipe leading to the screenbay structure would not differ from the existing intake. Flow patterns to the pumps would not change from the existing conditions.

Installation of the cylindrical wedgewire screens would replace the velocity cap and eliminate the need for operation and maintenance of the existing traveling water screens. Maintenance requirements for the circulating water pumps with the wedgewire screens in place would not change. Additional operation and maintenance efforts associated with the new screens would require approximately 197 MWh per year. Facility personnel would be required to operate the air compressors and monitor backwashing operation to maintain the air supply equipment. An annual inspection by divers would be necessary to identify any damage or debris build up that could affect facility operations and to verify effective cleaning by the air backwash system. This inspection would take approximately 2 weeks using a three-man diving crew working from a workboat.

Implementation of this alternative would involve environmental impacts associated with dredging of bottom material and disposing of dredge spoil. If analytical results of the dredged materials were to indicate excessive contamination by priority pollutants, disposal of the spoil could be a difficult problem. Disposal of the dredge spoil would have to comply with all applicable laws and regulations. Dredging would have to be performed in a manner to minimize adverse impacts to the marine environment.

Wide-slot wedgewire screens would not reduce entrainment appreciably. The low through-slot velocity of 0.5 ft/s would meet Compliance Alternative 1under the Phase II §316(b) Rule.

4.5 Modular Inclined Screen

The MIS concept is a new fish diversion system that has been developed to guide fish into a bypass at high velocities. A MIS module consists of a square entrance, upstream and downstream dewatering gates, an inclined screen set at a shallow angle (10 to 20 degrees) to the flow, and a bypass for directing diverted fish to a transport pipe. The module is completely enclosed and is designed to operate at relatively high water velocities ranging from 2 to 10 ft/sec, depending on species and life stages to be protected.

A MIS unit could be installed downstream of the existing screenhouse. The current trash racks would be removed completely and the MIS unit would be positioned in their place. The layout appears in Figure 4-7. The module would have a 12 ft square approach area in a vertical plane immediately downstream of the trash rack. The average approach velocity to the screen would be 5.9 ft/sec at the design flow rate of 794.5 cfs. A fish bypass would be located at the downstream end of the screen.

The module would include a 12 ft wide by 45 ft long rectangular screen. The screen would be inclined in the downstream direction at an angle of 15 degrees from horizontal. A plan and section of the MIS module appear on Figure 4-6. The screen material would be wedgewire, with the screen bars arranged parallel to the flow direction. The screen panel would have a uniform porosity of 50 percent, with a 2 mm clear bar spacing along its entire length. The panel would be supported by a steel frame designed for a 5 ft differential pressure that could result from debris accumulation. The screen would be rotated to backwash debris from the screen face.

The fish bypass entrance at the downstream end of the screen would be a 2 ft diameter pipe that would connect to a fish pump. A fish pump would regulate bypass flow to 26 cfs. The fish pump would also provide the head needed to return the bypass flow back to the river outside of the intake canal. The fish pump would pump bypass flow into a drop basin that would flow into a 2 ft diameter fish return pipe. The fish return pipe would extend to the Pacific Ocean.

The existing trash rack at the upstream end of the screenbay could be modified slightly and used at the face of the MIS to prevent large debris from impacting on the screen or entering into the fish bypass. Cleaning of the screens would be necessary to minimize adverse impacts on facility operation resulting from debris accumulation (additional head losses) and to maintain the fish diversion efficiency of the inclined screens. The screen facility would operate year-round.

Installation of the MIS unit would take approximately 2 months to complete. First, the MIS unit would be fabricated either onsite or offsite. Once the MIS is built, the existing traveling screens inside the screenhouse would be removed and the MIS installed. The unit would have to be shut down for about 2 months during the installation.

The MIS facility would not significantly affect facility operations. Daily monitoring of the screens would be necessary. Monitoring and cleaning of the screens would require about 1 hour per day. Additional operation and maintenance efforts associated with operating the fish bypass pump would require 2,000 MWh per year.

No biological information is available for the species impinged at HBGS. However, MIS tests at 6 ft/s demonstrated survivals of 99% or greater with 10 of the 11 species tested. Juvenile Alosids, which are considered to be “fragile,” exhibited survival rates of 81.6%. Some reduction in entrainment of larger larvae may be achieved with the 2.0 mm slot width.

4.6 Reduced Circulating Water Pump Operation

AES could also accomplish a 60% reduction in entrainment at HBGS by reducing the number of operating circulating water pumps (from the current operating procedures) during periods of high entrainment. A 60% reduction in pumping capacity for Units 1–4 would meet the proposed USEPA entrainment reduction goals for the existing CWIS. To achieve this reduced flow, two units (Unit 1 and Unit 4) would be shut down, Unit 3 operated at 100% capacity and Unit 2 operated at about 40%, thus reducing facility flow and therefore entrainment by 61%. However, a detailed analysis of entrainment rates for all of the species and life stages at the HBGS CWIS would be necessary to determine the potential reduction in entrainment resulting from a flow reduction option.

Operation and maintenance of the existing traveling water screens and the circulating water pumps would be reduced during periods of reduced facility operation. With a 60% reduction in flow, total pump operation power requirements would be reduced by roughly 60%. The existing intake structure and traveling water screens would not require replacement or upgrade for this modified operation option. With this reduced flow option both of the circulating water pumps for Unit 2 would be required to be retrofitted with new variable frequency drives.

Removal of two existing circulating water pump drives and installation of the new variable frequency drives would be accomplished over an 8-week period using a truck-mounted crane. The gates in the pump-well structure may be used to isolate individual pumps. Therefore, installation of the new equipment would require only one unit to be shut down during construction.

The reduced flow alternative, when implemented in the 6-month (April–September) entrainment period would reduce the facility output to about 526 MW. Replacement power necessary during this period would amount to about 584,239 MWh assuming a 26% capacity factor for all units. The actual loss in generation may be slightly smaller than estimated in this evaluation as there will be some power saved as a result of shutting down several circulating water pumps.

The number of organisms entrained would be reduced in proportion to the flow reduction achieved by modifying the pump operation (60% reduction). To maximize the biological benefits of this alternative, reduced flow periods would occur during the months of estimated peak entrainment. Since the existing screens would not be modified, mortality of impinged fish would remain unchanged. The relationship between flow and impingement on screens has not been established for power plant CWISs, but suspect some reduction in impingement might occur. However, it is not possible to accurately estimate what reduction in impingement the reduced flows might achieve.

4.7 Retrofit Facility with Closed-Cycle Cooling System

Retrofitting the once-through cooling water system with a closed-cycle cooling system would reduce water use for plant cooling systems. The average amount of make-up water required for cooling towers would be about 24 cfs (about 3.0% of the once-through cooling water requirement), with a commensurate reduction in organism entrainment. An evaluation of cooling tower costs for retrofitting existing power stations was provided in EPRI's report entitled "Cooling System Retrofit Costs Analysis" prepared in July 2002. This report was prepared in response to the proposed USEPA Rulemaking. This study was conducted to provide generalized methods and supporting data for estimating the cost of retrofitting existing plants with recirculating systems (EPRI 2002).

The EPRI report (2002) developed the likely costs for "all cooling towers." To develop these costs, three assumptions were made:

1. The addition of a cooling tower would connect to the existing condenser so circulating water rates would not change.
2. Portions of the existing condenser conduit systems can be used, even though some modifications may be required.
3. The cost methodology is based on new facilities and must be adjusted using multiplying factors to determine the cost of retrofitting an existing facility.

Using these assumptions, the costs were broken down into easy, average, and difficult retrofitting costs, based mainly on site-specific factors (EPRI 2002).

A mechanical or natural draft cooling tower could be retrofitted to meet the cooling requirements of the plant. For the purpose of this evaluation, Alden has assumed that a mechanical draft tower would be installed at the site. Land space for new cooling towers is limited at HBGS and may need to be acquired by AES from adjacent property owners. Mist eliminators and plume abatement measures would be necessary to reduce cooling tower drift and minimize impacts on transportation (air traffic, shipping, highways, and railroad). For these reasons, HBGS would be classified as a difficult site relative to EPRI's cooling tower cost methodology.

Most of the condenser and cooling system components would remain intact and would use approximately the same condenser flows. Cooling water that is currently discharged into the discharge channel would be redirected into a wet pit pump structure, where booster pumps would convey cooling water to the cooling tower spray deck and back to the existing intake. Gravity would be used to convey the cooling water through the condensers similar to the existing once-through system. A new, smaller pump would be installed in the intake to supply makeup water from the intake channel for the closed-cycle cooling system.

Most of the construction efforts on the cooling tower would exist independently of the existing circulating water system and would not affect facility operations. However, replacement power would be required to implement the intake modifications and the final circulating water pipe modifications. These efforts would require Units 1–4 to be shut down for about 6 months, which would amount to about 1,029,475 MWh.

The mechanical draft cooling tower would require approximately 1.2% of the total plant output for auxiliary power (EPRI 2002). The extra power would be required to operate the additional cooling water supply pumps for the tower, the tower fans, the blowdown facility equipment, and the makeup water pumps. Since the temperature of the cold water produced by the tower would be proportional to approach temperature (local wet bulb temperature), the closed-cycle system would produce warmer water than the current once-through cooling water. All retrofitted closed-cycle cooling system alternatives would cause a reduction in net generation and a corresponding increase in the heat rate, except for periods when the turbine output is limited by high backpressures. The higher water temperatures at the condenser inlet would reduce Units 1–4 output by 1% of total capacity or about 20,590 MWh during the year (EPRI 2002). The net loss of salable power would be about 45,050 MWh per year.

Annual maintenance is necessary on the mechanical and electrical components of a mechanical draft tower and the other pumping components for a closed-loop cooling water system. Pumps, fans, motors, controls, fill sections, support structures, and the tower basin and hardware all require periodic inspections and maintenance. The EPRI study indicates that the operating and maintenance costs for a cooling tower retrofit would be 2% of the total construction costs.

Similar to the reduced flow option discussed above, the reduction in entrainment with this option would be commensurate with the reduction in flow, assuming an even distribution of larvae and egg during periods of flow reduction.

Table 4-1 Estimated Retention, Survival, and Overall Effectiveness of Fine-mesh Screens at Huntington Beach Generating Station.

Species	Fine-mesh screens		
	Retention	Survival	Overall Effectiveness (Reduction in Entrainment Losses)
Gobiidae	64.1	0.0	0.0
spotfin croaker	7.5	18.0	1.4
northern anchovy	71.7	10.0	7.2
queenfish	85.8	18.0	15.4
white croaker	58.9	18.0	10.6
salema [1]	0.8	18.0	0.1
black croaker	9.6	18.0	1.7
combtooth blennies [2]	21.8	0.0	0.0
diamond turbot	11.3	79.5	9.0

Table 4-2 Estimated Reduction in Entrainment with the Use of Narrow-slot (0.5 mm) Wedgewire Screens at Huntington Beach Generating Station.

Species	Narrow-slot Wedgewire
	Percent Reduction in Entrainment
Gobiidae	64.1
spotfin croaker	7.5
northern anchovy	71.7
queenfish	85.8
white croaker	58.9
salema [1]	0.8
black croaker	9.6
combtooth blennies [2]	21.8
diamond turbot	11.3

Table 4-3 Estimated Post-impingement Survival of Juvenile and Adult Fish that Could be Achieved at Huntington Beach with Modified Traveling Screens

Common Name	Surrogate	*N*	Range	Weighted Mean	95% (CI) Lower	95% (CI) Upper
spotfin croaker	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
queenfish	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
white croaker	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
black croaker	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
combtooth blennies	*Hypsoblennius spp.*	1	100.0	100.0	50.0	150.0
gobies	Gobiidae	44	0.0 - 100.0	93.2	84.6	101.8
northern anchovy	Engraulidae	10,844	0.0 - 77.7	23.2	22.4	24.0
salema	no data available	--	--	--	--	--
diamond turbot	*Pseudopleuronectes americanus*	383	0.0 - 97.0	96.9	95.0	98.7
shiner perch	no data available	--	--	--	--	--
Pacific pompano	Stromateidae	125	72.2 - 76.1	74.4	66.3	82.5
walleye surfperch	no data available	--	--	--	--	--
jacksmelt	Atherinopsidae	965	97.8 - 100.0	98.2	97.4	99.1
topsmelt	Atherinopsidae	965	97.8 - 100.0	98.2	97.4	99.1

Table 4-4 Reduced Circulating Water Pump Scenarios

Description	Unit 1	Unit 2	Unit 3	Unit 4	Total Intake Flow (gpm)	Percent Flow Reduction	Plant Output (MW)
Existing once-through cooling water flow (gpm)	88,000	88,000	88,000	92,600	356,000	0%	904
Scenario 1: shut down Unit 4 and one other unit, reduce flow to two other units (gpm)	off	88,000	54,640	off	142,640	60%	358
Scenario 2: shut down 2 of Units 1–3, reduce flow to Unit 4 (gpm)	off	off	88,000	54,634	142,640	60%	358

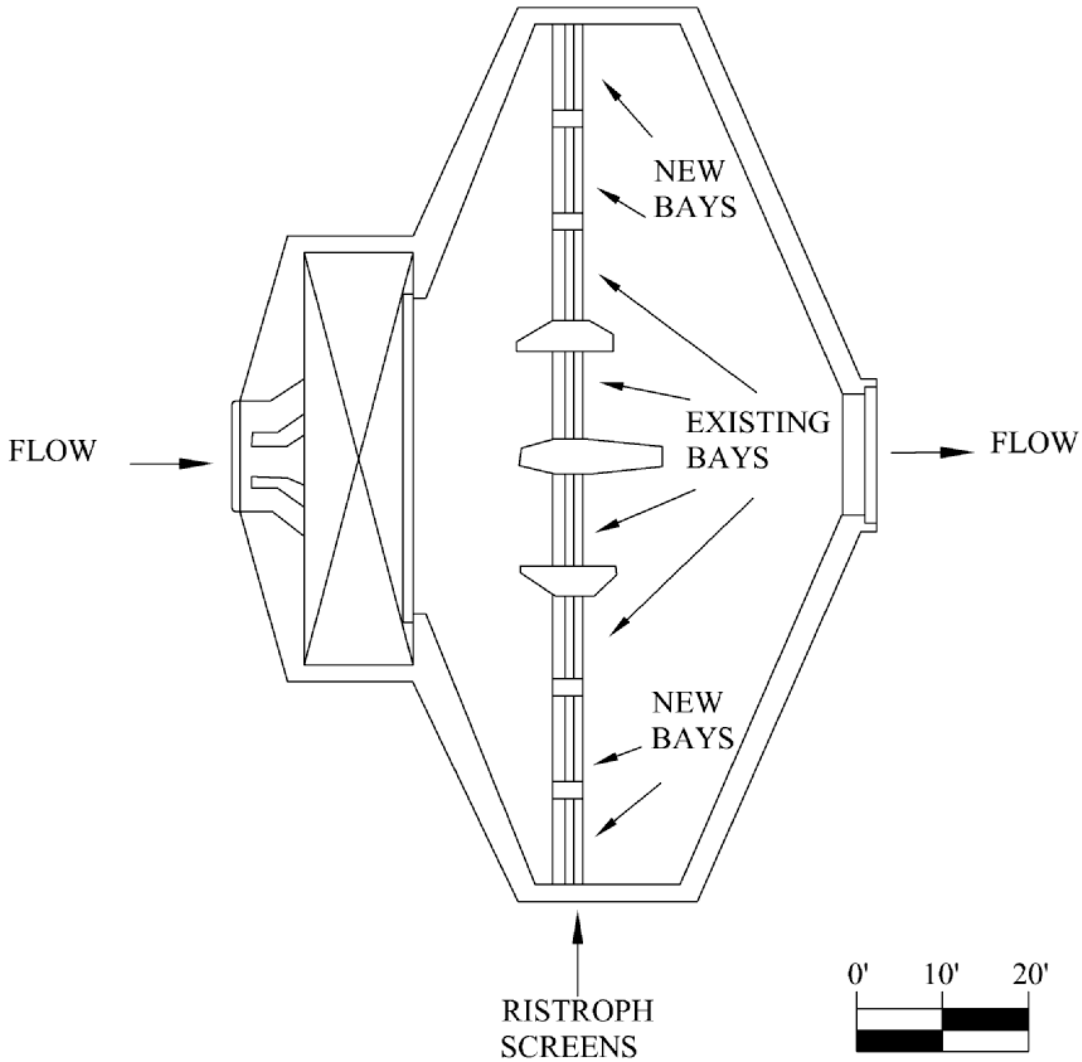


Figure 4-1 Expanded Intake with Fine-mesh Ristroph Screens

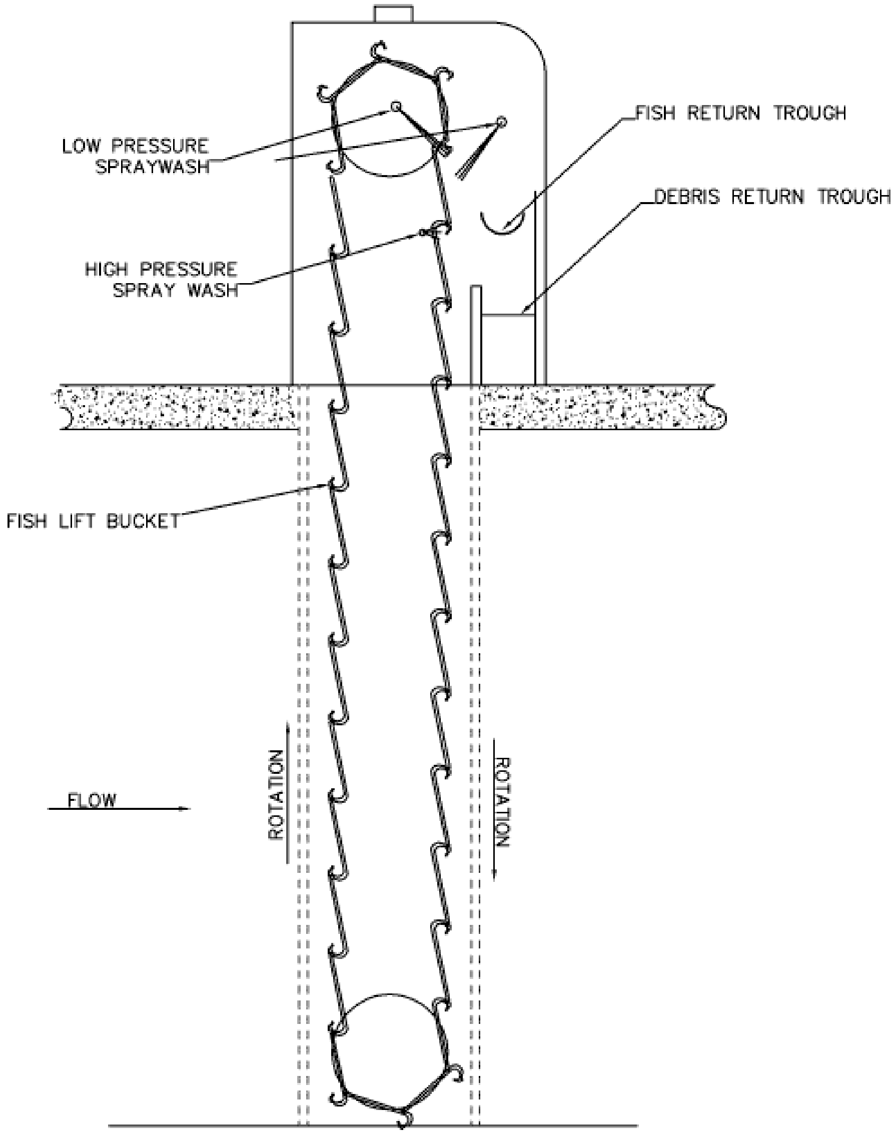


Figure 4-2 Typical Ristroph Screen — Section

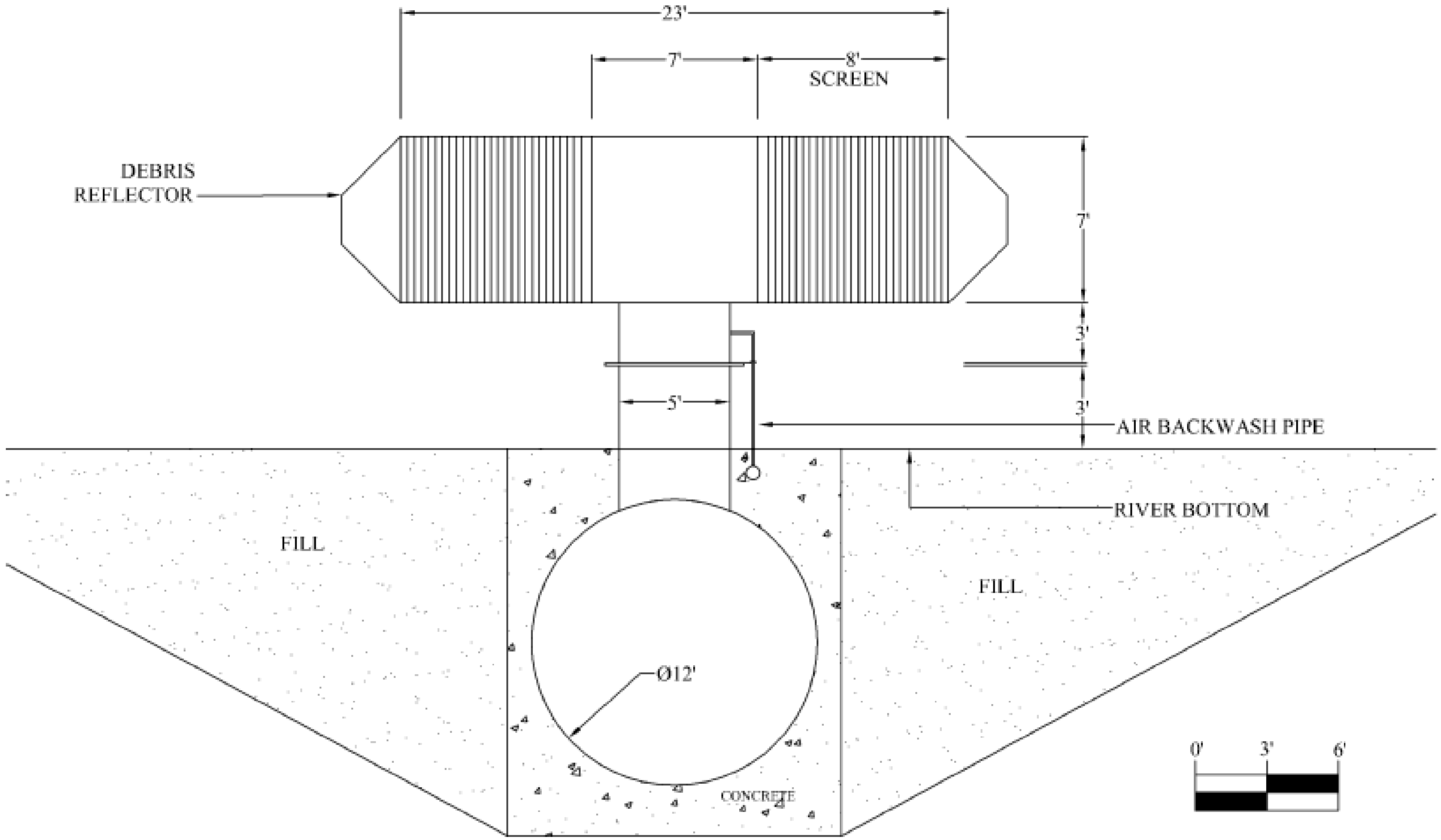


Figure 4-3 Typical Wedgewire Screen — Section

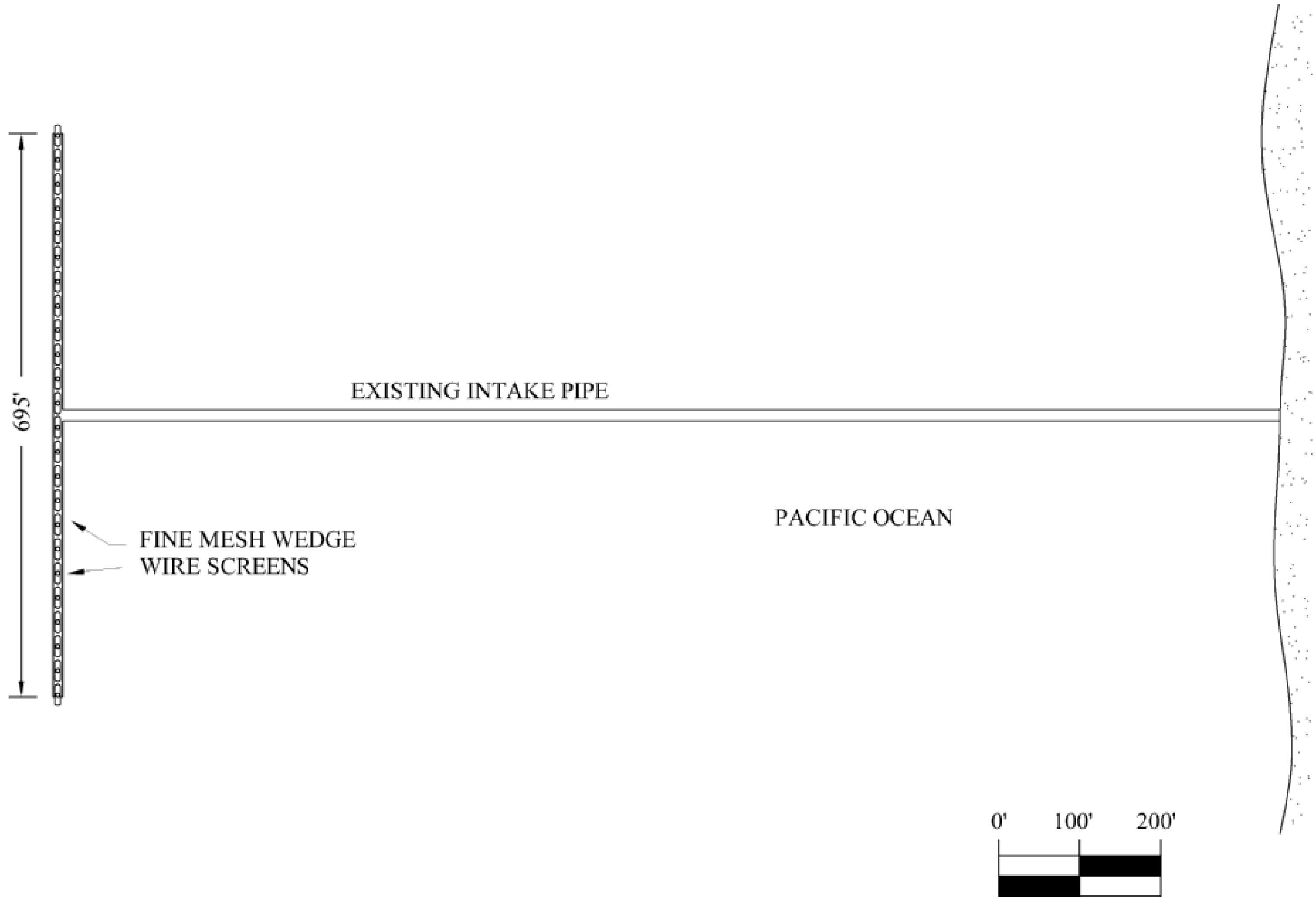


Figure 4-4 Cylindrical Wedgewire Screen, 0.5 mm Slot Width — Plan

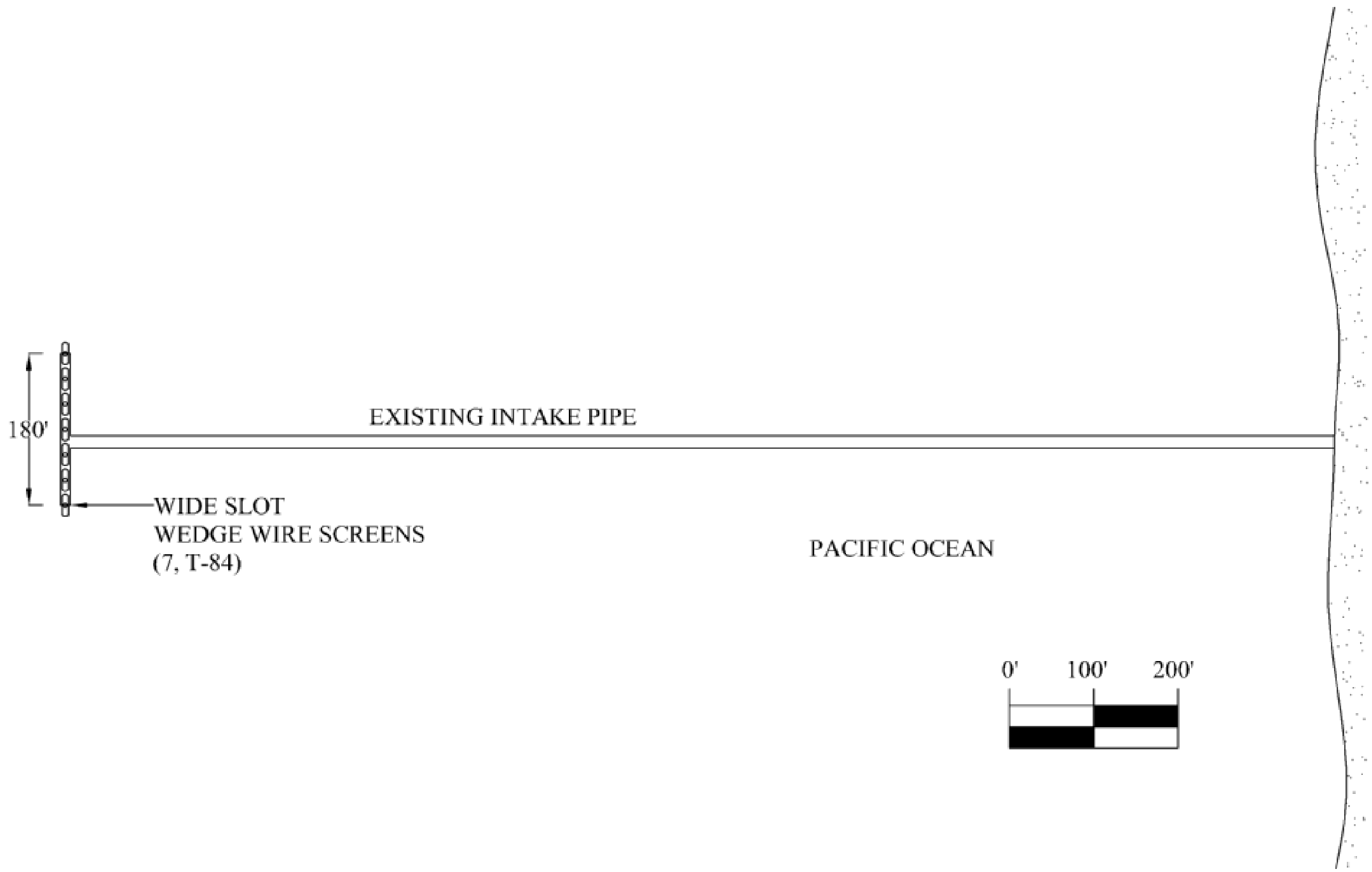


Figure 4-5 Cylindrical Wedgewire Screen, 9.5 mm Slot Width — Plan

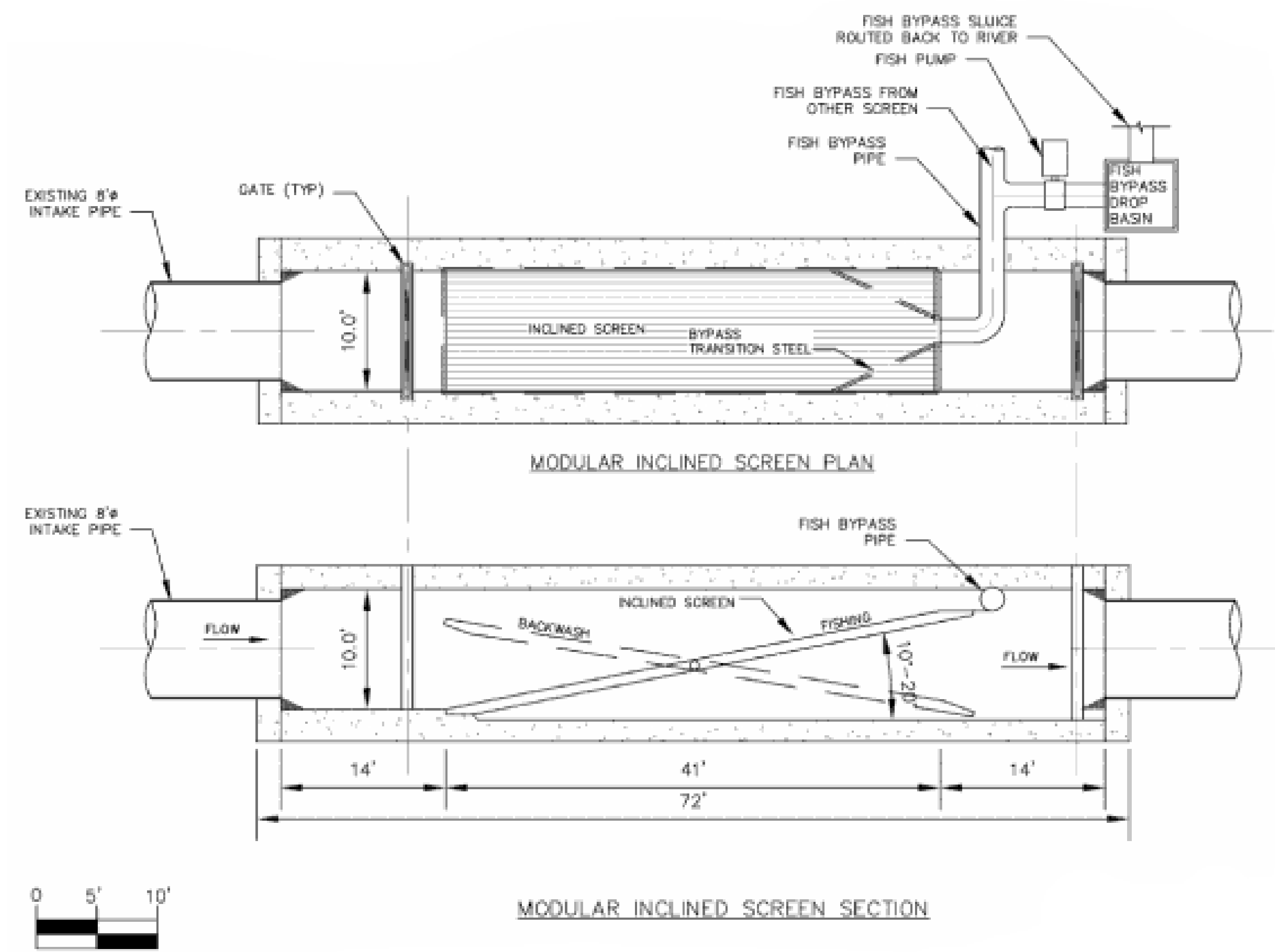


Figure 4-6 Modular Inclined Screen — Typical Plan and Section

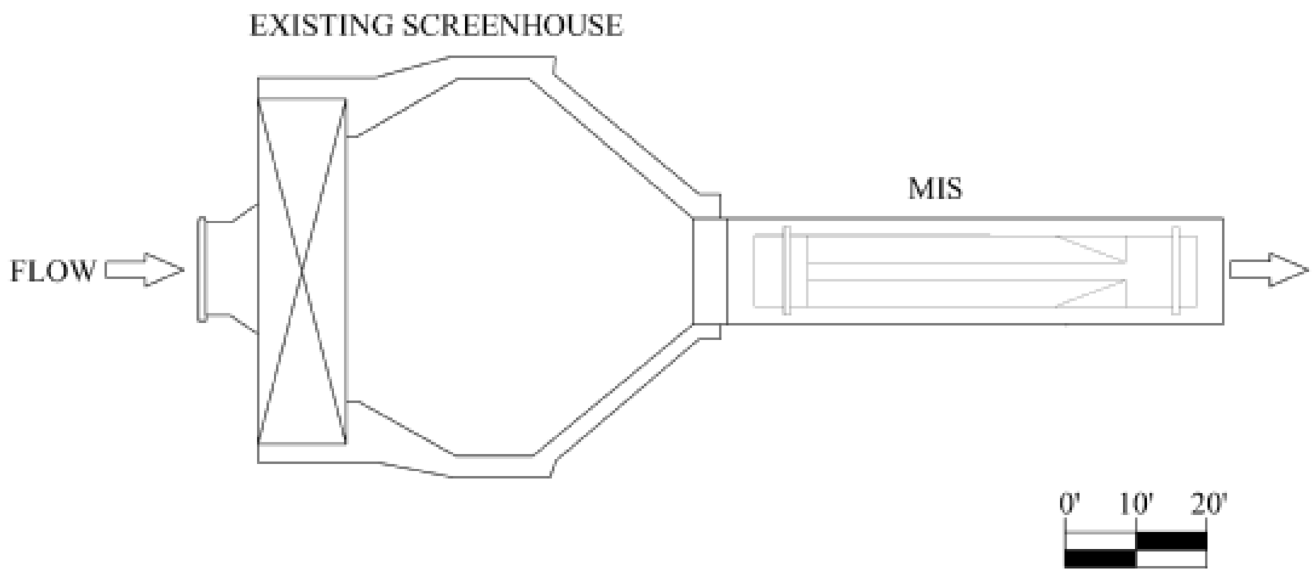


Figure 4-7 HBGS MIS — Plan

Section 5
ESTIMATED COSTS

The costs associated with meeting the Rule will likely determine the compliance strategy that is most desirable at HBGS. Preliminary installation and O&M costs associated with each of the alternatives identified in Section 3 and developed in Section 4 are presented below.

Appraisal level project costs were developed for the nine intake alternatives discussed in Section 4. The costs were estimated using Alden's cost database of alternatives for over 35 plants. These costs were adjusted for identifiable differences in project sizes and operations. Due to their generalized nature, these appraisal level cost estimates are intended to identify the relative cost differences between alternatives and the cost of compliance in relation to the USEPA selected technology for a facility. More detailed cost estimates based on detailed quantity takeoffs would be required if AES plans to apply one of these alternative technologies at HBGS.

Costs in Alden's historical database typically reflect the following assumptions:

- Present-day prices and fully contracted labor rates.
- A 40-hour work week with single-shift operation for construction activities that do not impact facility operations and a 50-hour work week with double-shift operation for construction activities that impact facility operations.
- Direct costs for material and labor required for construction of all project features.
- Distributable costs for site non-manual supervision, temporary facilities, equipment rental, and support services incurred during construction. These costs are estimated to be 85-100% of the labor portion of the direct costs for each alternative;
- Indirect costs for labor and related expenses for engineering services to prepare drawings, specifications, and design documents. The indirect costs are estimated to be 10% of the direct costs for each alternative;
- Allowance for indeterminates to cover uncertainties in design and construction at this preliminary stage of study. An allowance for indeterminates is a judgment factor that is added to estimated figures to complete the final cost estimate, while still allowing for other uncertainties in the data used in developing these estimates. The allowance for indeterminates is estimated to be 10% of the direct, distributable, and indirect costs of each alternative; and
- Contingency factor to account for possible additional costs that might develop but cannot be predetermined (e.g., labor difficulties, delivery delays, weather). The contingency factor is estimated to be 15% of the direct, distributable, indirect, and allowance for indeterminate costs of each concept.

It is imperative to include the following commonly overlooked items in estimates of the total capital costs:

- Costs to perform additional pilot studies, including laboratory or field studies that may be required.
- Costs to dispose of any hazardous or non-hazardous materials that the facility may encounter during excavation and dredging activities.
- Costs for administration of project contracts and for engineering and construction management incurred by AES.
- Escalation (increases in wages, materials, and other costs as a result of various economic factors).
- Permitting costs.

For a closed-cycle cooling system alternative, EPRI's estimated costs (EPRI 2002) were used. This study reflected retrofit cost data from 50 nuclear and fossil plants on fresh, brackish, and saline water sources. Facility sizes were 100 to 2,600 MW, with cooling tower retrofit costs ranging between $11 million and $860 million. Costs are $125/gpm for "easy" projects, $200/gpm for "average" projects, and $250–$300/gpm for "difficult" projects (EPRI 2002). Power to operate cooling towers is typically 1.0–1.5% of the facility capacity, and O&M costs are typically 1–2% of the tower capital costs (EPRI 2002). The Team has considered HBGS to be an "average" project for retrofit of a cooling tower.

To allow Alden's cost estimates to be directly comparable to USEPA's cost for a like facility, Alden had to adjust its costs to the methodology used by USEPA in developing the national costs. The adjustments appear below:

- All costs are given in 2007 dollars.
- At nuclear facilities, both the O&M and Capital costs for a given technology were multiplied by a cost factor to account for additional burdens as a result of added security and safety requirements.
- A cost factor ranging from 1.1 to 1.2 (based upon well depth) was added to the cost of Ristroph screens for the installation of dual flow screens.
- The cost for wedgewire screens was adjusted by a factor of 1.1 for facilities located on salt water or in a state with zebra mussels.

Costs for intake technologies and operational measures based on Alden's database appear in Table 5-1. In addition to initial capital costs and annual O&M costs, this table includes costs (lost generation and potential lost revenue) associated with construction shutdowns and energy penalties. Where applicable, costs for losses in generating capacity as a result of the compliance option were included. For technologies that do not require the use of the existing traveling screens, the annualized O&M costs are the O&M costs for a given alternative minus baseline O&M costs. As shown in Table 5-1, the annualized Alden costs for intake retrofit alternatives range from $300,000 for 9.5 mm wedgewire screens to $9,966,000 for fine-mesh Ristroph screens. Cooling tower retrofit costs for HBGS would be about $19,245,000 per year.

Table 5-1 Alden's Appraisal Level Costs of Evaluated Alternatives

	Estimated from Alden Database							
Alternative	**Construction Costs (2002 $)**	**Replacement Power During Shutdown (MWh)**	**Total Capital Cost (2002 $)[1]**	**O&M Costs (2002 $)**	**Lost Generation (MWh)[2]**	**Annualized Capital Costs (2002 $)[3]**	**Annualized O&M Costs (2002 $)[1, 2]**	**Total Annualized Costs (2002 $)**
Expanded intake with fine-mesh Ristroph screens	$5,472,000	1,544,213	$67,241,000	$308,000	2,102	$9,574,000	$392,000	$9,966,000
Retrofit intake with 0.5mm wedgewire screens	$5,850,000	0	$5,850,000	$88,000	657	$833,000	$114,000	$947,000
Install coarse-mesh Ristroph screens in existing intake	$2,011,000	343,159	$15,737,000	$155,000	788	$2,241,000	$187,000	$2,428,000
Retrofit intake with 9.5mm wedgewire screens	$1,865,000	0	$1,865,000	$26,000	197	$266,000	$34,000	$300,000
Install MIS in existing intake	$2,157,000	343,159	$15,883,000	$33,000	990	$2,261,000	$73,000	$2,334,000
Limit the number of operating pumps	$383,000	0	$383,000	$0	584,239	$55,000	$23,370,000	$23,425,000
Retrofit plant with closed-cycle cooling system[4]	$71,320,000	1,029,475	$112,499,000	$1,426,400	45,050	$16,017,000	$3,228,000	$19,245,000

1. Based off a cost for lost generation of $40 per MWh
2. Includes costs as a result of any power penalties associated with the technology
3. Alden assumed a discount rate of 7%, and an amortization rate of 10 years for the capital costs and 30 years for the pilot study and downtime costs
4. Cooling tower costs based on EPRI study (EPRI 2002)

Section 6
CONCLUSIONS

USEPA will require HBGS to meet both the IM&E standards because it withdraws water from the ocean and has a capacity utilization rate greater than 15%. The Team believes the current configuration of HBGS's CWIS will not meet the IM&E standards. Therefore, AES should review technological, operational, and/or restoration measures that have the potential to meet both standards.

Some key findings of our preliminary analysis included:

- The existing offshore intake with a velocity cap may provide credit toward meeting the IM&E standards. The magnitude of the credit cannot be determined until AES samples near shore fish populations and compares the densities of fish with those it observed in the Impingement Mortality and Entrainment Characterization Study (IM&E Study).

- Seven technological or operational options (expanded intakes with fine-mesh Ristroph screens, narrow-slot wedgewire screens, wide-slot wedgewire screens, install coarse-mesh Ristroph in existing intakes, an MIS unit, limited pump operation, and closed-cycle cooling) were considered to have potential for meeting the impingement mortality and/or entrainment reduction standards and deemed practicable from an engineering standpoint. Technologies that solely reduce impingement were evaluated in case AES were to meet the IM standard with a technology while meeting the entrainment standard through operational changes or restoration measures.

- Of the four options that could meet the entrainment reduction standard, Alden estimated annualized costs ranging from $947,000 for installation of narrow-slot wedgewire screens to $23,234,000 for reducing flow during periods of high entrainment.

- Wide-slot wedgewire screens and the Modular Inclined Screen (MIS) have the greatest potential to meet the IM standard. The annualized costs for wide-slot wedgewire screens were $300,000. An MIS could meet the standard at an annualized cost of $2,334,000.

Section 7
REFERENCES

Consolidated Edison Company of New York, Inc. 1994. Evaluation of Underwater Sound to Reduce Impingement at the Arthur Kill Station.

Dunning, D. 1995. Ultrasound Deterrence: Alewife at a Nuclear Generating Station in New York. In T. J. Carlson and A. N. Popper (eds.): Using Sound to Modify Fish Behavior at Power-Production and Water-Control Facilities: A Workshop. Prepared for U.S. Department of Energy and Bonneville Power Administration, DOE/BP-62611-11.

Electric Power Research Institute (EPRI). 1998. Evaluation of Fish Behavioral Barriers. TR-109483.

EPRI. 1999. Fish Protection at Cooling Water Intakes: Status Report. TR-114013.

EPRI. 2002. Cooling System Retrofit Cost Analysis.

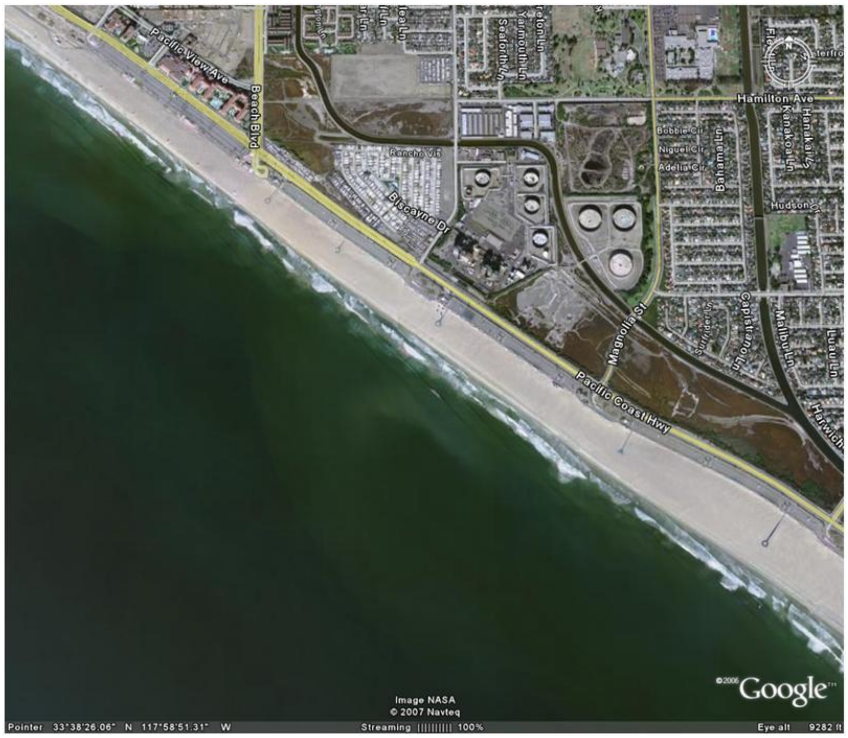
EPRI. 2003. Enhancement Strategies for Mitigating Potential Operational Impacts of Cooling Water Intake Structures: Final Technical Report. Report 1007454. June 2003. Palo Alto, CA. (Michoud)

MBC Applied Environmental Services and Tenera. 2005. AES Huntington Beach L.L.C. Generating Station Entrainment and Impingement Study. Final Report. April 2005.

MBC Applied Environmental Sciences. 2001. National Pollution Discharge Elimination System 2001 receiving Water Monitoring Report AES Huntington Beach L.L.C. Generating Station Orange County, California. Prepared for: AES Huntington Beach L.L.C.

Ploskey, G. R., J. M. Nestler, G. N. Weeks, and C. Schilt. 1995. Evaluation of an Integrated Fish-Protection System. Waterpower 95, Proceedings of the International Conference on Waterpower. American Society of Civil Engineers, New York, NY.

APPENDIX B
DETAILED INVESTIGATION OF
OFFSHORE NARROW-SLOT WEDGEWIRE SCREENS
FOR THE HUNTINGTON BEACH GENERATING STATION



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APPENDIX B
DETAILED INVESTIGATION OF OFFSHORE NARROW-SLOT WEDGEWIRE SCREENS FOR THE HUNTINGTON BEACH GENERATING STATION

1.0 Introduction

A "conventional" wedgewire screen system at the Huntington Beach Generating Station (HBGS) was initially discounted because of several issues. The primary limitation was associated with the air-burst cleaning component. Compressed air is required, and there is a limited distance that air can be transported to provide effective cleaning at the screen. Also, marine biofouling in CWISs at California generating stations is a major concern. This concern is exacerbated when considering narrow-slot wedgewire. In addition, the presence of a "sweeping current" to carry debris and fish from the system needed to be ascertained. Finally, the species of fish and invertebrates impinged and entrained dictates the slot-size required. Additional biological data is now available and Alden has considered some unique offshore wedgewire installation options which are discussed in this report.

2.0 Review of Existing Data

In order to design an effective, offshore wedgewire intake system at HBGS, a detailed understanding of the facility, the surrounding environmental conditions, and the technology is needed.

2.1. Plant Data

HBGS is located on the shore of the Pacific Ocean in the City of Huntington Beach, California (see Figure 2-1). Huntington Beach has four gas/oil steam turbine units (Units 1–4) that use once-through cooling and one jet fuel/natural gas combustion turbine peaking unit (Unit 5) for a total generating capacity of 1,020 MW. The circulating water for Units1-4 is withdrawn through a single offshore intake. The total flow is 794.5 cfs (356,600 gpm).

The existing offshore intake includes a velocity cap and is located approximately 1,500 ft offshore in about 33 ft of water. A rough plan showing the intake is shown on Figure 2-2. The velocity cap has an invert of El. -23.3 ft (all elevations refer to Mean Sea Level, El. 0.0 ft) and is approximately 5 ft above the ocean bottom. The horizontal velocity through the openings is approximately 2.0 ft/sec at full plant flow. The velocity cap is 33 ft by 28 ft and has a 5 ft high opening. Water flows through a 14 ft diameter intake pipe to the onshore screen structure. The pipe and the velocity cap are made out of concrete. Mammal barriers are mounted on risers around the velocity cap to help prevent aquatic mammals, large fish, or turtles from entering the intake. The barrier consists of bars spaced approximately 18 in. on center.

1.1 Waterbody Data

The HBGS CWIS is located within the near-shore zone of the Pacific Ocean (defined as the zone between the shoreline and 1,000 ft from shore or the 30-foot depth contour, whichever is farther). Tides in the region are semi-diurnal, with two high and two low tides of unequal heights during each 25-hour tidal period. Flood tides flow up-coast while ebb tides flow down-coast. The extreme low water level is El. -4.0 ft; while the mean tidal range is approximately 3.7 ft.

A detailed analysis of the currents in the area surrounding the HBGS intake was conducted for the Huntington Beach Shoreline Contamination Investigation Phase III (USGS 2004). The purpose of the USGS 2004 investigation was to determine the costal circulation and transport patterns surrounding the Orange County Sanitation District's (OCSD) wastewater outfall. This study was initiated because it was believed that the OCSD plume resulted in reduced water quality on the Huntington Beach shoreline.

The USGS study looked at a myriad of data over different temporal and spatial scales, including currents, wind, tides, waves, and upwelling to evaluate the transport processes in the region. Multiple fixed-moorings were used to measure the currents, waves, temperature, and conductivity. The location of these moorings is provided on Figure 2-3 and Figure 2-4. A diagram of a typical mooring is provided as an insert in Figure 2-3.

The USGS report indicated the along-shore currents (parallel to the shoreline) are the dominant currents in the near shore region near the HBGS intake. The currents are typically down-coast in the near-shore regions but occasionally switch to an up-coast direction. In general, these currents are not wind-driven; but, over short periods of time the wind can result in fluctuations in the near-shore flow. Typically, the magnitude of these currents ranges from about 0.3 ft/sec to 0.7 ft/sec. This should be adequate to provide the necessary "sweeping flow" to remove debris. To assure maximum efficacy, the number of screens could be doubled. However, Alden has not costed this option. Prior to proposing this alternative, Alden would suggest a site-specific pilot study of a T-screen. A plot of the along-shore currents is provided on Figure 2-5. Based on the depth and location of the velocity cap, Alden selected data collected from Location AES3 to represent conditions that can be expected at the HBGS intake. Cross-shelf currents, perpendicular to the shore, are also present near the HBGS intake, but they are about an order-of-magnitude less than the along-shore currents. Velocity and directions of both the along-shore and cross-shore currents offshore are shown on Figure 2-6.

1.2 Biological Data

Entrainment and source water sampling began in September 2003. Field studies were completed in late-August 2004. Thirty-two entrainment surveys and twelve combined entrainment/source water surveys were performed from September 2003 through August 2004. Fish larvae from 57 different taxonomic groups were collected during the entrainment surveys. Unidentifiable CIQ gobies were the most abundant fishes in the entrainment samples, contributing 37% to the total. This group is comprised of one or more of the following near-shore gobies that cannot be distinguished during early larval stages: arrow goby (*Clevelandia ios*), cheekspot goby (*Ilypnus gilberti*), and shadow goby (*Quietula y-cauda*). Other abundant larval fish taxa included:

northern anchovy (*Engraulis mordax*; 18%), spotfin croaker (*Roncador stearnsii*; 14%), white croaker (*Genyonemus lineatus*; 7%), and queenfish (*Seriphus politus*; 5%). Seventy-nine larval fish taxa were collected during the source water surveys. . Along with CIQ gobies, five other taxa comprised 80% of the total fishes collected from the source water samples: northern anchovy (18%), queenfish (10%), white croaker (9%), unidentified croakers (4%), and combtooth blennies (*Hypsoblennius* spp.; 3%) (MBC and Tenera, 2007).

1.3 Wedgewire Screen Data

Wedgewire installations are typically located at, or near, the shoreline to be in close proximity to their air-burst debris clearing system. Typically, a maximum distance of 200 ft is recommended. At greater distances, the head loss in the air pipes becomes very large, reducing air flow and velocity which, in turn, reduces the impulse of air needed at the screen to dislodge debris. This head loss can be overcome with a significant increase in the pipe diameter; however, the resulting air pipes can approach the size of the intake pipes. It is known that marine biofouling is substantial in the CWISs of California generating stations. Alden contacted screen vendors regarding available slot sizes, cleaning methods, and anti-fouling materials.

The smallest slot size currently available for use at circulating water intakes is 0.5 mm. This slot size is sufficiently narrow to prevent the entrainment of all but the smallest eggs and larvae. Smaller slot sizes (0.2 mm) can be manufactured; however, screens installed at CWISs with this slot size have never been tested. The vendor also questions whether the air-burst backwash system would function effectively with such small slot openings. It is anticipated that biofouling problems would increase with the narrower slot size.

Cylindrical wedgewire screens are available in sizes ranging from 12 to 120 in. in diameter. To reduce the number and therefore the cost of the screens, Alden assumed that AES could use T-120 (120 in. diameter) screens at HBGS. The vendor has stated that this size screen has been designed but has yet to be manufactured.

Alden performed a detailed review of the literature concerning the deployment of wedgewire screens in marine environments. Based on this review, Alden found two studies that are relevant to HBGS.

A study was conducted at the Redondo Beach Generating Station to assess fouling and clogging of fine-mesh screens (McGroddy et.al. 1981). This study was conducted in two parts; the first part looked at debris clogging and the second investigated the propensity of different materials to fouling.

The debris study was conducted in a small test tank using an 18 in. diameter wedgewire screen. The slot size tested was not reported. Based on the flow characteristics of this screen, Alden estimated that it had 1.0 mm slot openings. Flow for this tank was provided from behind the existing traveling screens. An air bubbler was used to provide a cross-current of between 0.2 and 0.3 ft/sec. Debris obtained from the intake waters was added and the head-loss measured. The results of this study indicated that the screens are prone to debris clogging and that multiple air-bursts were needed to completely clean the screens. The cleaning was most effective when the screen was less than 50% blocked; in actual application, the screens would need to be air-burst daily or more frequently during high debris loading periods. Additionally, the researchers noted that re-impingement of debris on the screens occurred at low cross-screen velocities.

The second stage of the McGroddy et al. (1981) study compared the rate of biofouling with several potential screening materials. Small material coupons were placed on the intakes for several weeks. The materials tested included carbon steel, epoxy-coated steel, copper, and stainless steel. The mesh size of these materials varied from 0.7 mm to 2.0 mm. Some of these coupons were also subject to a heat treatment to determine the effectiveness of the heat treatment on controlling biofouling.

The results showed that stainless steel was the least prone to bio-fouling of all the materials tested. However, the stainless steel coupons all had larger mesh openings than the other screen types. In addition, there appeared to be inconsistencies between the percent covered and headloss through identical meshes. The results of the heat treatment tests indicated that the heat treatment killed attached organisms but did not remove their shells; the screens were quickly re-colonized.

The second study was conducted in Galveston Bay, Texas (Wiersema et al. 1979). This study compared the rates of fouling for several small wedgewire screens. All the test screens were 9.5 in. in diameter with 2.0 mm slot openings. The only difference between the screens was the material they were made of; one was stainless steel, two were copper-nickel alloys (CDA 706 and CDA 715), and one was a silicon-bronze-manganese alloy (CDA 655). These screens were mounted to a test apparatus that contained pumps and flow meters to measure the flow through each screen during the test period. The total duration of the test was 145 days.

The results indicate that the copper alloys significantly reduced biofouling of the screens. At the conclusion of the test period, the copper alloy screens remained at least 50% open. The stainless steel screen fouled very quickly and was completely clogged after 2 weeks. In general, the progression of biofouling agents was similar for all the screens. First, a slime layer formed over the screens which trapped sediments and provided a base for further colonization. After about 4 weeks, hydroids began to colonize the screens. The hydroids were the dominant bio-fouling organism until tube-building amphipods appeared. The amphipods were only able to establish themselves on the portions of the screen with significant hydroid cover. This is assumed to be a result of the hydroids providing a buffer between the screens and the amphipods. Throughout the test period, there was a small amount of colonization by bryozoans and loosely attached barnacles.

While this study did not include an air backwash, the researchers postulated that an air-burst could be used to break up the slime layer thus retarding the growth of other bio-fouling agents. To date, there have been no studies to determine if an air backwash would effectively remove the slime layer.

1.4 Offshore Design Criteria

Due to site-specific constraints at the HBGS, substantial offshore structures would be needed to maintain a wedgewire installation. Alden has assumed that any offshore structure would need to be designed similar to a shallow water offshore platform (e.g. petroleum drilling platform). A vital part of any offshore design would be a soil investigation, which Alden has not conducted. Rather, Alden has assumed that the substrate would be suitable for anchoring structures. Pilings would need to be designed to withstand the forces and moments resulting from wind and waves. Since the offshore structure is to house a work deck for compressors and machinery, the deck height was designed to be 5 ft above the 100-year wave height (API 1993). In addition to these general considerations, any structures at HBGS would need to be designed to handle the spectral acceleration associated with earthquakes.

Figure 2-1Aerial Photograph of Huntington Beach (Google)

Figure 2-2 HBGS Circulating Water System

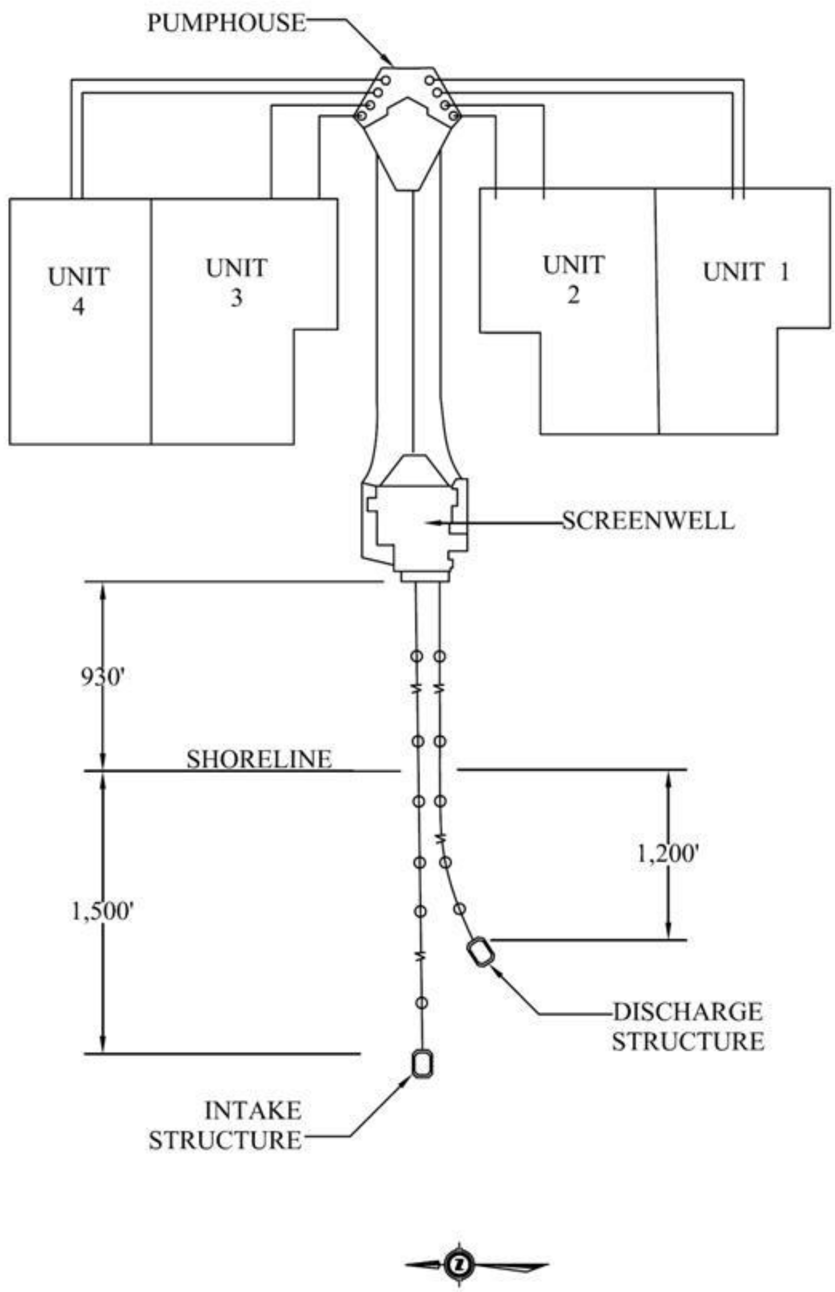


Figure 2-3 Map of the region, mooring sites, surf-zone sampling stations, and instrumentations of a typical mooring (inset). (Figure 1-2 USGS 2004)

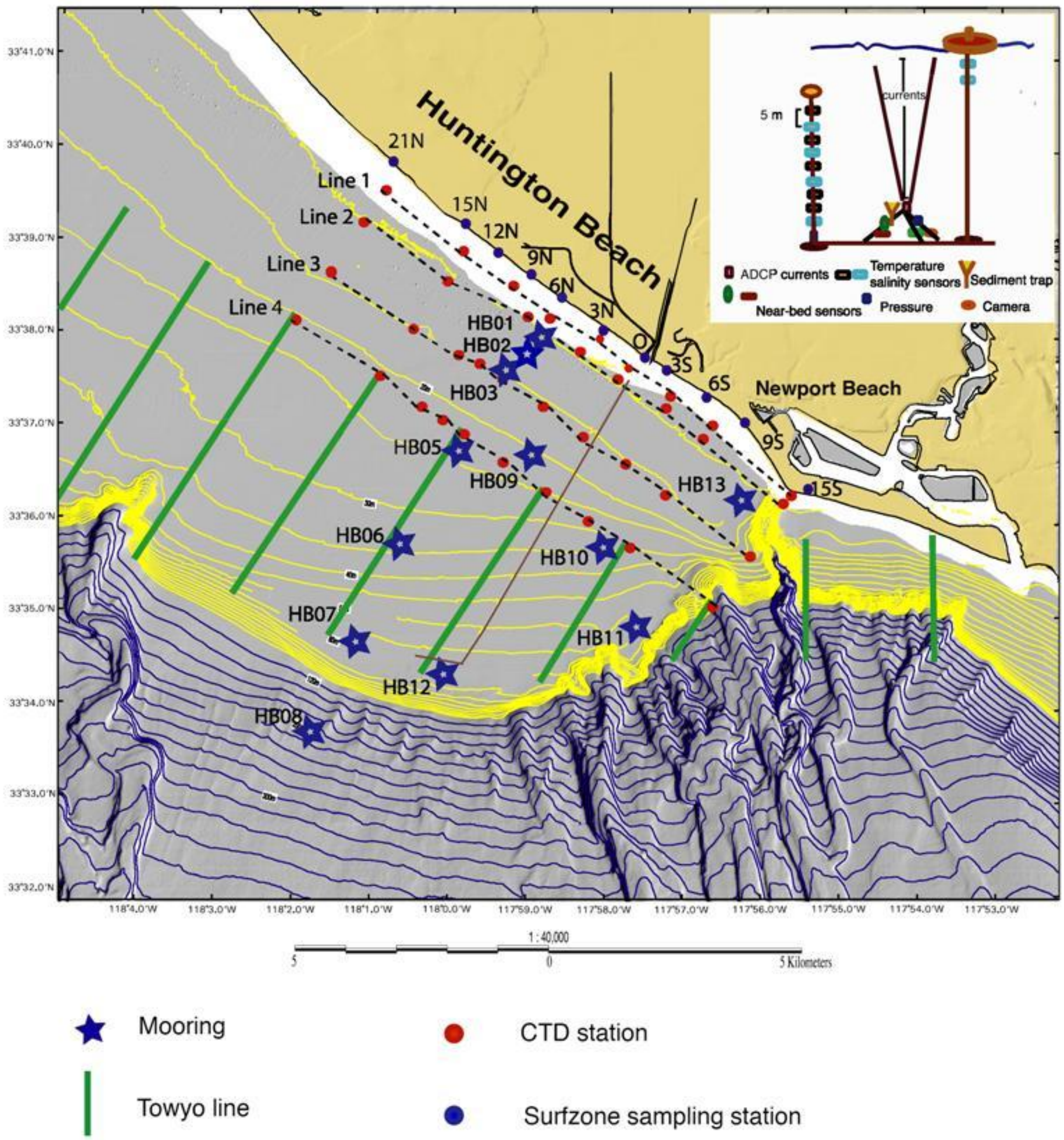


Figure 2-4 Location of near-shore moorings (red squares), beach sampling (blue squares), power plant intake (blue), and discharge (red), Talbert Marsh, and Santa Ana River. (Figure 2-9 USGS 2004)

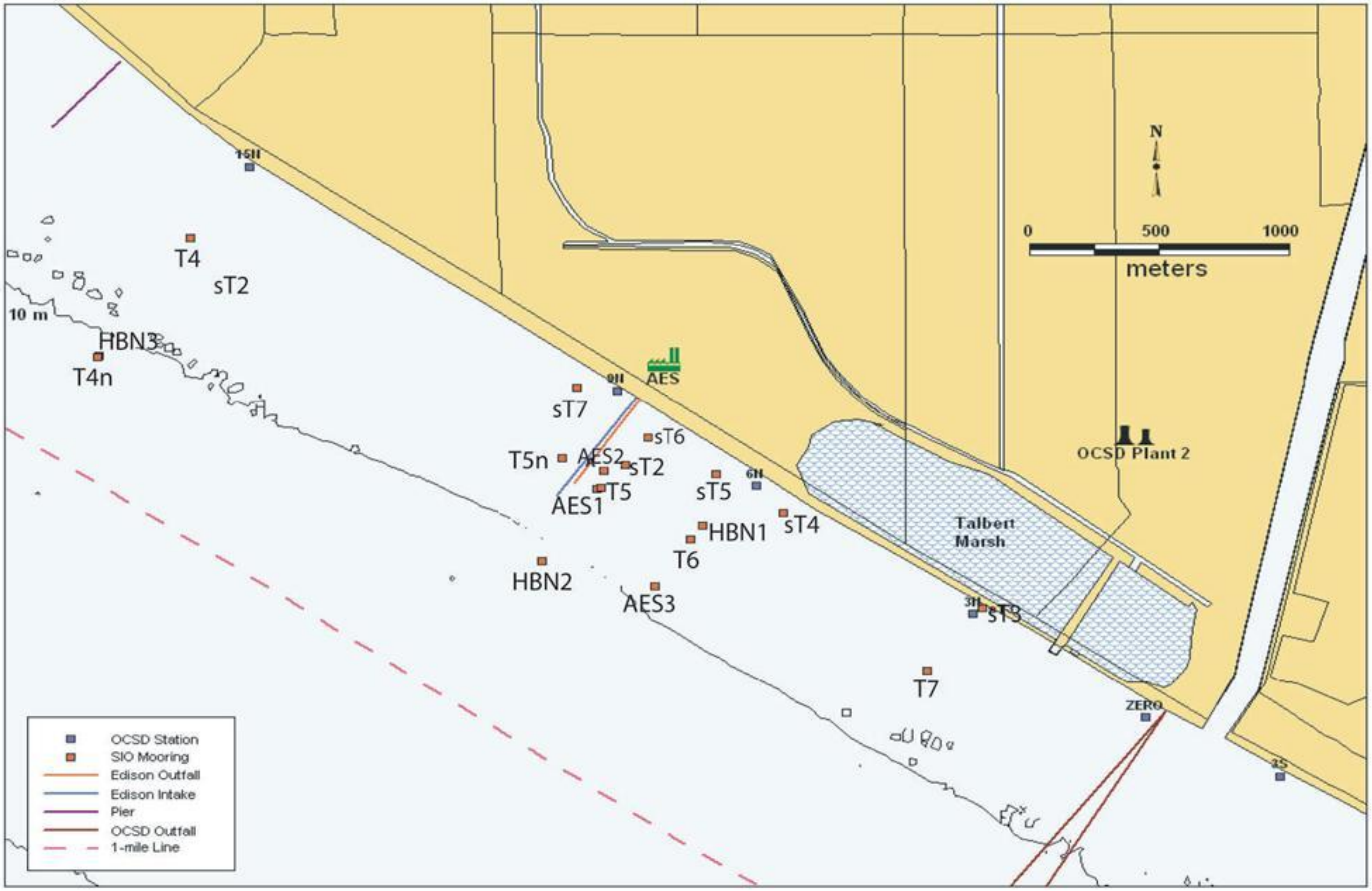


Figure 2-5 40-HLP mean along-shore currents, including the full depth of the slope mooring HB08. (Figure 4-5 USGS 2004)

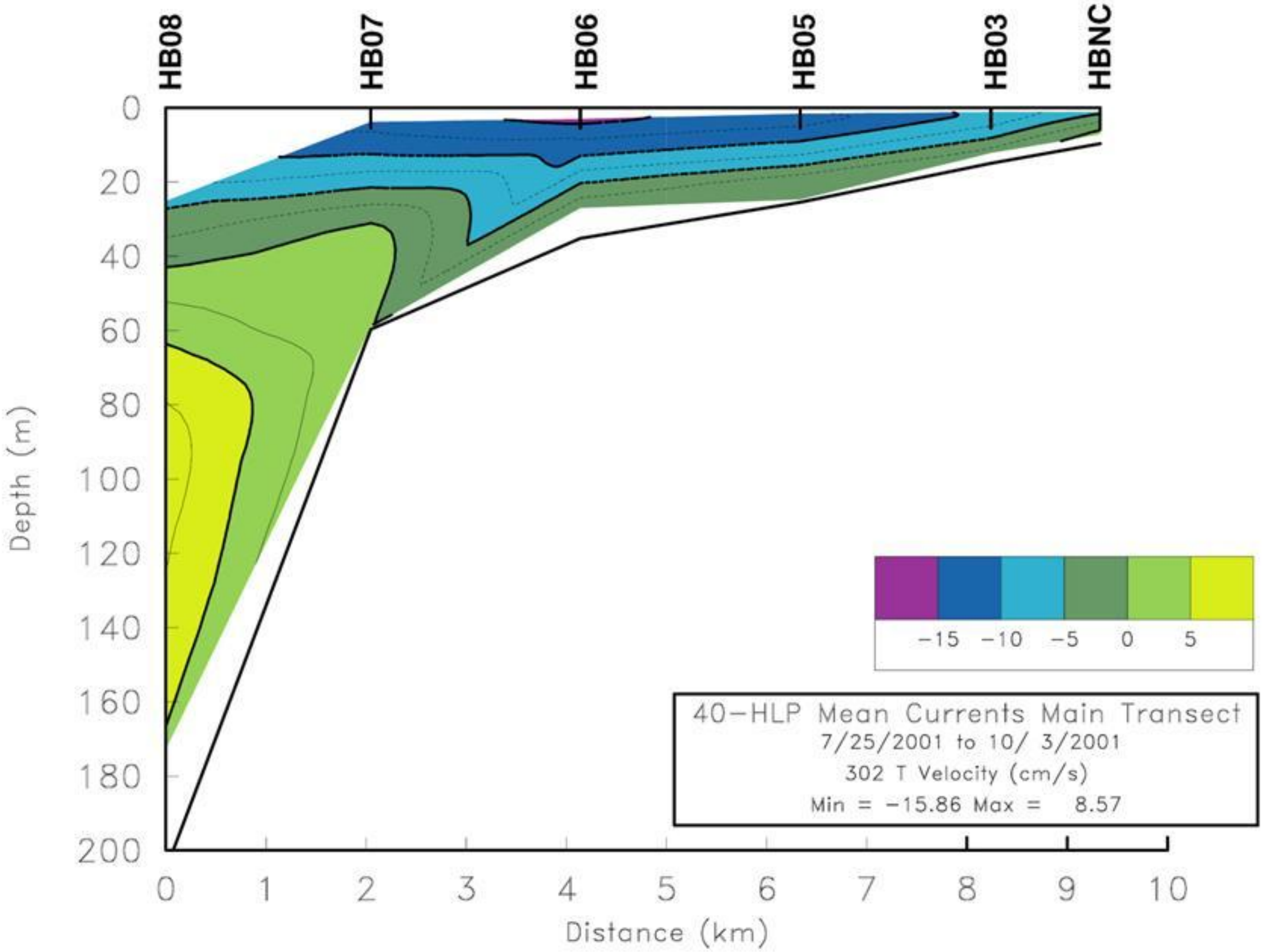
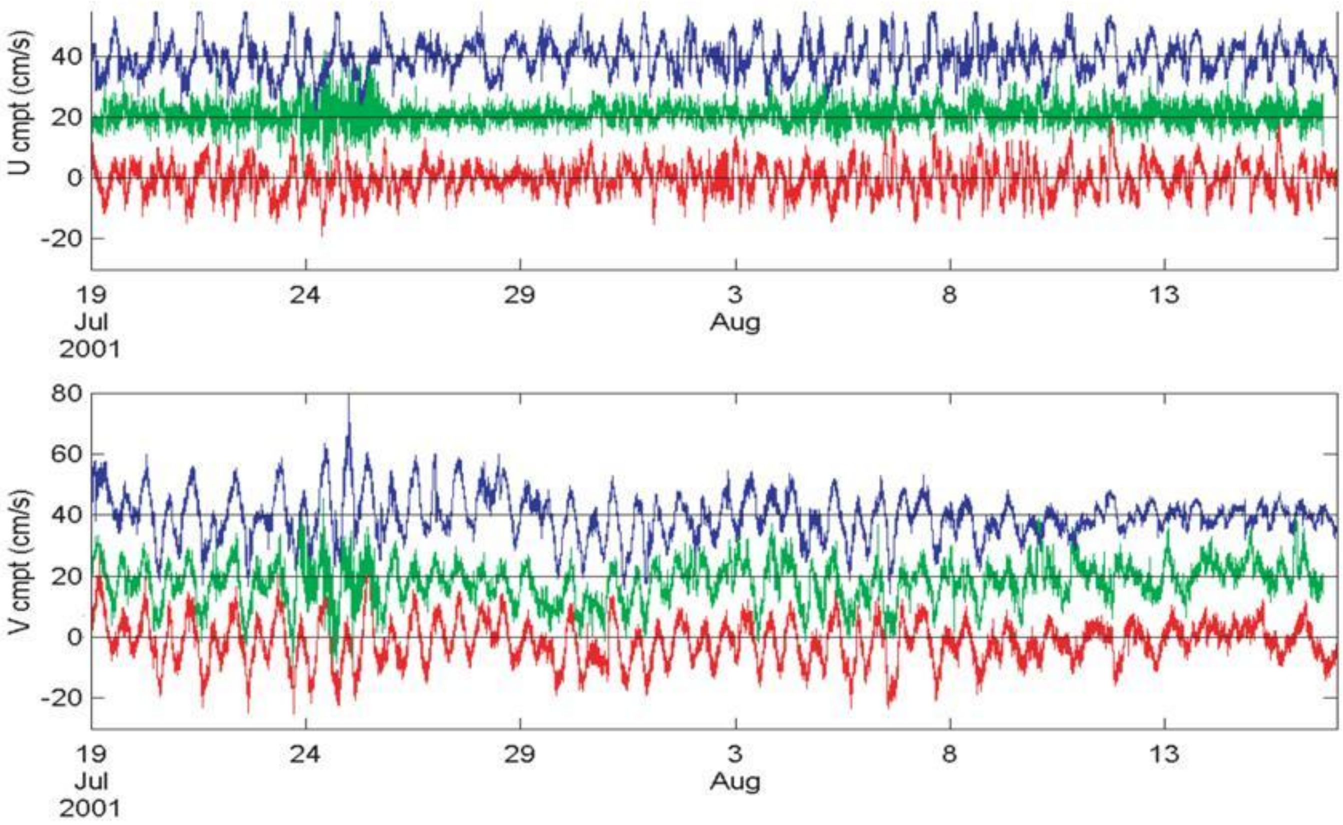


Figure 2-6 Near-bottom cross-shore velocities (U) (upper panel) and along-shore velocities (V) (lower panel) at HB03 (15 m, blue), HBN2 (10 m, red), and AES2 (6.5 m, green). Plots are offset 20 cm/s to separate lines–a zero line is shown for each trace. Note the decrease in both energy and coherence of cross-shore flows in the near-shore, in contrast to strong along-shore flows. (Figure 9-6 USGS 2004)



3.0 Preliminary Wedgewire Design

Based on the site-specific information and the literature review, Alden was able to develop several conceptual wedgewire designs. The following considerations were used as the basis for all of the conceptual designs considered for HBGS.

- Alternatives would be designed to handle the full plant flow of 794.5 cfs (356,600 gpm)
- Alternatives would be designed based on a mean low water elevation 0.0 ft
- All wedgewire screens would be designed with 0.5 mm slot openings to reduce both IM&E
- All wedgewire screens would be made out of "Z-alloy" a 70-30 copper nickel alloy (CDA 715) to reduce biofouling
- All wedgewire screens would be equipped with an air backwash system.
- Due to the magnitude of the offshore currents (0.3ft/sec to 0.7 ft/sec) all the wedgewire screen designs would incorporate a manual cleaning system
- The top of the offshore structure would be about 5 ft above the 100-year wave height. (Alden assumed 30 ft above mean low water).
- Any offshore structures would be built to withstand spectral acceleration resulting from an earthquake.

Using this criteria Alden selected three possible offshore wedgewire arrangements. Each of these potential designs uses identical screens and has very similar air-burst systems. The three alternatives are:

- Tee layout,
- Pod layout, and
- Pipe-mount layout.

All three alternative designs incorporate twenty, T-120 (10 ft diameter) screens with 0.5 mm slot openings. Only fourteen screens are needed to screen the HBGS flow but six additional screens were added to create a margin of safety in the designs. Additional screens reduce through-slot velocities which should reduce the rate of debris loading and improve the efficiency of the air backwash system. This design also allows one-quarter of the screens to be out of service for cleaning at any one time without increasing the through-slot velocity above 0.5 ft/sec.

T-120 screens are 10 ft in diameter and T-shaped, with an overall length of approximately 33 ft. These screens were selected because they are the largest screens currently available. Smaller screens could be used but fewer larger screens are typically less expensive than smaller screens. The T-120 screens have two screen sections, each about 10 ft long, located on either side of a 13-ft long solid T-section outlet pipe. The outlet pipe of each screen is about 7 ft in diameter and would be located in the middle of the T-section. A typical section of a wedgewire screen is shown on Figure 3-1.

Routine cleaning of the screens for all three options would be conducted with an automated air-burst system. Due to head loss associated with pumping air over long distances, the air compressors and tanks would need to be located near the screens. To accommodate this equipment, an offshore storm-proof shelter was designed. For design purposes, Alden assumed that four sets of compressors and tanks would be needed, one for every five screens. Each compressor and tank set would require a 100 hp compressor coupled with an 11,500 gallon air receiver. This design allows four screens to be air-burst every half hour; or all 20 screens in 2.5 hours. Assuming that the screens need to be air-burst four times a day this would require 1,095,000 kWh per year. To provide this power a transmission line would need to be run from HBGS to the intake platform(s).

As the effectiveness of the air-burst at HBGS is not known, each alternative would need to incorporate a secondary cleaning system. For the options utilizing a fixed platform, this cleaning would be conducted by lifting the screens out of the water and manually removing attached macrofouling organisms. For the pipe-mount system, the cleaning would need to be conducted by divers. For costing purposes, Alden estimated the cleaning would be required four times a year.

The velocity cap, trash racks, and traveling water screens would no longer be needed in any of the three screen designs, however AES may want to keep the trash rack and traveling screens in place and operational to provide a backup screening system in the event of extreme fouling of the wedgewire screens.

3.1. Layout 1 – "Tee"

Layout 1 would be constructed similar to a shallow offshore oil platform with driven piles and elevated work deck. The 20 wedgewire screens would be arranged in four rows each with 5 screens. These screens would connect to an 8 ft diameter intake pipe mounted to the support superstructure. The center line of the pipe would be located about 15 ft above the ocean floor. Each of these pipes would be 230 ft long and would connect to a pipe manifold placed over the existing intake tunnel. To allow the pipes to be isolated for cleaning and provide an emergency by-pass during periods of extreme fouling, isolation gates would be located at each end. A slide gate would also be located at the connection between the screens and intake pipe to allow the screens to be lifted for cleaning. A solid panel would be incorporated into this gate to prevent short-circuiting of the screens. A plan of this alternative is provided on Figure 3-2 . A sectional view across this layout is shown on Figure 3-3.

All the piping for the airburst system would run along a top deck which would allow all the valves and mechanical components to be located above the water surface. In addition to the air-burst piping, the work deck would include a gantry crane to lift the screens for manual cleaning. Once the screens are lifted above the water surface, workers would be able to use pressure washes and brushes to clean the screens. Alden estimated about four hours per screen for this process. During the manual cleanings, the screens should also be inspected for any mechanical/structural problems. To inspect the pipes and support structure, Alden estimated an annual inspection by divers would be needed. In total, Alden estimated that operation and maintenance on the screens would require about 1,774 MWh and 2,390 man-hours. This estimate assumes that the screens would require daily air-bursts and would need to be removed for cleaning every other week. With this layout a crane could also be used to load and unload any screens that needed to be returned to shore for repair or replacement.

The "Tee" alternative has the benefit of the offshore platform which would allow the screens to be maintained during most weather conditions. This layout would also allow most of the construction to be conducted above water, which would reduce the costs and decrease the construction duration. One disadvantage is the platform would result in significant visual impacts to the Huntington Beach area. With a total width of about 650 ft and with 30 ft above mean low water, the offshore platform would be very visible from shore.

3.2. Layout 2 – "Pods"

The "pod" layout as shown on Figure 3-4 is very similar to layout 1 except that the 20 screens would be divided among four small pods; not installed in rows. These pods would be pentagon-shaped with 90 ft long sides. They would be located about 50 ft from the center platform and the air-burst equipment.

The wedgewire screens on each pod would be connected to a single 8 ft diameter header pipe which would connect to the existing intake pipe. As with the "Tee" design, each of the header pipes would have an isolation gate near the intake pipe and an emergency bypass gate at the other end. A rotating derrick located in the center of each pod would be used to lift the screens for maintenance.

Operation and maintenance with this alternative would be identical to Layout 1. With this layout however, the screen lifting derrick would not be able to aid in loading and unloading screens from barges. A section of one of the pods is shown on Figure 3-5.

A benefit of this option is that it is only 370 ft wide and would have a smaller profile when seen from shore.

3.3. Layout 3 – "Pipe-mount"

In this option, the 20 screens would be mounted on four header pipes buried in the sea floor that would be connected to a pipe manifold over the existing intake pipe. Each header pipe would be 8 ft in diameter and would service 5 screens. The screens would be mounted directly to these pipes. A plan and section of this layout is provided on Figure 3-6 and Figure 3-7, respectively. To allow water into the intake during extreme fouling events, the pipe manifold would include an emergency bypass gate.

The storm proof shelter and air-burst equipment would be located above the central manifold. To allow the air control valves to be located within the storm proof shelter, each screen would need to be connected to a separate air line, requiring significantly more pipe than the other two options. As the screen and air-burst pipe would be mounted directly to the header pipes they could not be removed for easy cleaning. If the screens became heavily fouled and the air-burst could not remove the fouling, then divers would be required to clean the screens. This cleaning is expected to take about four hours per screen. During extreme weather divers may not be able to work, which could result in clogging of the screens. The power to operate the air backwash system is the same as for the other two options. However, 4,480 additional man-hours have been included for diver support.

The Pipe-mount option would require less materials and construction time and have less of a visual impact than the other two alternatives. However, there are several drawbacks with this option when compared to the other two options. The screens would be fixed to the header pipes so they could not be easily removed for cleaning. This could limit the level and timing of the cleanings. Additionally, the air-burst valves would be more prone to failure as they would be submerged and would not be inspected as frequently as the air valves located on a work deck.

Figure 3-1 General Cylindrical Wedgewire - Section

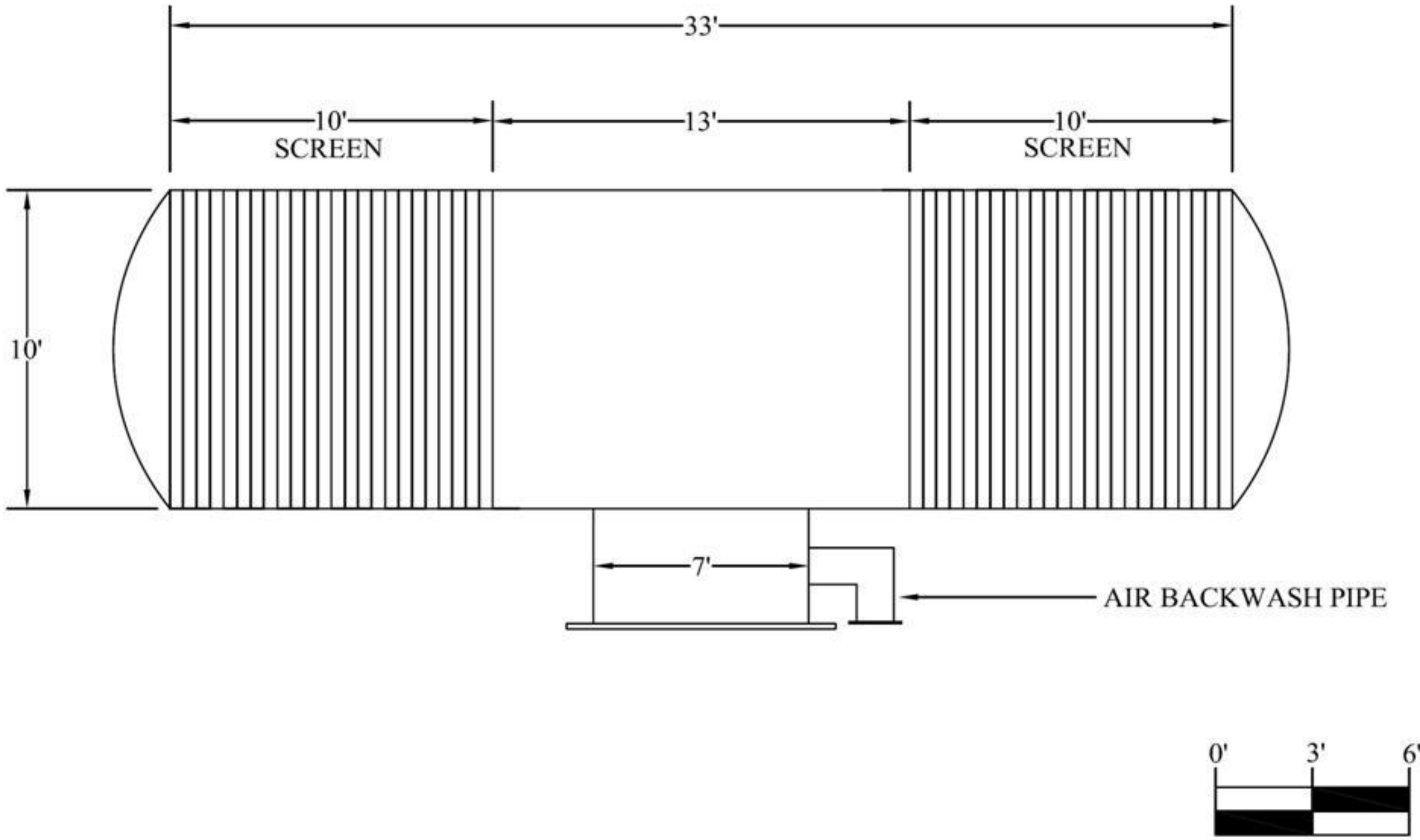


Figure 3-2 Wedgewire Layout 1 "Tee"- Plan

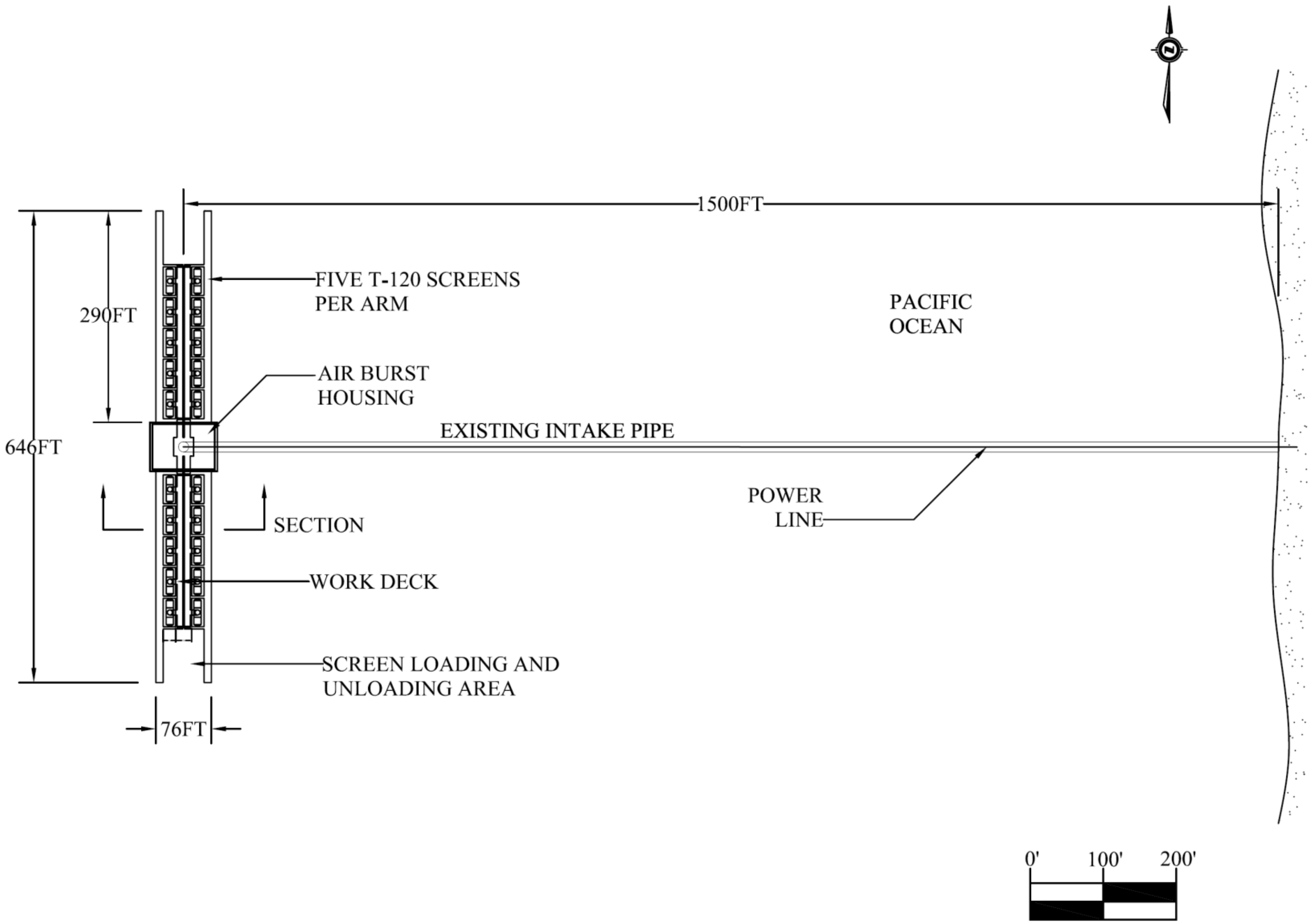


Figure 3-3 Wedgewire Layout 1 "Tee"- Section

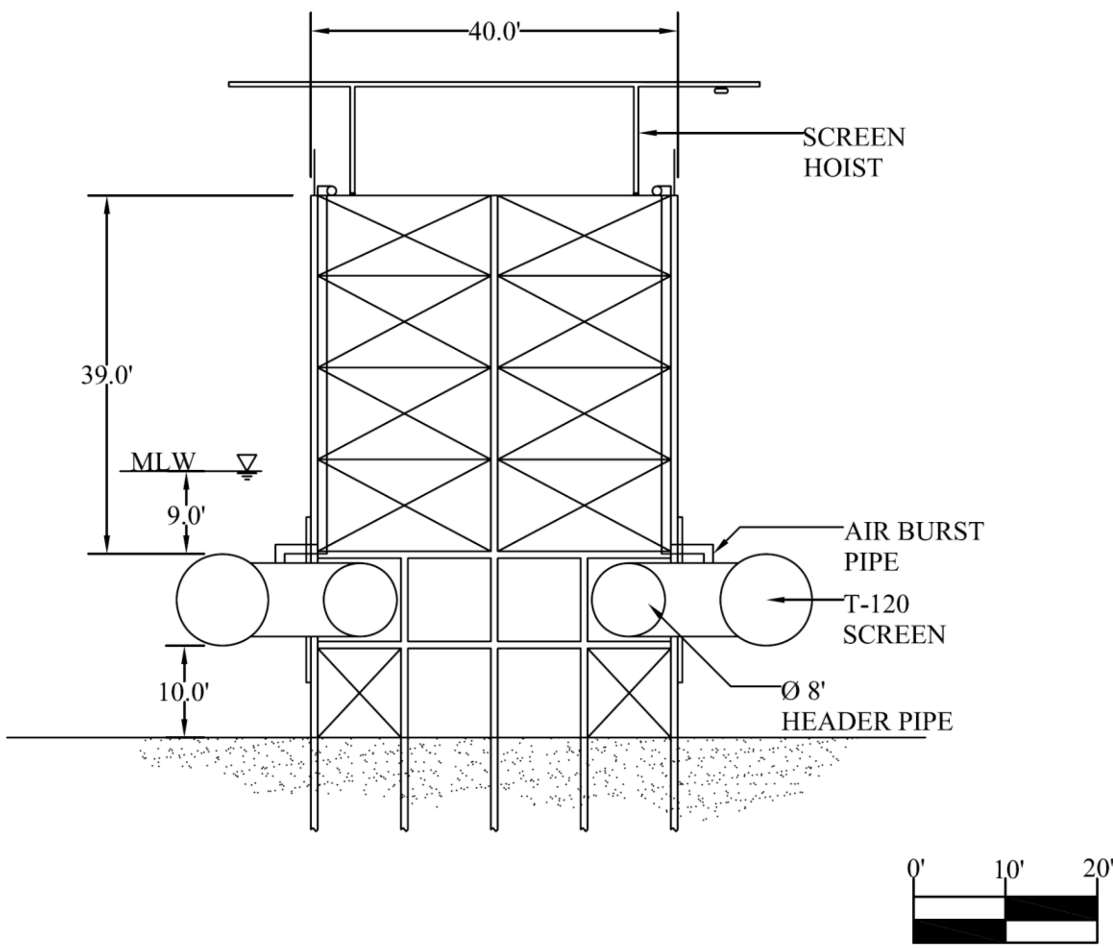


Figure 3-4 Wedgewire Layout 2 "Pods" - Plan

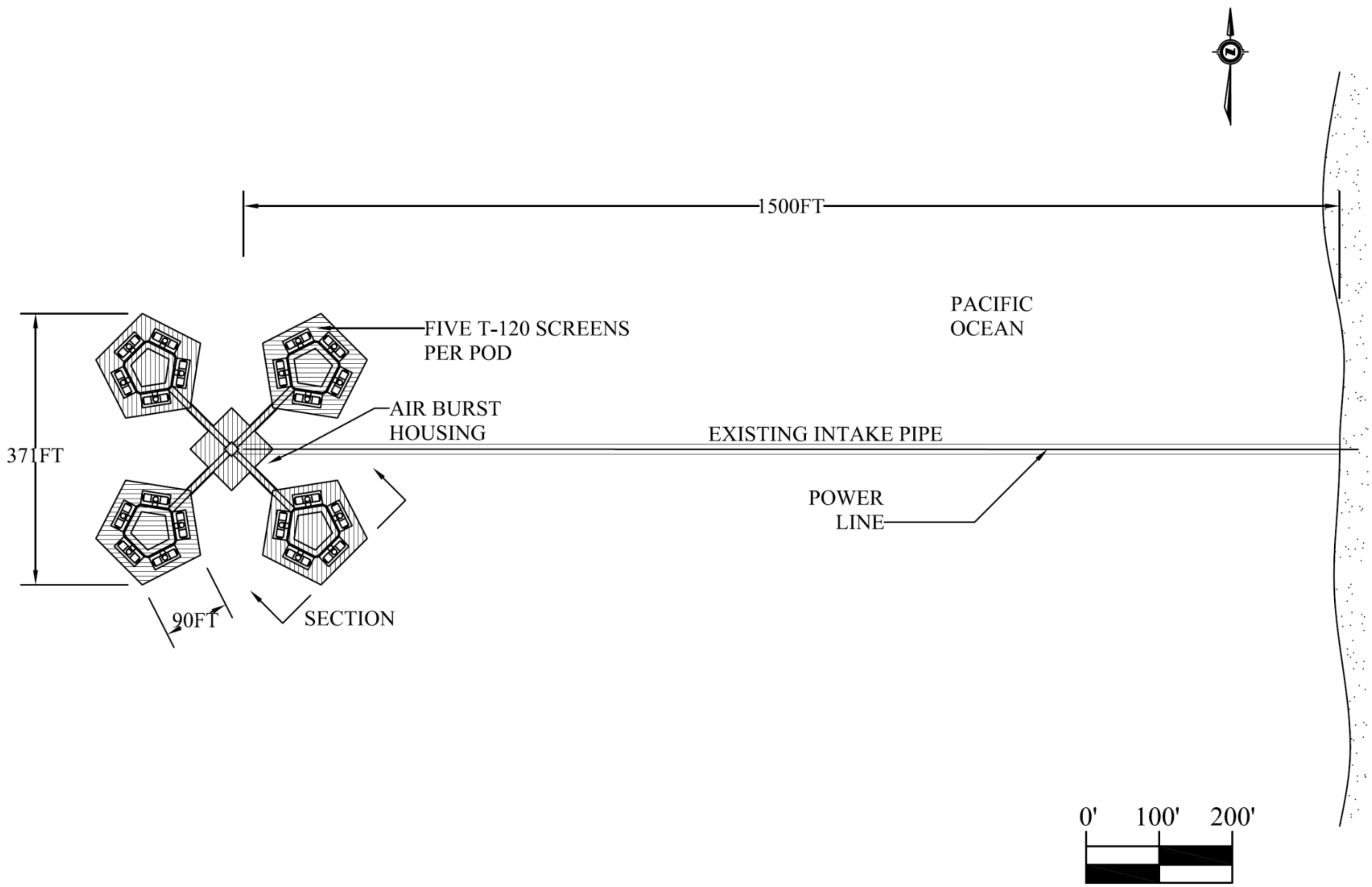


Figure 3-5 Wedgewire Layout 2 "Pods" - Section

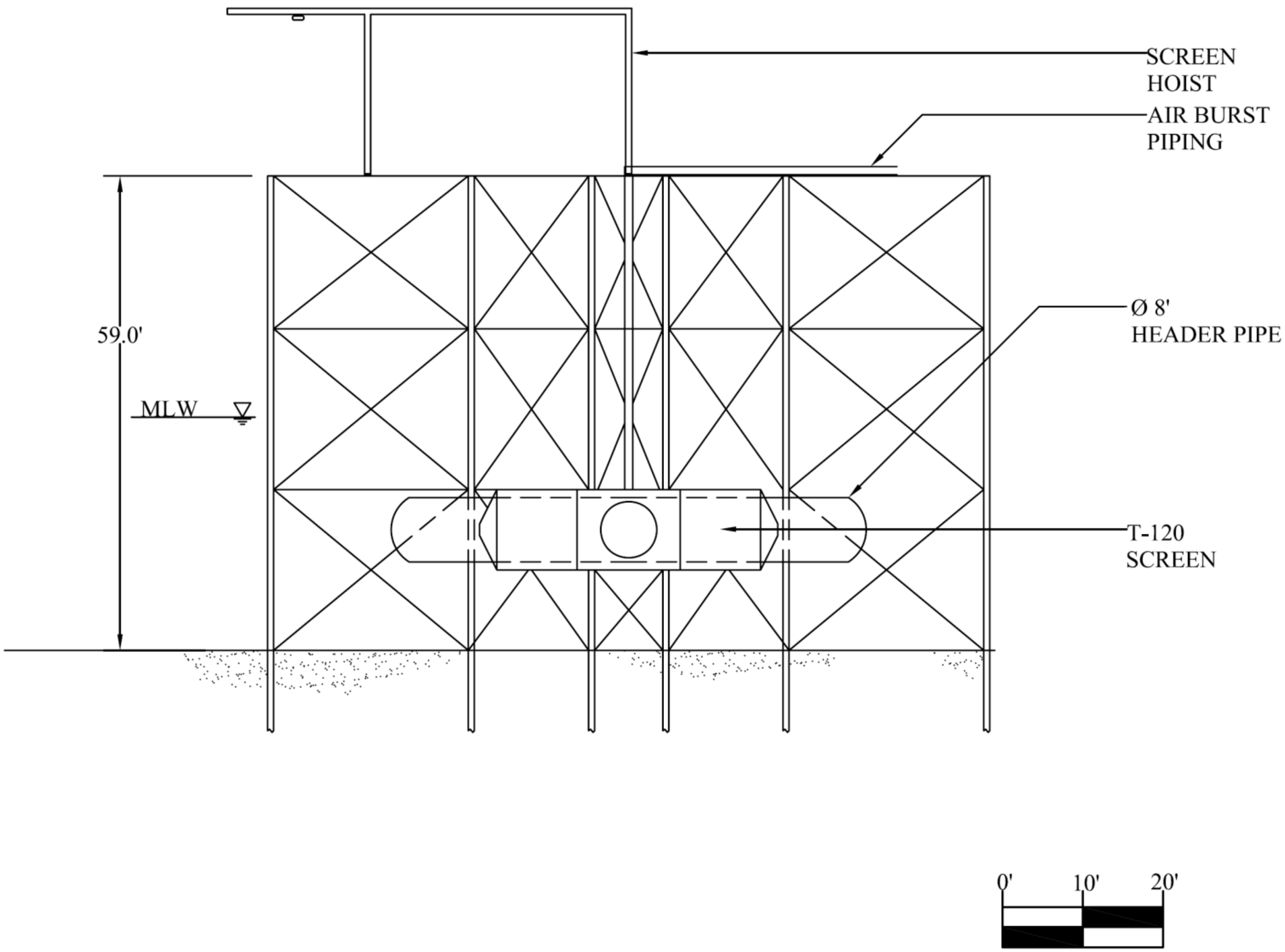


Figure 3-6 Wedgewire Layout 3 "Pipe-mount"- Plan

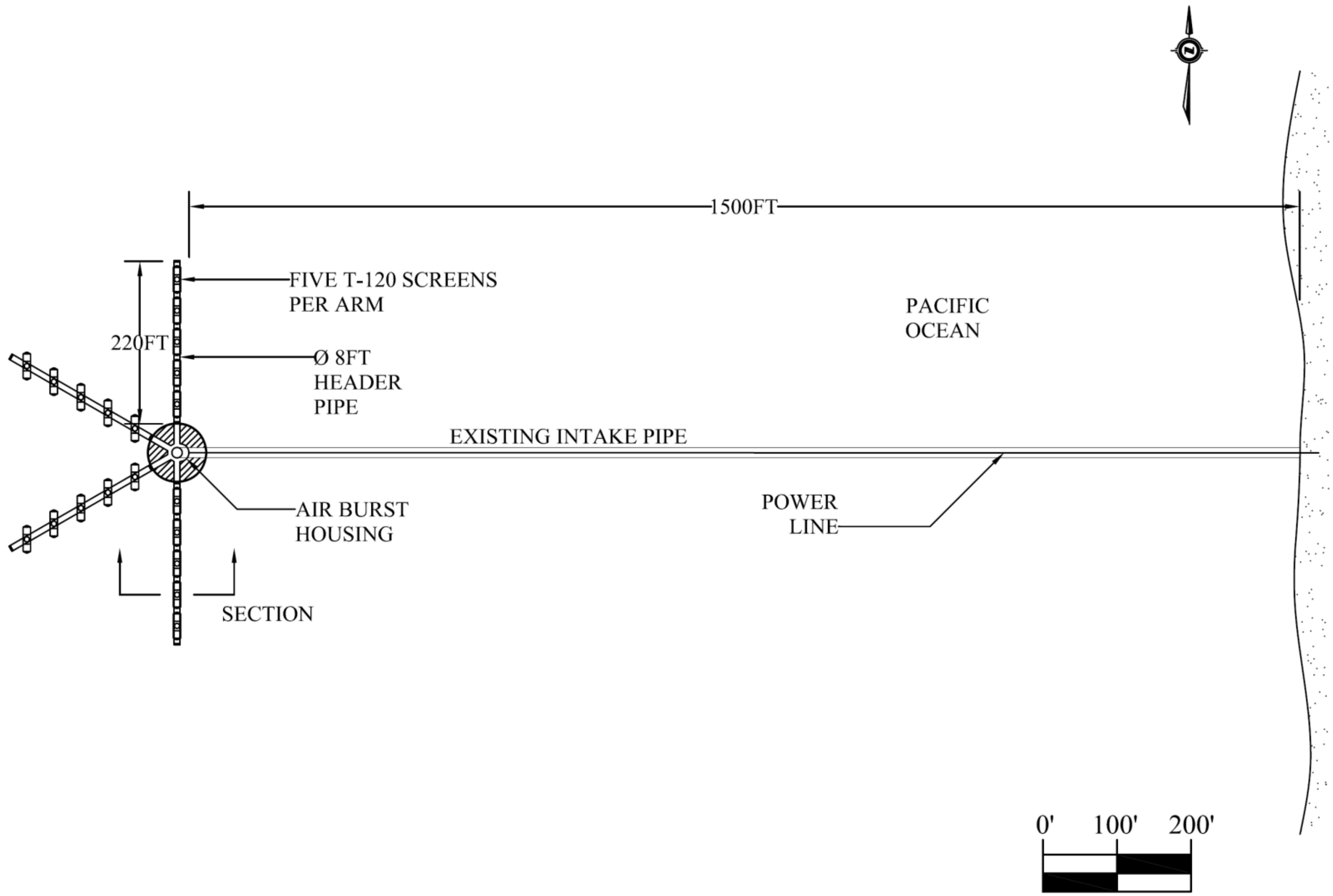
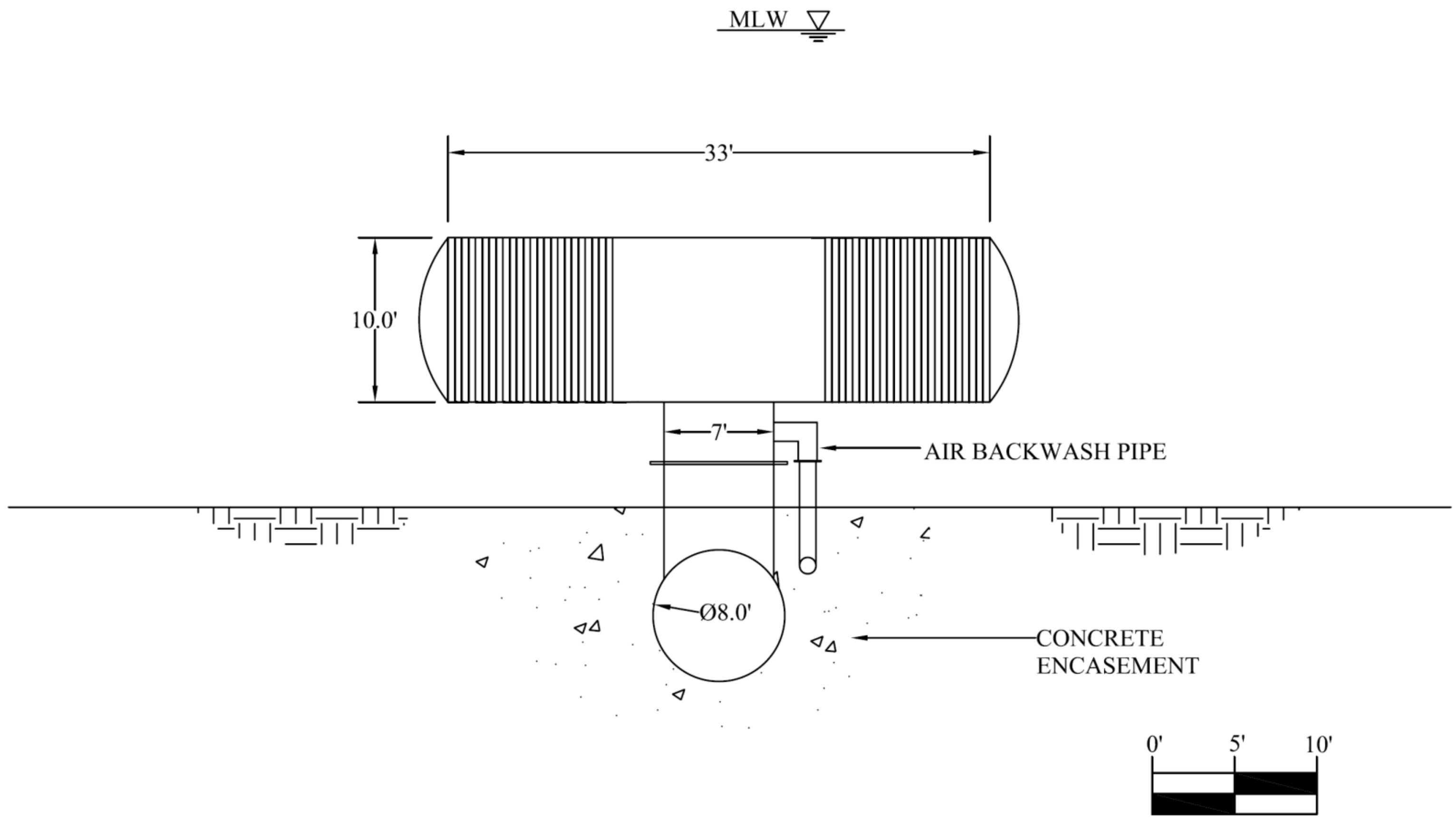


Figure 3-7 Wedgewire Layout 3 “Pipe-mount”- Section



4.0 Appraisal-level Cost Summary

The costs in this evaluation were estimated using Alden's cost database of alternatives for more than 35 plants. These costs were adjusted for identifiable differences in project sizes and operations. Due to their generalized nature, these appraisal level cost estimates are intended to identify the relative cost differences between selected alternatives. The actual cost of each of these layouts may be several times greater than the costs presented here as these costs do not take into consideration site-specific environmental factors that could significantly increase the costs. A more detailed cost estimate for the selected layout based site specific factors and detailed quantities will be included with the final design.

The appraisal-level estimate of the capital cost and associated annual operation and maintenance (O&M) for each of the three alternatives discussed above are show in Table 4-1. The O&M costs presented are total annual O&M costs and do not take into consideration the reduction in O&M associated with no longer operating the traveling water screens. Alden has calculated annualized costs using the EPA methodology consistent with the way in which EPA presented costs in Appendix A of the Rule for Phase II facilities. These annualized costs also provide a more realistic estimate of what a technology will actually cost the facility.

These costs do not include costs associated with testing or permits that may be require for any offshore wedgewire installation.

Table 4-1 Estimated Costs for Offshore Wedgewire Alternatives

Alternatives	Total Capital Costs	Annual Operation and Maintenance Costs	Total Annualized Costs
Layout 1 "Tee"	$14,291,000	$369,000	$2,404,000
Layout 2 "Pods"	$19,128,000	$369,000	$3,092,000
Layout 3 "Pipe mounted"	$12,439,000	$783,000	$2,554,000

5.0 Summary and Conclusions

Based on Alden's review of the available data pertaining to site characteristics wedgewire screens may be considered a feasible option at HBGS. Three layouts have potential for application at HBGS. The table below provides the advantages and disadvantages of the three layouts.

Layout	Total Annualized Cost	Advantages	Disadvantages
Layout 1 "Tee"	$2,404,000	Manual cleaning can be done in-the-dry Air burst cleaning system for regular cleanings Easy screen replacement	Large visual impact
Layout 2 "Pods"	$3,092,000	Manual cleaning can be done in-the-dry Air burst cleaning system for regular cleanings	Medium visual impact
Layout 3 "Pipe"	$2,554,000	Divers needed to clean screens	Lower visual impact

If AES is to move forward with a wedgewire alternative additional studies would be needed since a wedgewire installation of this type and size in an offshore marine environment has never been constructed.

Based on the species and life stages collected at HBGS, a wedgewire screen with 0.5 mm slot size will not exclude all entrainable organisms. Alden conducted an assessment of larval exclusion based on head capsule depth. Early larval gobies, blennies, northern anchovy, and croaker will not be excluded. These species and life stages are dominant in entrainment. Site-specific factors may result in an increase in exclusion beyond what can be derived through a paper study. To determine the actual exclusion efficiency, AES may want to consider a pilot study near the HBGS intake.

A second biological uncertainty is the type and rate of biofouling that can be expected. Alden understands that a field evaluation of wedgewire screens is currently being conducted in California. This study should provide an indication of the biofouling components of the screen material. If these results are not available, Alden would recommend a biofouling assessment. This study would be similar to the 1979 Galveston Bay study (Wiersema et al. 1979). This study would determine which materials are less prone to biofouling at HBGS as well as the rate of fouling and the effectiveness of an air burst system.

Several engineering studies would be needed prior to determining the final lay-out and costs. The currents in the vicinity of Huntington Beach are well known, but no information was available regarding the sea floor geology. A detailed survey of the sea floor geology would be needed to determine the composition and loading strength of the substrate. If the substrate contains either very poor soils or is composed of bedrock, the costs to anchor any offshore structure could increase over 10 times.

Due to the number and size of wedgewire screens needed, Alden recommends that a hydraulic study (numeric and/or physical) be conducted to ensure equal flow through the wedgewire screens. Cost for these studies have not been included but could range from about $20,000 for a simple two-dimensional numeric study up to about $200,000 for both three-dimensional numeric and physical models.

6.0 Detailed Cost Estimate for the Selected Narrow-slot Alternative

Based on a review of the available data, the Layout 1 “Tee” option was selected as the best retrofit option for HBGS. This layout was selected because the screens can be removed for cleaning and all the screens are installed parallel to the prevailing currents, which should increase the cleaning efficiency. Additionally, the Tee shape, along with the barge unloading areas, simplifies the loading and unloading of screens. A detailed cost estimate for this design is provided below.

These costs are based on a detailed quantity take-off estimates and account for site-specific factors that were not included in the preliminary costs. While a more accurate predictor of the actual costs for this alternative, these costs should be considered minimal estimates. If AES is to move forward with this option, then the studies outlined in the Summary and Conclusions would need to be conducted. The results of these tests could affect the design and costs of this alternative.

Item	Estimated Cost
Direct Costs	-
Mobilization and Demobilization	$2,380,000
Work Deck	$13,142,000
Pipes and Connections	$3,469,000
T-120 Screens	$4,895,000
Slide Gates	$1,142,000
Hoist	$255,000
Replace Velocity Cap	$521,000
Spray wash	$380,000
Air Burst	$1,145,000
Direct Costs (2007 $)	$26,184,000
Indirect Costs	2,618,000
Subtotal	$28,802,000
Allowance for Indeterminates/Contingencies	7,201,000
Total Estimated Project Costs (2007 $)	$36,003,000

Impacts on Plant Operation	
Item	**Impact**
Construction	
Duration (months)	15
Outage (months)	3
Incremental Annual Operation and Maintenance	
Labor, (hrs)	1,690
Component Replacement	$579,000
Energy (kwh)	1,096,800
Peak Power (kw)	125

7.0 References

American Petroleum Institute (API). 1993. Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms - Load and Resistance Factor Design. 1st Edition: July 1, 1993.

MBC *Applied Environmental Sciences* and Tenera Environmental. 2007. Clean Water Act Section 316(b) Impingement Mortality and Entrainment Characterization Study. Prepared for AES Huntington Beach, LLC. Huntington Beach, California. February 26, 2007.

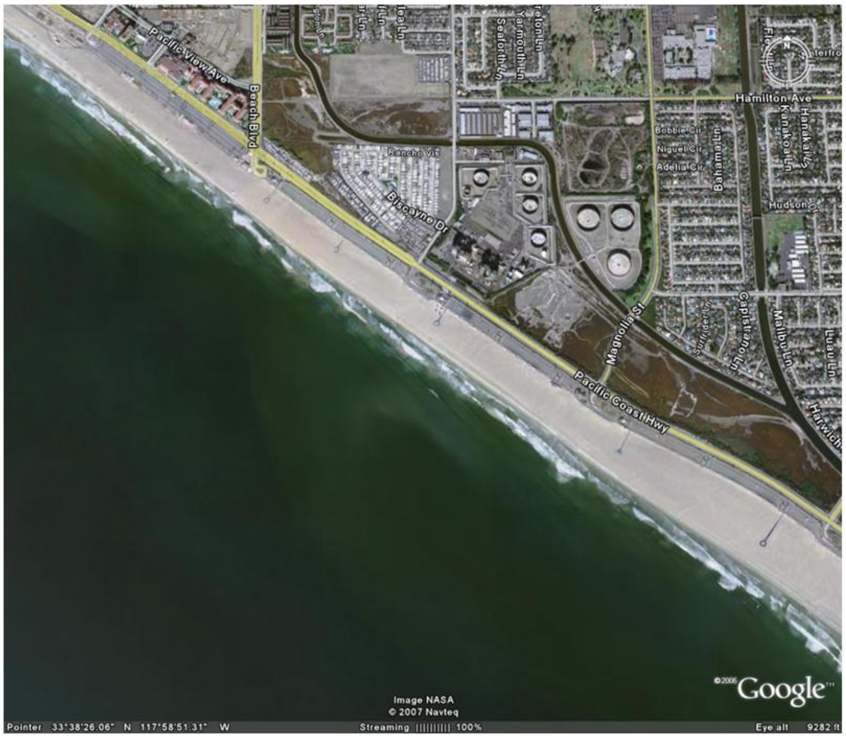
McGroddy, Peter M., Steven Petrich, and Lory Larson. 1981. Fouling and Clogging Evaluation of Fine-Mesh Screens for Offshore Intakes in the Marine Environment. In: Advanced Intake Technology for Power Plant Cooling Water Systems. Proceedings of the Workshop on Advanced Intake Technology. April 22-24, 1981.

Todd, B. 2007. Materials Selection for High Reliability Copper Alloy Seawater Systems. Adapted from original paper "Materials Selection for High Reliability Seawater Systems". Consultant to Nickel Development Institute. http://www.copper.org/applications/cuni/txt_materials_selection.html#cor

Wiersema, James M., Dorothy Hogg, and Lowell J Eck. 1979. Biofouling Studies in Galveston Bay-Biological Aspects. In: Passive Intake Screen Workshop. December 4-5, 1979. Chicago, IL.

United States Geological Survey (USGS). 2004. Huntington Beach Shoreline Contamination Investigation Phase III. Coastal Circulation and Transport Patterns: The Likelihood of OCSD's Plume Impacting the Huntington Beach Shoreline. Prepared for Orange County Sanitation District. Open-File Report 04-1019.

APPENDIX C
EVALUATION OF RELOCATING THE HUNTINGTON BEACH GENERATING STATION COOLING WATER INTAKE STRUCTURE FARTHER OFFSHORE



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Prepared for:
AES Huntington Beach
December 2007

APPENDIX C

EVALUATION OF RELOCATING THE HBGS CWIS FARTHER OFFSHORE

Relocating the entrance of the cooling water intake structure approximately five miles offshore was considered to have the potential to reduce impingement and entrainment. The new intake structure entrance would be constructed approximately five miles west of the existing intake; below the thermocline at a water depth of 100 ft. The location of the new intake structure entrance could potentially entrain water from the Orange County Sanitation District (OCSD) discharge pipe. If this were to occur it would result in waste from the OCSD being discharged through the existing HBGS discharge structure near the shore. This, in all likelihood, would not be allowed.

Construction of the new intake would be accomplished over a three-year period using a tunnel boring machine (TBM) and barge-mounted equipment. Most of the construction-related activities would be the tunneling process. Alden has assumed that construction would be done in the dry with the TBM tunneling west from the shore through mostly hard rock. The tunnel walls would be lined with concrete to provide structural support and to reduce head losses in the tunnel. The TBM would be left in place after construction. Upon completion of the horizontal section of the intake tunnel, the vertical portion would be connected to the horizontal portion and a velocity cap would be installed and the tunnel flooded.

Head loss in the new intake tunnel would be about 10 ft assuming a 14 foot diameter tunnel. Excessive head loss may result in inadequate pump submergence which would require further modifications to the existing pumphouse. Modifications to the pumphouse would include lowering the invert of the pumphouse to meet pump submergence requirements and the installation of new circulating water pumps. The additional modifications would require about six months. Costs for eight new circulating water pumps are included in the cost estimate for this option.

Alden estimates that HBGS would only need to be shut down for about six months if interruption to the operation of the existing intake structure is minimized. The actual length of shutdown would depend on construction methods and schedule.

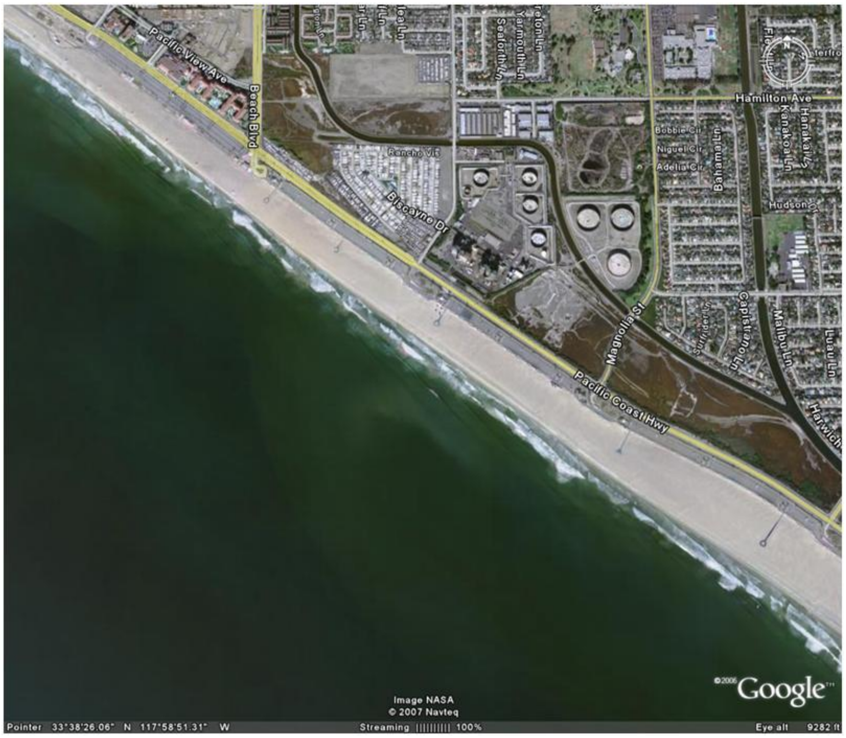
Operation of the new intake would be similar to the existing intake. Head losses associated with the new intake would be about 8.5 ft more than the head losses associated with the existing intake. Hydraulic studies of the new intake would be required to identify any adverse affects resulting from any potential interaction with the OCSD discharge. Heat transfer evaluations would be required to determine if a reduction in circulating water flow can be achieved due to lower water temperatures at the new intake structure's water depth.

Estimated capital and O&M costs for this option are provided in the following table.

Item	Estimated Cost
Direct Costs	
Mobilization and Demobilization	$12,764,000
Tunnel Entrance	$4,309,000
Offshore intake (includes V-cap)	$3,570,000
Modifications to existing pump bays	$1,028,000
New Circ Water Pumps	$8,000,000
Tunnel	$106,044,000
Cranes, Barges and Equipment (not including V-cap)	$4,693,000
Direct Costs (2007 $)	$140,408,000
Indirect Costs	14,041,000
Subtotal	$154,449,000
Allowance for Indeterminates/Contingencies	38,612,000
Total Estimated Project Costs (2007 $)	$193,061,000

Impacts on Plant Operation	
Item	**Impact**
Construction	
Duration (months)	36
Outage (months)	6
Incremental Annual Operation and Maintenance	
Labor, (hrs)	0
Component Replacement	0
Energy (kwh)	0
Peak Power (kw)	0

APPENDIX D
EVALUATION OF USING RECLAIMED WATER AT
HUNTINGTON BEACH GENERATING STATION



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December 2007

APPENDIX D
EVALUATION OF USING RECLAIMED WATER AT HBGS

HBGS may be able to use water discharged by the Orange County Sanitation District (OCSD) to supplement existing circulating water needs. HBGS currently withdraws about 794.5 cfs (513.5 MGD) of circulating water directly from the Pacific Ocean. Units 1-3 each withdraw 196.2 cfs (126.8 MGD) and Unit 4 withdraws 205.4 cfs (132.8 MGD). The OCSD currently discharges an average of about 371.3 cfs (240 MGD) of treated sewage into the Pacific Ocean. Of this 108.4 cfs (70 MGD) has already been allotted for recycling and not available to HBGS. If 100% of the remaining OCSD discharge water is used by HBGS for cooling purposes, it would result in a 33% reduction in cooling water intake flow for HBGS. Based on the average daily flow the OCDS should be able to provide sufficient flow to cool one unit. As Units 3 and 4 already meet the entrainment standard Alden recommends that recycled water only be used to provide circulating water to either Unit 1 or 2.

The actual quantity of water available from OCSD will dictate how AES can use that water. The OCSD discharge flow varies on an hourly basis, and is based on the water consumption within the service area. A plot of a typical dry weather day is provided on Figure 1 (OCSD 2007). This plot includes the current discharge, the discharge minus the 70 MGS that is already allotted for, along with the HBGS Unit 1 flow. For the period from about 3 AM to noon, the OCSD flow is less than the flow required for Unit 1. During this period additional flow would be required or generation would have to be curtailed.

To prevent the discharge of secondary-treated wastewater in the nearshore region, any reclaimed water used by HBGS would have to be isolated from the existing station discharge water and returned to the OCSD system. This water would then be available for other reclamation projects by OCDS. Using less seawater would also result in a reduction in the velocity in the intake tunnel and approaching the traveling water screens.

Using reclaimed water at HBGS would have several drawbacks.

- Availability
  - The flow of reclaimed water is not consistent and during low flow periods there may not be enough water available to adequately cool a unit.
  - Future reclaimed water allotments may further reduce the amount of water available to HBGS
- Delivery
  - A 1.5 mile long delivery pipe/tunnel from the OCSD discharge line to the HBGS intake line would have to be constructed.
  - The OCSD may need to be shutdown during the final connection to HBGS to prevent mixing of the OCSD waste water with clean ocean water.
  - The location of the new delivery pipe may interfere with existing infrastructure.

- Discharge
  - Discharge of OCSD water has been an issue and has resulted in construction of an offshore discharge.
  - The HBGS thermal discharge outfall is not permitted to discharge reclaimed water.
  - Any reclaimed water used at the facility would have to be piped back to the OCSD discharge pipes for offshore discharge or re-use.
  - If reclaimed water was used to supplement the existing flow the combined flow would need to be returned to the OCSD discharge pipe. The ability of the OCSD line to handle the additional volume would have to be considered.
- Chemical
  - OCSD water may contain high levels of chemicals (e.g. ammonia) that may adversely interact with the existing cooling system components.
  - Discharge of reclaimed water from the HBGS circulating water system may not meet OSCD discharge limits

Alden has provided appraisal-level costs for using reclaimed water to provide circulating water for one unit, either Unit 1 or 2, shown on Table 1. This cost is only designed to provide an order-of-magnitude estimate for decision-making purposes. The costs are based on two 8,000 ft long pipes that would allow water to be delivered to HBGS and returned to the OCSD discharge pipe. The same methodology used in the 2004 report was used for this assessment. The true cost of reclaimed water would be heavily dependent on the amount of existing infrastructure that would need to be relocated to install the pipes, and any in plant modifications that would be required. Additional pretreatment may be required to prevent material damage or generation of unanticipated chemical by-products.

Table 1 Estimated Cost to use Reclaimed Water at HBGS

	Estimated from Alden Database							
Alternative	**Construction Costs (2006 $)**	**Replacement Power During Shutdown (MWh)**	**Total Capital Cost (2006 $)[1]**	**O&M Costs (2006 $)**	**Lost Generation (MWh) [2]**	**Annualized Capital Costs (2006 $)[3]**	**Incremental Annualized O&M Costs (2006 $)[1, 2]**	**Total Incremental Annualized Costs (2006 $)**
Use 100% of OCSD effluent for cooling for one unit	$29,317,041	0	$29,317,000	0	0	$4,174,000	$0	$4,174,000

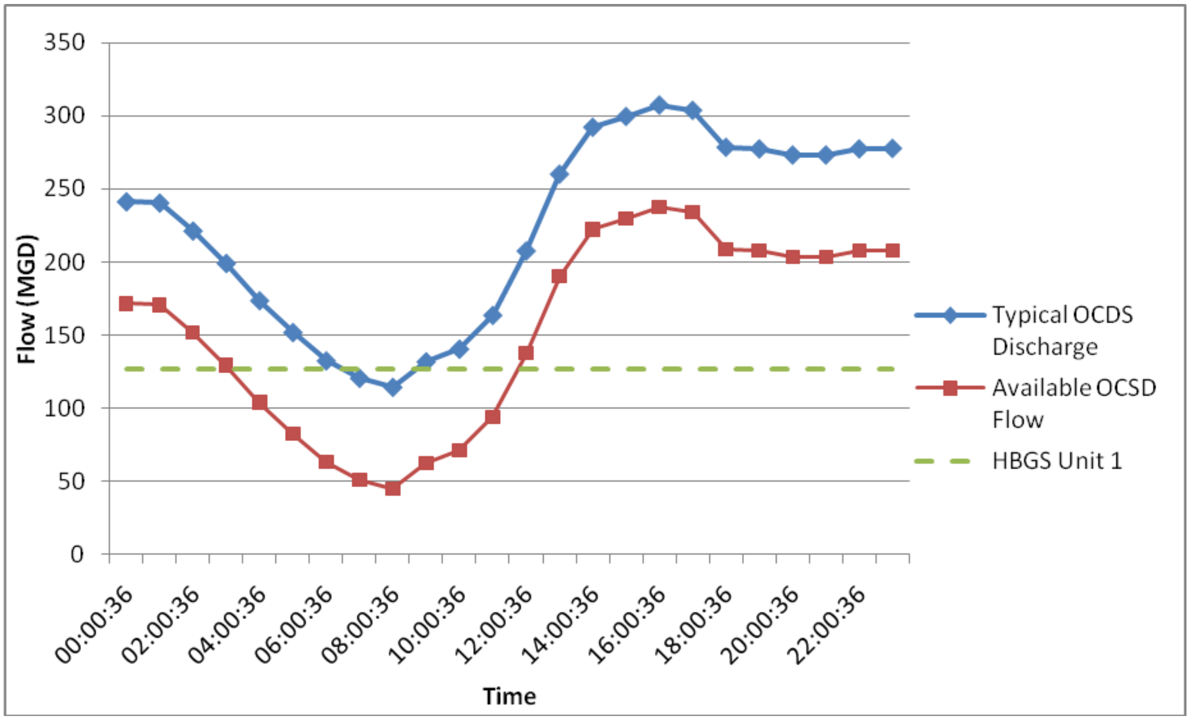
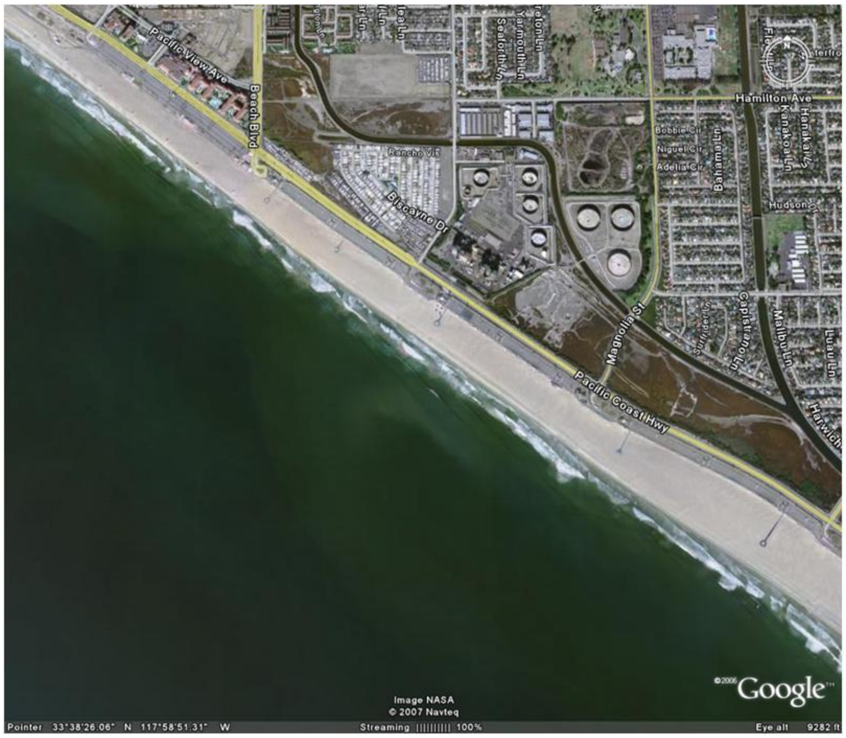


Figure 1 Typical Dry Weather Discharge at the OCSD Outfall[1]

References

Orange County sanitation District (OCSD). 2007 October Outfall Flows - 7 days. Provided by Nick Ahrontes. November 2007.

APPENDIX E
BIOLOGICAL EFFICACY OF FINE-MESH SCREENS
AND
HEADLOSS CALCULATIONS



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December 2007

APPENDIX E
BIOLOGICAL EFFICACY OF FINE-MESH SCREENS AND HEADLOSS CALCULATIONS FOR HUNTINGTON

There have been few empirical studies to determine the effects of organism length on entrainment through fine-mesh screen panels. The majority of studies has looked at extrusion through towed, ichthyoplankton nets and may not be representative of the efficiency of fine-mesh traveling water screens to exclude specific sizes of organisms.

Given the limited data, the predicted retention (or exclusion) that can be achieved with a given mesh-size can be estimated using the body depth of the organism. Estimates of the retention of organisms by a given mesh size can be developed from the physical dimensions of the organism. Since larval fish are soft bodied and can be compressed, the deepest non-compressible portion of the body (head capsule) can be used to predict exclusion. Exclusion is species-specific because there is substantial variation in the morphometric characteristics of the head capsule among species. Therefore, species-specific estimates were generated for several of the commonly entrained species at HBGS. To estimate retention, relationships between head capsule depth and fish length were developed for each species. Smith et al. (1968) found that the maximum cross-sectional diameter of the organism must be greater than the mesh diagonal if it is to be fully retained. Therefore, for a given cross-sectional diameter and associated standard deviation, the percentage retained and excluded is calculated by integration under a normal curve.

Head capsule depths were estimated by developing regressions of body length to head capsule depth based on measurements from scale-drawings of specimens (Moser 1996). These regressions were then used to interpolate head capsule depths for fish of given lengths (Table 1). For members of the family Sciaenidae, white croaker (*Genyonemus lineatus*) morphometric data were used as representative of other members of the family (spotfin croaker [*Roncador stearnsii*], black croaker [*Cheilotrema saturnum*], and queenfish [*Seriphus politus*]).This regression was also used for salema (*Xenistius californiensis*). Morphometric data for diamond turbot (*Pleuronichthys guttulatus*) were supplemented with other closely related species: C-O turbot (*Pleuronichthys coenosus*), curlfin turbot (*P. decurrens*), hornyhead turbot (*P. verticalis*), and spotted turbot (*P. ritteri*). For these flat fishes, head capsule width after transformation was used in the calculations. Data from barnaclebill blenny (*Hypsoblennius brevipinnis*), bay blenny (*H. gentilis*), rockpool blenny (*H. gilberti*), mussel blenny (*H. jenkinsi*), and Socorro blenny (*H. proteus*) were used to represent combtooth blennies. The estimated retention of several important taxa at Huntington Beach is presented in Figure 1. The probability of entrainment is displayed graphically in Figure 2.

The size distribution of entrained organisms (based on histograms presented in the IM&E Characterization Study - MBC and Tenera 2005) demonstrates that the majority of organisms are very small. By applying the species- and length-specific retention estimates to the size-and species distributions sampled at Huntington Beach, one can estimate the total estimated reduction in entrainment by species that could be expected with fine-mesh screens (Table 2). Given their small size, exclusion of ichthyoplankton at Huntington Beach is predicted to be very low.

The second measurement of effectiveness is the survival of the eggs, larvae, and early juveniles, which were previously entrained and that now would be retained on the fine-mesh screens. The survival of impinged organisms is dependent upon their biology (life stage, relative hardiness, etc.) and the screen operating characteristics (rotation speed, spraywash pressure, etc.).

Survival estimates were derived from other sites with data from modified traveling screens or from other evaluations (e.g., laboratory and pilot-scale studies). Data on the efficacy of fine-mesh screens with fish eggs and larvae are limited and estimates are often based on only a few data points. In such cases, data were expanded to include other members of the same genus or family where no other data within the same genus were available. The underlying assumption is that fish in the same genus or family have similar morphology and hardiness. Estimates of egg and larval survival are presented in Figure 1.

Species-specific post-impingement survival estimates for juvenile and adult stages of several fish species commonly impinged at HBGS were developed for modified traveling water screens. Biological estimates were derived from other sites with data from modified traveling screens or from other evaluations (e.g., laboratory and pilot-scale studies). Data were also obtained from published papers in peer-reviewed journals and corporate-sponsored efficacy reports (gray literature). Data were limited to juvenile or adult fish. The data were further limited to studies that: 1) were conducted at facilities with modified Ristroph or other screen designs with fish-friendly modifications, 2) were conducted at facilities with the more sophisticated bucket designs developed in the 1980s, and 3) held organisms for at least 24 hours post-impingement to assess the latent survival rate.

Post-impingement survival of juvenile and adult fish from fine-mesh screens is assumed to be similar to what has been observed at other locations with other modified screen designs (regardless of mesh-size). That is, survival of a 45 mm juvenile from a fine-mesh screen should not be different than survival from a coarse-mesh screen. Estimates of juvenile and adult post-impingement survival are presented in Table 3.

There is limited data on the post-impingement larval survival (and to a lesser extent juvenile and adult fish) for the species of fishes typically entrained at Huntington. Since these estimates are generated from facilities with a wide range of operating conditions, there is substantial uncertainty on the performance that could be achieved at HBGS with fine-mesh screens. This lack of certainty about the efficacy of fine-mesh screens at HBGS emphasizes the need for species and life stage specific testing to verify performance in situ before embarking on full-scale deployment at HBGS.

<table>
<tr><td colspan="2">Sciaenidae</td><td colspan="50">Length (mm)</td></tr>
<tr><td></td><td>Eggs</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td></tr>
<tr><td>Survival</td><td>74</td><td colspan="23">18</td><td colspan="11">96</td><td colspan="16">See Juvenile Adult Table</td></tr>
<tr><td>Exclusion</td><td>56</td><td>0</td><td>2</td><td>98</td><td colspan="47">100</td></tr>
</table>

<table>
<tr><td colspan="2">Pleuronichthys sp.</td><td colspan="50">Length (mm)</td></tr>
<tr><td></td><td>Eggs</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td></tr>
<tr><td>Survival</td><td>74</td><td colspan="3">89</td><td colspan="2">3</td><td colspan="35">64</td><td colspan="10">See Juvenile Adult Table</td></tr>
<tr><td>Exclusion</td><td>67</td><td colspan="2">0</td><td>4</td><td>99</td><td colspan="46">100</td></tr>
</table>

<table>
<tr><td colspan="2">Combtooth Blenny</td><td colspan="50">Length (mm)</td></tr>
<tr><td></td><td>Eggs</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td></tr>
<tr><td>Survival</td><td>74</td><td colspan="29">no data</td><td colspan="21">See Juvenile and Adult Table</td></tr>
<tr><td>Exclusion</td><td>31</td><td>0</td><td>13</td><td>95</td><td colspan="47">100</td></tr>
</table>

<table>
<tr><td colspan="2">Northern Anchovy</td><td colspan="50">Length (mm)</td></tr>
<tr><td></td><td>Eggs</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td></tr>
<tr><td>Survival</td><td>26</td><td colspan="19">10</td><td colspan="14">22</td><td colspan="17">See Juvenile and Adult Table</td></tr>
<tr><td>Exclusion</td><td>47</td><td colspan="5">0</td><td>11</td><td>47</td><td>82</td><td>96</td><td>99</td><td colspan="40">100</td></tr>
</table>

<table>
<tr><td colspan="2">Gobies</td><td colspan="50">Length (mm)</td></tr>
<tr><td></td><td>Eggs</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td><td>32</td><td>33</td><td>34</td><td>35</td><td>36</td><td>37</td><td>38</td><td>39</td><td>40</td><td>41</td><td>42</td><td>43</td><td>44</td><td>45</td><td>46</td><td>47</td><td>48</td><td>49</td><td>50</td></tr>
<tr><td>Survival</td><td>74</td><td colspan="29">0</td><td colspan="21">See Juvenile and Adult Table</td></tr>
<tr><td>Exclusion</td><td>100</td><td>0</td><td>1</td><td>34</td><td>87</td><td>99</td><td colspan="45">100</td></tr>
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Figure 1 Estimated exclusion (reduction in entrainment) and survival by taxon and length – Huntington Beach.

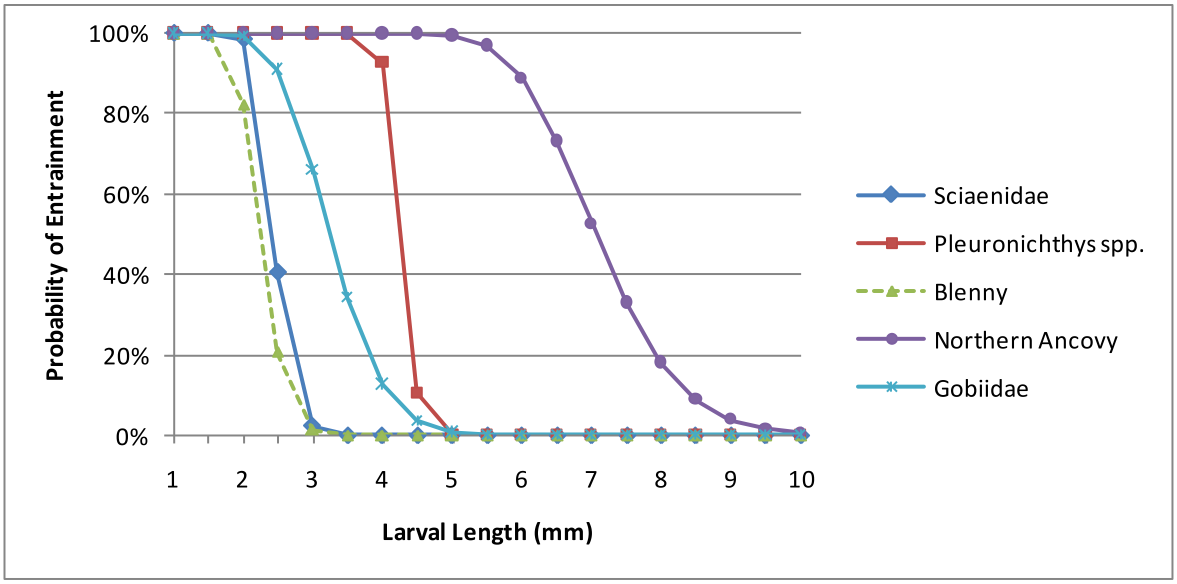


Figure 2 Predicted probability of entrainment of key taxa at Huntington Beach using 0.5 mm screens.

Table 1 Regression Results by Taxa

Species	Predictive Equation	R^2	Species Used to Develop Equation
combtooth blennies	Head Capsule Depth (HCD) = - 0.0174 + 0.202 Length	0.969	*Hypsoblennius proteus, H. jenkinsi, H. gilberti, H. gentilis, H. brevipinnis*
gobies	HCD = 0.101 + 0.123 Length	0.986	*Quietula y-cauda, Ilypnus gilberti, Gillichthys mirabilis, Clevelandia ios, Acanthogobius flavimanus*
diamond turbot	HCD = - 0.592 + 0.326 Length	0.925	*Hypsopsetta guttulata, Pleuronichthys coenosus, P. verticalis, P. ritteri*
northern anchovy	HCD = - 0.054 + 0.0784 Length	0.982	*Engraulis mordax*
croaker [1]	HCD = - 0.264 + 0.313 Length	0.998	*Genyonemus lineatus*

[1] Includes white, black, and spotfin croakers, queenfish and salema as all have similar larval morphology and sizes.

Table 2 Estimated overall reduction in entrainment associated with the use of 0.5 mm fine-mesh screens at Huntington Beach.

Taxon	Percent Reduction in Entrainment
Northern Anchovy	71.7
Gobiidae	64.1
Blenny	21.8
Diamond Turbot	11.3
Croaker [1]	58.8

[1] includes white, black, and spotfin croakers, queenfish, and salema as all have similar larval morphology and sizes

Table 3 Estimated Post-Impingement Survival (Weighted Mean), Number of Organisms Used to Estimate (N), the Range in Reported Post Impingement Survival, and the 95% Confidence Interval Surrounding the Weighted Mean

Common Name	Surrogate	*N*	Range	Weighted Mean	95% (CI) Lower	95% (CI) Upper
spotfin croaker	Sciaenidae [1]	22,176	0.0 - 100.0	56.0	55.4	56.7
queenfish	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
white croaker	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
black croaker	Sciaenidae	22,176	0.0 - 100.0	56.0	55.4	56.7
combtooth blennies	*Hypsoblennius* spp.[2]	1	100.0	100.0	50.0	150.0
gobies	Gobiidae	44	0.0 - 100.0	93.2	84.6	101.8
northern anchovy	Engraulidae	10,844	0.0 - 77.7	23.2	22.4	24.0
salema	no data available [3]	--	--	--	--	--
diamond turbot	*Pseudopleuronectes americanus*[4]	383	0.0 - 97.0	96.9	95.0	98.7
shiner perch	no data available	--	--	--	--	--
Pacific pompano	Stromateidae	125	72.2 - 76.1	74.4	66.3	82.5
walleye surfperch	no data available	--	--	--	--	--
jacksmelt	Atherinopsidae	965	97.8 - 100.0	98.2	97.4	99.1
topsmelt	Atherinopsidae	965	97.8 - 100.0	98.2	97.4	99.1

1 Scianidae were limited to marine and estuarine species (i.e., freshwater drum excluded from the analysis)

2 No other data for the family Blennidae were available, so the analysis was not expanded to family

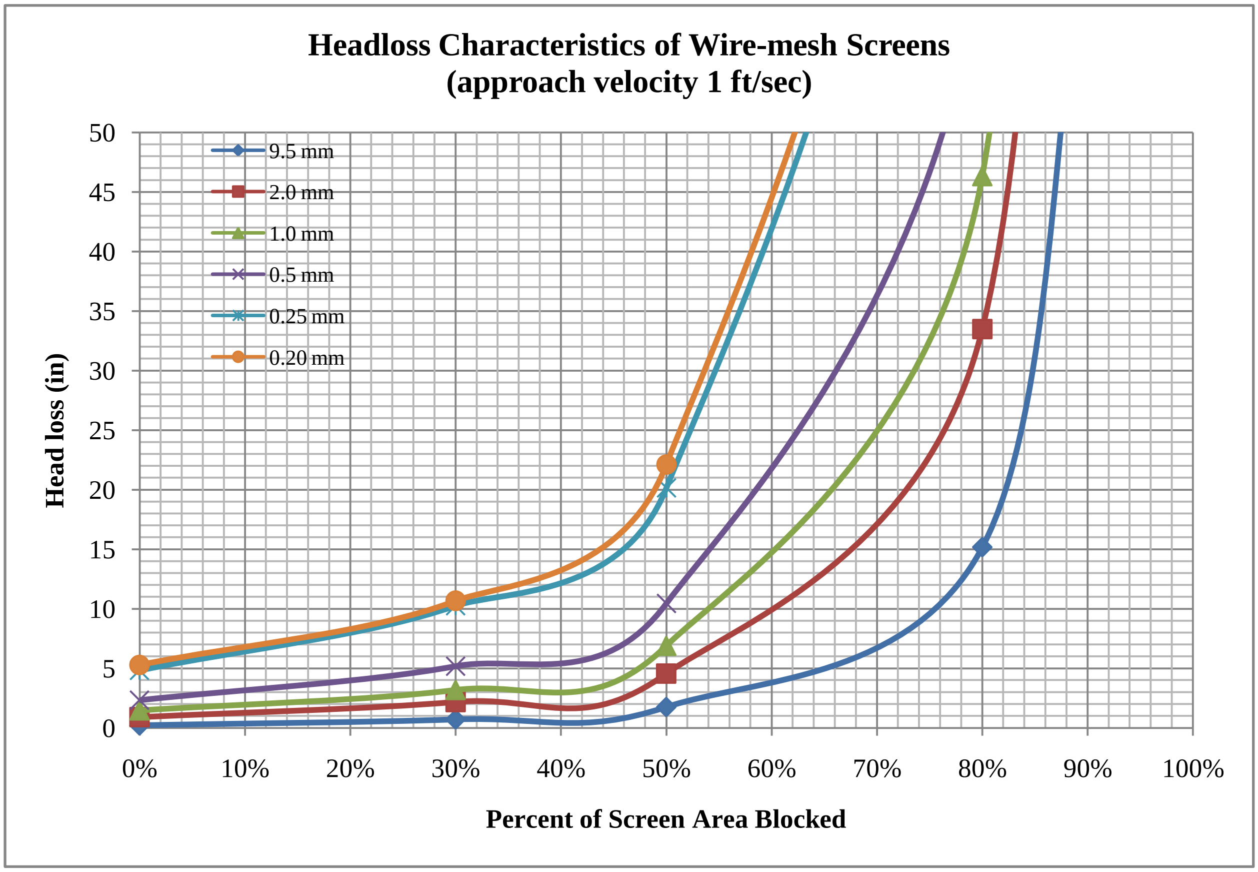
3 For three species (salema, shiner perch, and walleye surfperch), there were no other records for fish in the same family. No suitable surrogate was available for the analysis

4 There were no records for the family Pleuronectidae, therefore a commonly impinged flatfish on the Atlantic coast (winter flounder) was used as a surrogate for diamond turbot.

SCREEN MESH HEADLOSS

The screen mesh/headloss assessment was prepared by Alden with data provided by Johnson Screens and Siemens Screens.

<u>Wire-mesh screen head loss characteristics</u>



Assumptions for head loss calculations:

- Screen approach velocity at 1 feet/sec
- Through-flow screen (two screen mesh baskets in flow path)
- Head loss coefficients from M. Papworth 1972

Screen characteristics:

Screen Mesh	Wire spacing (in)	Wire dia. (in)	Wire dia. (mm)	Opening (mm)	Open area	Back-up screen (1" mesh)	Combined open area with 1" back-up screen
3/8" mesh	0.444	0.08	2.0	9.3	67%	no	67%
10 mesh	0.100	0.025	0.64	1.9	56%	yes	45%
18 mesh	0.056	0.017	0.43	1.0	48%	yes	39%
30 mesh	0.033	0.012	0.30	0.5	41%	yes	33%
50 mesh	0.020	0.009	0.23	0.3	30%	yes	24%
70 mesh	0.014	0.0065	0.17	0.2	30%	yes	24%

LITERATURE CITED

MBC Applied Environmental Services and Tenera Environmental (MBC and Tenera). 2005. AES Huntington Beach L.L.C. Generating Station Entrainment and Impingement Study. Draft Final Report. February 2005.

Moser, H.G. (ed.). 1996. The Early Stages of Fishes in the California Current Region. California Cooperative Oceanic Fisheries Investigations. Atlas No. 33. Pp. 1505.

Smith, P.E., R.C. Counts, and R.I. Clutter. 1968. Changes in Filtering Efficiency of Plankton Nets Due to Clogging Under Tow. ICES Journal of Marine Science 32: 232-248.

B.6 Huntington Beach Generating Station AES Corporation

Location

Huntington Beach, CA 92648
33° 55’ 06.17” N; 118° 25’ 33.90” W
Contact: Steve Maghy, 562-493-7384

Figure B-47
Huntington Beach Generating Station: Boundaries and Neighborhood

Figure B-48
Huntington Beach Generating Station: Site View

Plant/Site Information

Unit 1: 215 MW
Unit 2: 215 MW
Unit 3: 225 MW
Unit 4: 225 MW

Table B-55
Huntington Beach Cooling System Operating Conditions

Unit	MW	Cooling Water flow		Steam flow	Heat duty	Tin	Tex	Range	Tcond	TTD	Backpressure
		gpm	cfs	lb/hr	Btu/hr	F	F	F	F	F	in Hga
1	215	84,000	187	9.988E+05	9.488E+08	63.0	85.6	22.6	92.6	7.0	1.55
2	215	84,000	187	9.988E+05	9.488E+08	63.0	85.6	22.6	92.6	7.0	1.55
3	225	84,000	187	9.988E+05	9.488E+08	63.0	85.6	22.6	92.6	7.0	1.55
4	225	84,000	187	9.988E+05	9.488E+08	63.0	85.6	22.6	92.6	7.0	1.55

Table B-56
Huntington Beach Capacity Factors

Unit	2001	2002	2003	2004	2005	2006	Average
1	36.2%	31.5%	36.5%	38.6%	26.0%	20.4%	31.5%
2	32.4%	37.4%	36.8%	40.8%	22.1%	16.7%	31.0%
3	0.0%	0.0%	8.2%	18.7%	19.3%	11.6%	14.4%
4	0.0%	0.0%	8.9%	17.5%	13.7%	10.8%	12.7%

Table B-57
Huntington Beach Site Meteorological Data

Temperature	Max.	Average	Min.
Huntington Beach inlet temp, °F	69	62	57
Atmos. wet bulb, °F	71	56	30
Atmos. dry bulb, °F	107	63	32

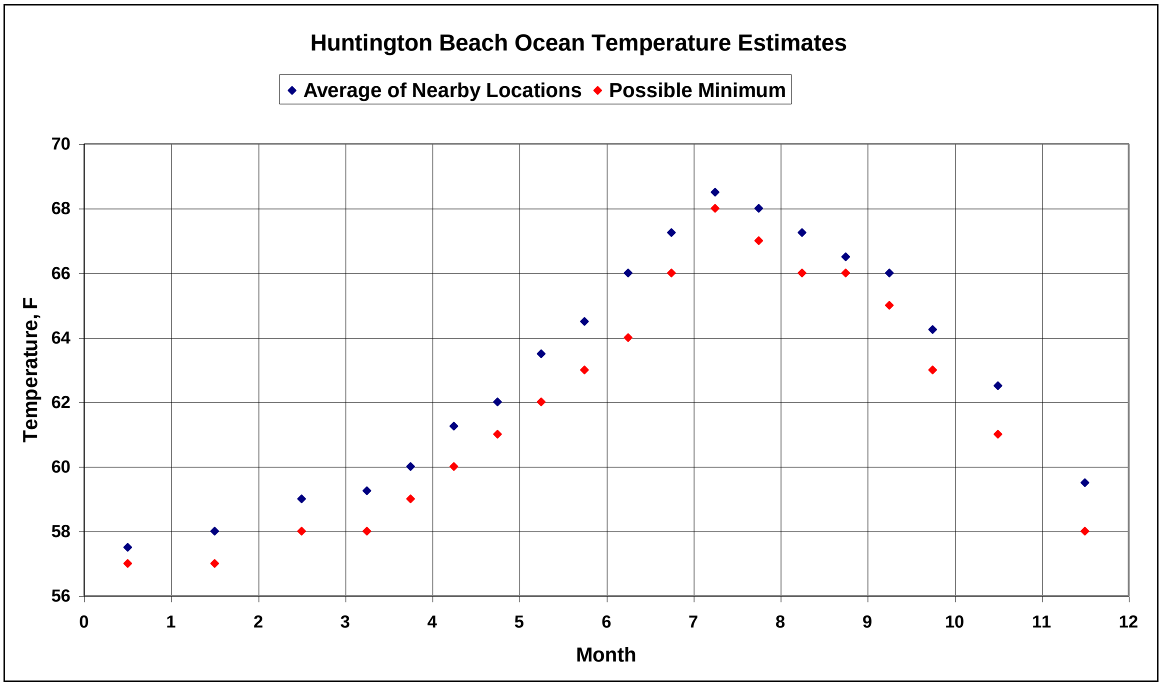


Figure B-49
Huntington Beach Inlet Temperatures

Plant Operating Data

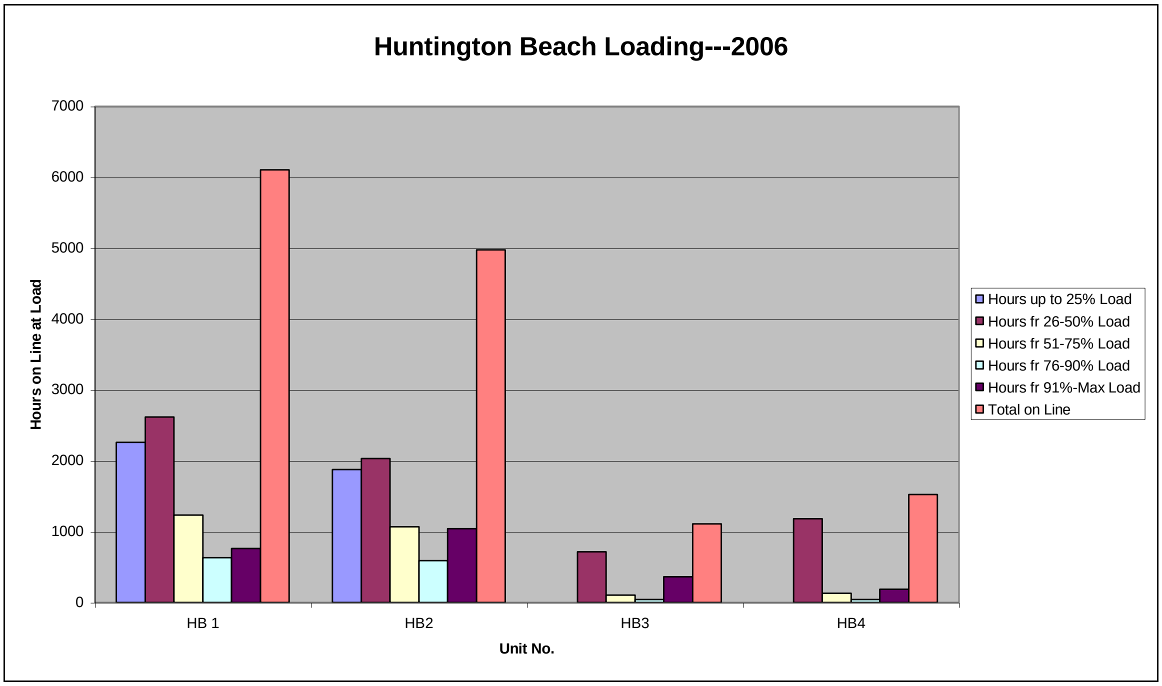


Figure B-50
Huntington Beach Operating Profiles

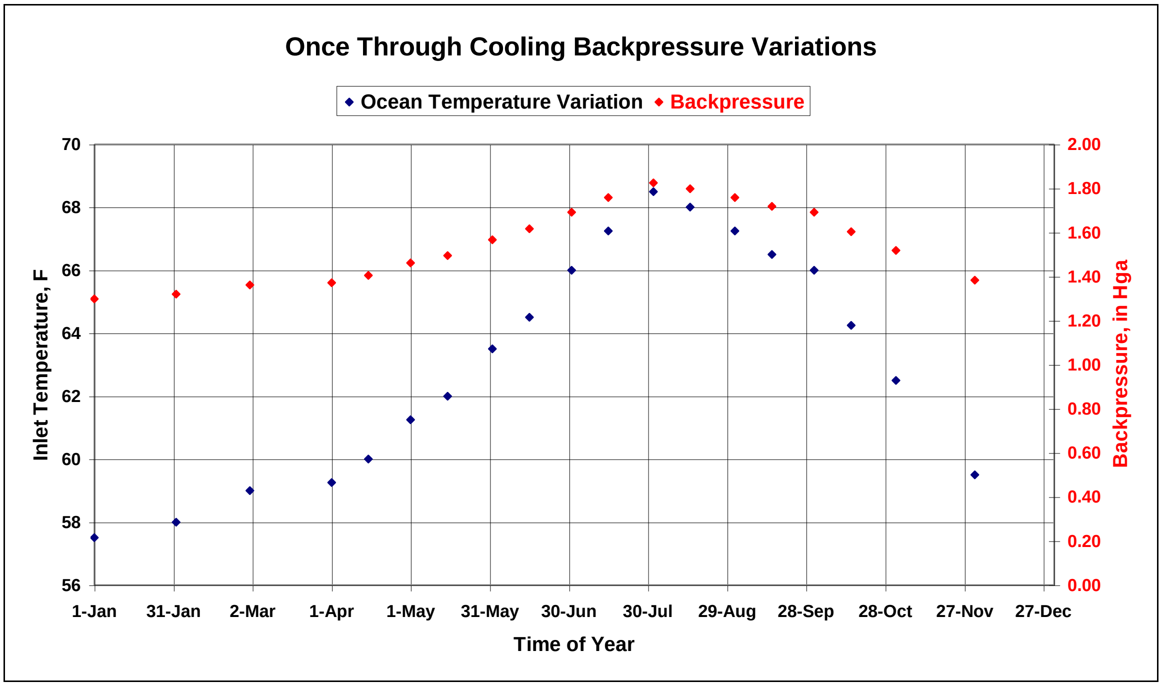


Figure B-51
Once-Through Cooling Backpressure Profile

Cooling Tower Assumptions/Design

- Tower type: mechanical draft, counterflow, FRP construction

- Make-up water source: Sea water; 35,000 ppm salinity
- Operating cycles of concentration: n = 1.5
- Evaporation rate: All units--- ~ 2,200 gpm each
- Make-up rate (@ n = 1.5): All units--- ~ 6,600 gpm each
- Blowdown (@ n = 1.5): All units--- ~ 4,400 gpm each

Tower design conditions are for all circulating water flows and condenser specifications unchanged, an assumed tower approach of 10°F and a peak (1%) wet bulb temperature of 71°F.

This results in a full load condensing temperature on the hottest day of

$$T_{cond} = 71 + 10 + 22.6 + 7 = 110.6°F$$

and a corresponding backpressure of 2.65 in Hga. Over the course of the year when the ambient wet bulb temperature would be lower, the backpressure would vary as indicated in the following figure. A comparison is given to the backpressure estimated with once-through cooling and indicates that the backpressure would normally be elevated by 0.5 to 1. in Hga.

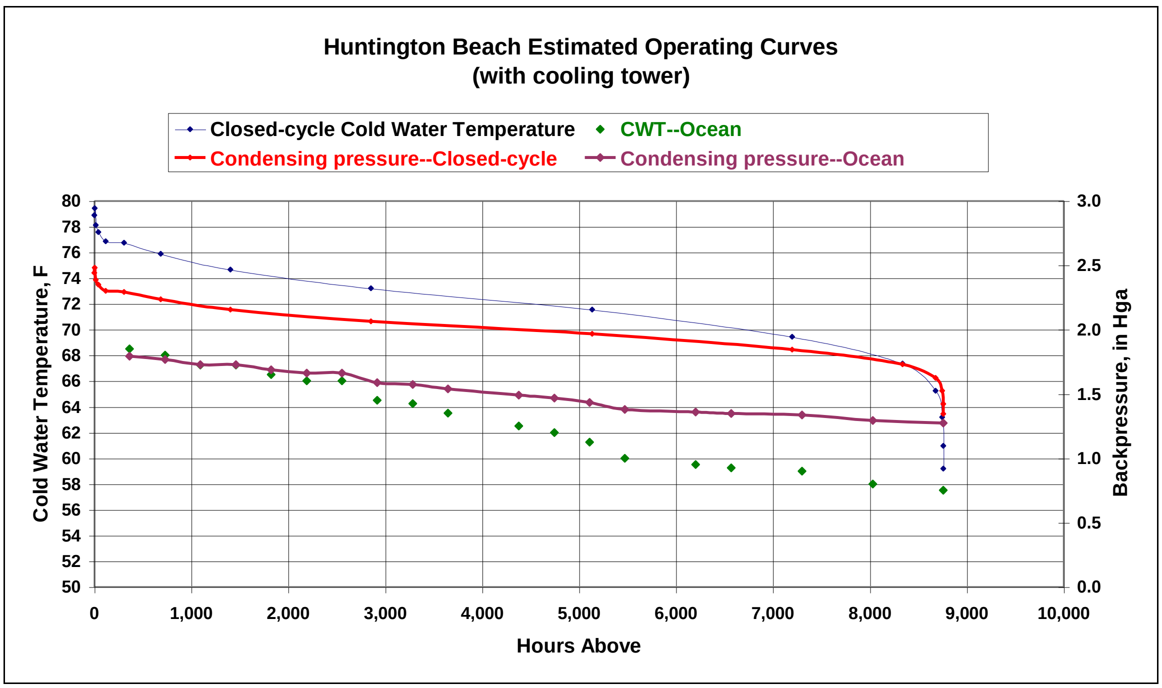


Figure B-52
Comparative Backpressure Performance

Wet Retro Fit Costs

Table B-58
S&W Cost Estimates

S&W Costs---escalated to 2007; x 1.07 for seawater					
Unit	**Labor**	**Material**	**Equipment**	**Indirect**	**Total**
1	**$5,855,000**	**$3,408,000**	**$5,799,000**	**$8,736,000**	**$23,798,000**
2	**$5,855,000**	**$3,408,000**	**$5,799,000**	**$8,736,000**	**$23,798,000**
3	**$5,855,000**	**$3,408,000**	**$5,799,000**	**$8,736,000**	**$23,798,000**
4	**$5,855,000**	**$3,408,000**	**$5,799,000**	**$8,736,000**	**$23,798,000**
Plant Total	**$23,420,000**	**$13,632,000**	**$23,196,000**	**$34,944,000**	**$95,192,000**

Table B-59
Maulbetsch Consulting Survey Estimates

Maulbetsch Consulting Survey; escalated to 2007 $; x 1.07 for salinity			
Unit	**Easy**	**Average**	**Difficult**
1	**$14,830,000**	**$24,717,000**	**$38,199,000**
2	**$14,830,000**	**$24,717,000**	**$38,199,000**
3	**$14,830,000**	**$24,717,000**	**$38,199,000**
4	**$14,830,000**	**$24,717,000**	**$38,199,000**
Plant Total	**$59,320,000**	**$98,868,000**	**$152,796,000**

Dry Cooling

Similar cost estimates can be made for a dry cooling retrofit. The basic assumption is that for plants with low capacity factors, they must be available to produce close to full load on the hottest days of the year when the system load is at its peak.

- Direct dry cooling: forced, mechanical-draft air-cooled condenser
- Steam flow: ~ 1,000,000 lb/hr (Each unit full load)
- Design dry bulb: 100°F (mid-way between 0.4% dry bulb and median of extreme highs)
- Design turbine exhaust pressure: 4.5 in Hga (based on assumption that turbines of this age and design trip at 5 in Hga and that the plant would not wish to reduce output on the hottest days)
- Corresponding condensing temperature: 130 ºF

Therefore, ACC design ITD ($T_{condensing}$ - $T_{design\ ambient}$) = 130°F – 100°F = **30°F**

Dry Cooling Retrofit Costs

AC costs can be roughly estimated from EPRI Report No. 1005358; "Comparison of Alternate Cooling Technologies for U.S. Power Plants", August, 2004.

Vendor information for a design of:

Steam flow: 1,000,000 lb/hr (scaled from example case of 1,128,000 lb/hr)
ITD: 30°F
Price: 2007 $

Table B-60
Dry Cooling Retrofit Cost Estimates

Source/Basis	Equip't	Erection	Electrical	Duct work	Total	Cells
Vendor 1	18,000,000	7,700,000	900,000	150,000	26,750,000	30
Vendor 2	14,900,000	7,300,000	900,000	150,000	23,250,000	30
Average	16,450,000	7,500,000	900,000	150,000	25,000,000	30
Scaled to 2007$	$20,562,500	$9,375,000	$1,125,000	$187,500	$31,250,000	
Including indirects	$32,488,750	$14,812,500	$1,777,500	$296,250	$49,375,000	
Plant total	**$129,955,000**	**$59,250,000**	**$7,110,000**	**$1,185,000**	**$197,500,000**	

Comparison with Individual Design Studies

An estimate of retrofit costs for both wet and dry cooling was performed for Huntington Beach by Sargent & Lundy on August, 2005. (S&L Report No. 11831-013) The agreement with estimates made in this study and discussed above was quite good as shown in the table below.

Cooling system	This study	Sargent & Lundy
Wet	$95,192,000/$98,868,000	$102,408,000
Dry	$197,500,000	$202,795,000

A second estimate was prepared for the Coast Law Group by Powers Engineering (Letter to Coast Law Group, LLC dated July 29, 2006). This estimate for wet closed-cycle cooling was approximately 20% lower at $80,000,000. The lack of agreement appears to be attributable primarily to two items.

First, the use of plume abatement towers was assumed. The costs were about x 1.3 to x 2 times what was estimated in this study for the cooling tower alone and this is consistent with the usual assumptions about the relative cost of plume abatement vs. conventional wet towers. This would might have been expected to cause this estimate to be higher. However, the total project costs were factored from the tower costs by assuming that the tower costs were about 40% of the retrofit costs. This simple factoring, as was discussed in an earlier section, always fails to capture any site-dependent features and results in a estimate that is normally too low. This was shown to be the case in comparisons of the survey data with factored estimates from EPA and appears to have resulted in an estimate in this case which is quite low compared to other estimates which are reasonably consistent.

Effect on Plant Performance

A retrofitted cooling system of either the wet or dry type would have a deleterious effect on the plant net heat rate. This arises from two effects:

1. Considering only the wet system, the power requirements will be higher than the current pumping power requirements for the once-through system. This power is used for the additional circulating pumps and for the cooling tower fans and represents power that must be generated but cannot be sold.

2. The plant will operate at a higher backpressure and therefore a higher heat rate with closed cycle cooling. This effect will be much more pronounced for a dry system than for a wet system.

The additional power requirements are estimated as follows:

Pumping power: The circulating water flow rate must be pumped through an additional head rise. This will be estimated at 40 feet to account for the lift out of the sump, the rise to the hot water distribution deck on the top of the tower and the head loss through the circulating water lines. A combined pump/motor efficiency of 75% is assumed. Each of these factors would be refined in a detailed analysis, but these are considered adequate to give a reasonable estimate of the effect of additional operating power on the plant. For the several units at Huntington Beach:

Table B-61
Huntington Beach Units: Retrofit Additional Pumping Power

Unit	Flow	Head	Eff	Power	Motor
	gpm	ft		kW	MW
1	84,000	40	0.75	632.7	0.84
2	84,000	40	0.75	632.7	0.84
3	84,000	40	0.75	632.7	0.84
4	84,000	40	0.75	632.7	0.84

Fan power: Similarly cooling tower fan power can be roughly estimated. It is assumed for retrofits on older, lower capacity factor units, the tower would be sized to "low first cost" design since the number of operating hours is low and power penalties are less severe. This is consistent with the assumptions made in the retrofit capital cost estimates. The number of cells will be estimated as one cell per 10,000 gpm of circulating water flow, the fan horsepower at 200 HP and a motor efficiency of 90%. For the Huntington Beach units this results in:

Table B-62
Huntington Beach Units: Retrofit Fan Power

Unit	Flow	Cells	Eff	Power	Motor
	gpm	n		hp	kW
1	84,000	8	0.9	1,600	1,326
2	84,000	8	0.9	1,600	1,326
3	84,000	8	0.9	1,600	1,326
4	84,000	8	0.9	1,600	1,326

This represents a combined, full-load operating power requirement of approximately 9. MW or approximately 1.% of the plant power rating of 900 MW. The actual annual cost will obviously depend on the capacity factor, the number of hours on-line, and whether some fans are turned off when operating at part load. Also, the cooling system was sized for full load at acceptable backpressures at so-called "1%" ambient conditions, it would be well oversized for nearly the entire year. Therefore, the effect of requiring additional operating power for the pumps and fans coupled with operation at higher heat rate would be an increase in the fuel burned rather than a reduction in plant output.

Heat rate penalty: As seen in the earlier plot of comparative backpressure, the condensing pressure with closed-cycle wet cooling will run typically 0.5 to 1.0 in Hga higher than it would with once-through ocean cooling and increases to about 2.5 in Hga on the hottest days. The effect is less at part load. Information for turbines of similar type and age indicate a heat rate penalty of approximately 0.25% for each increase in backpressure of 0.1 in Hga above design. The comparative plot shown earlier suggest that closed cycle cooling will result in increased backpressure throughout the year ranging from 0.5 to 1. in Hga with a corresponding heat rate penalty of 0.5 to 1.%.

Capacity Limits

The increased back pressure will likely results in an output restriction at the hottest day. The magnitude of the shortfall will depend on the operating philosophy. If the firing rate is held constant, a 1% heat rate penalty would correspond to roughly a 1% reduction in output.

If, however, it were to be decided that operation at a backpressure of 2.5 in Hga constituted an unacceptable maintenance risk to the turbine, then the firing rate would need to be reduced to hold whatever backpressure was consider acceptable. Information to estimate what the shortfall would be in that case is not available but presumably could be estimated by plant staff based on the information given above.

Maintenance Costs

Commonly used factors for maintenance (labor, materials, chemicals, etc.) for wet cooling systems range from 2. to 3. % of the system capital costs.

For wet systems, the important costs are for water treatment, biofouling control and keeping the basin clean. Using salt water and having salt drift around the plant would require rust control, extra painting, etc. Using the high end of typical factors, assume 3. to 3.5% of the capital cost of the tower. It is unclear how AES would allocate these costs between operation and maintenance, but an estimate of 3% of the "average" capital costs for all units of $60 million could amount to approximately $1,800,000 per year.

Additional Cost Considerations

Although the S&W costs are pretty close to the Maulbetsch Consulting survey's "Average" difficulty estimate, neither of those estimates can account for many site-specific difficulties which might be encountered at the Huntington Beach site. Those items that could cause a retrofit at this site to be in a different, either "High" or "Easy" category includes:

- Difficulty in locating the tower
- Unusual site preparation costs
- Significant interferences to the cost of installation of the circulating water lines
- The need for cooling tower plume abatement
- Stringent noise control
- The use of an alternate make-up water

Location of Tower/Unusual Site Preparation Costs/Interferences

It appears that space would be available for cooling towers in two locations:

i. The areas north and east of the plant at locations currently occupied by fuel and storage tanks which are no longer in use. Towers for Units 1 and 2 might be placed in the area occupied by the "east" fuel oil tank and the distillate storage tank. Lines from that location would be about 800 feet long. Towers for Units 3 and 4 would be farther away to the Northeast. Lines from there would be about 1,200 feet long. These circulating water lines would traverse much of the site and would likely encounter many underground interferences.

ii. It might also be possible to locate towers between the plant and the beach in a strip of land just inside the site boundary. The towers would be closer but the lines, while shorter, would have to go around and close to the plant buildings with an increased likelihood of numerous underground interferences.

All locations had serious drawbacks including

i. The need to demolish, relocate and rebuild existing structures for some locations.

ii. The possibility that the soil near the old tank farms would have been contaminated and that disturbing the ground and having to clean or dispose of the soil as a contaminated waste.

iii. Unstable soil conditions requiring significant foundation work such as deep pilings to stabilize the towers. There is no information on which to evaluate this issue, but given the location close to the shore, it is likely that the ground could be saturated, requiring special and costly excavation procedures and extra foundation work.

iv. Drift deposition from salt water towers.

v. Probable neighborhood objections to visible plumes, corrosive drift and noise.

vi. The need for PM10 offsets for expected drift from seawater towers.

Plume Abatement

Based on the view in the aerial photo of the neighboring area, it appears that a visible plume could be a serious issue at this site primarily from an aesthetic viewpoint. It is reasonable to assume that a plume abatement tower would be required to ameliorate any problems from a plume visible from residential areas and from the beach. Plume abatement towers have an air-cooled section on top of the wet tower. The hot water is pumped to the top of the tower, passes down through the dry section and then discharged onto the hot water distribution deck of the wet section. The air passing across the finned tubes of the dry section mixes with the wet plume coming off the wet section and keeps it from becoming saturated and condensing in the cold atmosphere. The need for a plume abatement tower would increase both the capital cost of the tower itself by a factor of perhaps 2.0 to 2.5 and the additional pumping power by an additional 30 to 50% due to the greater height to which the hot water must be pumped.

Aesthetics

In addition to any issues with a visual plume, the simple appearance of a cooling tower is sometimes considered an aesthetic affront. In this instance, the towers would be visible to neighbors and from the beach. Considering the number, size and bulk of the plant buildings already present, this may not present a major problem. However, given the prevailing attitudes with regard to scenic issues on the coast and from recreational areas, it may turn out to be a contentious, time-consuming and costly issue.

Noise Control

Noise from wet cooling towers comes both from the fans and from the water cascading through the fill. Fan noise can be diminished by fan design or the reduction in air velocity which sometime requires the use of bigger, or more, cells. The water noise is more difficult to reduce and usually requires the construction of sound barriers around the cooling tower. As in the case of the plume abatement question, the aerial photo of the plant and the neighboring area including the beach makes it appear that cooling tower noise may be a serious constraint. In the case that it is, the capital cost of the tower itself cost might increase from 20 to 40%.

Alternate Sources of Make-Up Water

The use of seawater make-up can introduce intractable problems regarding drift and related maintenance considerations. (See later discussion of drift and PM10.) An alternative can be to purchase reclaimed water from nearby municipal water treatment facilities.

In this instance, however, possibility of using reclaimed water for wet cooling tower makeup was considered and rejected due to the distance of sources from the plant, the expected very high cost of installing delivery and return pipelines to the remote sources and the expected extended time required to obtain permits even if the approach were deemed feasible.

Shutdown Period

There is often concern over the period of post plant availability during the retrofit construction period. In this instance, it appears that the major part of the construction could be done while the plant is on-line, with shutdown required only for the final tie-in of the circulating water lines to the existing water circuit. There is no information available to estimate how long this might be. However, the operating profiles shown earlier, especially for Units 3 and 4, indicate periods of little or no operation. Therefore, it appears that the tie-in could be accomplished with no serious downtime.

Other Environmental Issues

Retrofit to a closed-cycle cooling system introduces some environmental issues which a once-through cooling system does not. These are increased air emissions from the stack and drift from the cooling tower.

Stack Emissions

In an earlier section it was noted that a closed-cycle retrofit increase the unit net output because of heat rate penalties and the use of increased operating power. In this instance these together were estimated at from 1 to 2%. Therefore, the delivery of the same amount of electric power to the grid will require the burning of additional fuel at some location to make up that lost at Huntington Beach. Based on the unit heat rate information provided, this does not appear to be major effect in this case. Furthermore, in the discussion of this issue in Chapter 7, it was pointed out that the effect of making up this shortfall was highly variable depending on how and where the replacement per was generated. Therefore, no attempt is made to assess the effect in quantitative terms beyond pointing out that reliable estimates of the shortfall to be expected from full load operation can be made.

Drift

It is assumed that any cooling tower would be equipped with state-of-the-art drift eliminators rated at about 0.0005% of circulating water flow. The following table estimates the amount of drift to be expected from such designs. In addition, as discussed earlier, Federal EPA and State regulations characterize all solids carried off in cooling tower drift as PM10. The cost of offsetting these amount, should it be necessary will vary considerably from site to site as will the severity of the regulatory constraints.

Table B-63
Huntington Beach Drift Estimates

Unit	Flow	Drift[1]	Drift	PM10	PM10	Cap. Factor	PM10
	gpm	gpm	lb/hr	lb/hr	tons/year[2]	%	tons/year[3]
1	**84,000**	0.42	210	10.50	46.0	**24.7**	**11.4**
2	**84,000**	0.42	210	10.50	46.0	**24.7**	**11.4**
3	**84,000**	0.42	210	10.50	46.0	**24.7**	**11.4**
4	**84,000**	0.42	210	10.50	46.0	**25.7**	**11.8**

1. At drift eliminator efficiency of 0.0005%
2. Assumes full load all year
3. At 2006 capacity factor

General Conclusion

On balance, it is concluded that there are a number of likely problems and additional costs to be encountered at Huntington Beach which would put the retrofit at this site in a “difficult” category. Based on the results from the Maulbetsch Consulting survey presented above, this would put the project cost in the range of $150. million. Given the capacity factors, particularly for Units 3 and 4, a retrofit effort of this cost may be an uneconomical option.

ATTACHMENT 5

Benefit Valuation Study

Huntington Beach Generating Station Benefit Valuation Study

Final Report, December 2007

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REPORT SUMMARY

The Huntington Beach Generating Station (HBGS) provides reliable generation of electricity in an urban setting. The four generating units produce enough electricity to light nearly one million homes. To help support California's growing energy needs, HBGS recently invested in refurbishing Units 3 and 4 so that they could be returned to service. Thus, the HBGS is a critical component of the southern California power generation strategy and plays an important role in stabilizing the electrical system within Orange County. Moreover, the facility produces 10 percent of the state's peak electricity demand.

HBGS also produces clean power generation through the use of selective catalytic reduction (SCR) technology, which is designed to reduce atmospheric emissions. This technology reduced emission of NO_x by more than 90 percent. AES is also one of the only generators in the state with carbon monoxide reduction catalyst technology in use.

HBGS also contributes to the local economy and the quality of life in Orange County. It provides employment for 50 people and a source of revenue for the City of Huntington Beach.

HBGS is required to comply with 316(b) regulations. This report is a Draft Benefits Valuation Study (BVS) for Huntington Beach Generating Station. The now suspended 316(b) Phase II rule requires a BVS as part of an Alternative 5 Comprehensive Demonstration Study (CDS). The Phase II 316(b) rule addresses impingement mortality and entrainment (I&E) standards for existing power plants that use more than 50 million gallons per day of cooling water. The rule's standards require that facilities reduce impingement mortality by 80 to 95 percent and, if applicable, entrainment by 60 to 90 percent from a calculation baseline. The California State Water Resources Control Board has developed a draft 316(b) policy that is more stringent, requiring a reduction of 90 percent for entrainment and 95 percent for impingement. Under Alternative 5, a determination that the costs of meeting the standards are significantly greater than the benefits indicates that site-specific standards are appropriate. Although the rule has been suspended, the permit under which HBGS operates requires compliance with the Phase II rule.

The BVS quantifies the economic benefits of reducing I&E at HBGS. The annualized (net present value/20) benefits associated with I&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928. The 20-year discounted value of that benefit stream ranges from $94,000 to $254,000 with a mean estimate of $158,600. This distribution of expected benefits is conditional upon the presumption that reducing I&E leads to increases in local fish populations and corresponding increases in expected commercial and recreational catch. The equilibrium expected change in recreational catch is 543 fish per year. The equilibrium expected change in commercial harvest is 80 pounds per year. The remainder of the document describes the specific methodology, analysis, and data used to estimate the benefits of reducing I&E.

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1
INTRODUCTION

The Huntington Beach Generating Station (HBGS) provides reliable generation of electricity in an urban setting. The four generating units produce enough electricity to light nearly one million homes. To help support California's growing energy needs, HBGS recently invested in refurbishing Units 3 and 4 so that they could be returned to service. Thus, the HBGS is a critical component of the southern California power generation strategy and plays an important role in stabilizing the electrical system within Orange County. Moreover, the facility produces 10 percent of the state's peak electricity demand. HBGS also contributes to the local economy and the quality of life in Orange County. It provides employment for 50 people and a source of revenue for the City of Huntington Beach.

HBGS also produces clean power generation through the use of selective catalytic reduction (SCR) technology, which is designed to reduce atmospheric emissions. This technology reduced emission of NO_x by more than 90 percent. AES is also one of the only generators in the state with carbon monoxide reduction catalyst technology in use.

In the course of its normal operation, HBGS withdraws ocean water through a cooling water intake structure (CWIS). CWISs are regulated under Section 316(b) of the Clean Water Act (CWA). This statute directs the EPA to ensure that the location, design, construction and capacity of CWIS reflect the best technology available (BTA) for minimizing adverse environmental impacts (AEI). EPA developed national technology standards in three phases. The Phase II Rule generally applies to existing electric generating plants with significant cooling water intake capacity. It requires that these plants reduce impingement mortality and entrainment (I&E) of aquatic organisms according to national standards.[1] The rule's standards require that facilities reduce impingement mortality by 80 to 95 percent and, if applicable, entrainment by 60 to 90 percent from a calculation baseline. The California State Water Resources Control Board has developed a draft 316(b) policy that is more stringent, requiring a reduction of 90 percent for entrainment and 95 percent for impingement.

On January 25, 2007 the Second Circuit Court of Appeals released a ruling that disallowed many significant components of the EPA's Phase II § 316(b) rule for cooling water intake structures (*Riverkeeper et al. v. U.S. Environmental Protection Agency*). In response to the Second Circuit Court ruling, EPA has suspended the Phase II Rule and directed that all permits for Phase II facilities be considered on a Best Professional Judgment basis as described at 40 *CFR* § 401.14 (Grumbles 2007; 72 *Federal Register* 37107).

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[1] Impingement occurs when fish and aquatic species become trapped on equipment at the entrance of the cooling system. Entrainment occurs when aquatic organisms, eggs, and larvae are taken into the cooling system, through the heat exchangers, and discharged back into the waterbody.

Because the permit for HBGS requires that it comply with the Phase II rule, this assessment reflects the Phase II rule with California reduction requirements. The rule provides five specific compliance alternatives to achieve these standards. Alternative 5, a demonstration that a site-specific determination of BTA is appropriate (EPA 2004a, p. 41,593), allows site-specific standards based on cost and benefit analyses (e.g., the cost-cost test and the cost-benefit test [EPA 2004a, p.41, 503–41,604]). Specifically, if the costs of meeting the performance standards are significantly greater than the corresponding benefits, then the plant can qualify for alternative performance standards. Making and supporting such a determination requires conducting a sound benefit-cost analysis.[2] It also entails identifying what constitutes costs of I&E reductions being significantly greater than the corresponding benefits. This report contains a benefit-cost analysis for the Huntington Beach Generating Station (HBGS) and serves as the plant's Benefit Valuation Study (BVS)—one of the regulatory submittals required as part of an Alternative 5 Comprehensive Demonstration Study (CDS).

Overview of Results

The benefit estimates in this assessment reflect the current I&E estimates provided by Applied Environmental Sciences and Tenera Environmental (2007). The organisms analyzed by MBC and Tenera are limited to those that were sufficiently abundant to provide a reasonable assessment of impacts. Specifically, the I&E estimates reflect the most abundant fish taxa that together comprised 90 percent of all larvae entrained and/or juveniles and adults impinged at HBGS. Moreover, the benefit estimates reflect the benefits of complying with the performance standards. Based on the existing technology at HBGS, compliance with the impingement mortality standard requires a 13 percent reduction in impingement for all units at HBGS. Compliance with the entrainment standard requires a 90 percent reduction in entrainment for Units 1 and 2 at HBGS.

The annualized (NPV/20) benefits associated with I&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928. The 20-year discounted value of that benefit stream ranges from $94,000 to $254,000 with a mean estimate of $158,600. This distribution of expected benefits is conditional upon the presumption that reducing I&E leads to increases in local fish populations and corresponding increases in expected commercial and recreational catch. The equilibrium expected change in recreational catch is 543 fish per year. The equilibrium expected change in commercial harvest is 80 pounds per year. In addition, this distribution of expected benefits recognizes that nonuse benefits do not need to be quantified because HBGS's I&E does not cause "substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function" in the coastal waters near HBGS (EPA 2004a, p. 41,648).

Organization of the Report

Section 2 presents an overview of the methodology used for the analysis. Section 3 discusses the recreational and commercial fisheries. Section 4 describes the I&E data on which the benefit estimates are based and the approaches used to estimate the fishery impacts and the forgone

[2] Appendix A contains a discussion of benefit-cost analysis.

fishery harvests. Section 5 provides a conceptual overview of valuing use and nonuse benefits. Section 6 details the calculation of economic benefits from reducing I&E at the Huntington Beach Generating Station.

2

OVERVIEW OF METHODOLOGY FOR BENEFIT VALUATION

This section presents an overview of the methodology for estimating the economic benefits associated with reducing I&E at HBGS. The benefit-estimation methodology uses a *site-calibrated benefits transfer* based on dynamic population modeling, site-specific application of an existing random utility model (RUM) of recreational angling demand, species-specific consideration of the relevant commercial fisheries, and qualitative evaluation of the potential nonuse benefits associated with I&E reductions.[3] With respect to quantifying uncertainty, the methodology uses a scientific analysis of uncertainty, where uncertainty in catch changes is based on equilibrium concepts of dynamic modeling and uncertainty in the value of those catch changes is determined based on coefficients from transferred methods.[4]

Figure 2-1 provides an overview of the methodology for evaluating the economic benefits of reducing I&E. Each step depicted in the figure is summarized below.

[3] By calibrated benefits transfer, we mean that an already estimated equation is transferred to the policy context and then tailored to the affected population and resource.

[4] By "scientific analysis of uncertainty" we mean that the degree of uncertainty can be quantified in a manner that allows formulation and testing of statistical hypotheses.

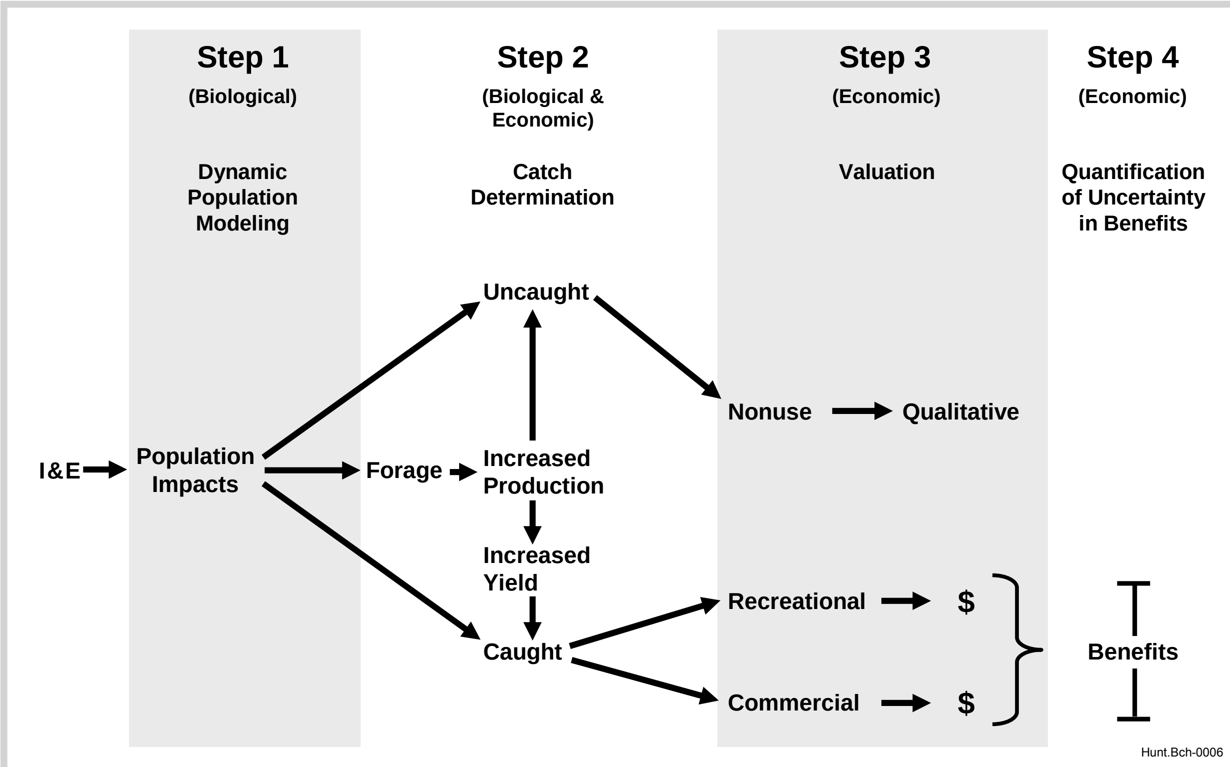


Figure 2-1
Overview of Methodology for Estimating the Benefits of I&E Reductions

Step 1: Develop Dynamic Population Models

Step 1 involves developing dynamic population models from the HBGS impingement and entrainment data. The methodology uses the best available information on life stages, natural and fishing mortality rates, and fecundity to develop population increases for the I&E species. The methodology follows Leslie (1945) and is widely used by fishery managers. Section 4 presents a detailed description of this methodology as well as the results of applying it to HBGS's I&E data.

Step 2: Catch Determination

In this step, the methodology entails determining forgone yield, production, and species categorization (i.e., the percentage of impinged and entrained organisms that would have been caught, uncaught, or are forage). The determination of harvested versus forage species is based on the best available information, including consultation with local fishery experts, EPA's regional case study for California (2004b), and local catch data. Step 2 uses calibrated natural and fishing mortality parameters to determine the forgone yield and forgone production for each species.

As Step 2 shows, the methodology relates reductions in forage species to the increased production of uncaught fish as well as the increased production and yield of caught fish. Section 4 contains a detailed description of the methodology along with the results of its application.

Step 3: Determine the Value of Fish Produced as a Result of I&E Reductions

After completing Steps 1 and 2, the methodology values the additional fish production that would be achieved through I&E reductions. There are three categories of benefits that result from reducing a plant's I&E: recreational, commercial, and potential nonuse benefits.

As part of this step, the methodology determines which species are recreational versus commercial. This determination is based on the best available information, including consultation with local fishery experts, recreational breakdowns employed in EPA's Regional Study, and local creel/harvest data. The methods for assessing each benefit category are summarized below. Section 5 describes the economic concepts that underlie estimating each benefit category, and Section 6 presents the specific methodology and estimates for each benefit category.

Step 3a: Recreational Benefits

Correctly calculating recreational benefits requires a significant amount of information and calculations. The calculations are based on a simulation of angler behavior and changes in social welfare resulting from reductions in I&E and the associated increases in expected catch. Important factors that should be accounted for include the number and quality of substitute fishing sites, the geographic range of impacted species, the number of trips with improved catch rates, and the number of anglers associated with those trips.

Random utility analysis is the best method for valuing I&E reductions on recreational fishing.[5] However, conducting an original random utility model (RUM) study can require extensive primary data collection. A site-calibrated transfer of an existing RUM study can capture important behavioral responses (i.e., changes in trip-taking behavior as a result of changes to a fishery) without requiring survey-data collection. The accuracy of this methodology is limited only by the analyst's ability to calibrate an already estimated preference function to a different population using appropriate economic methodologies (Smith, van Houtven, and Pattanayak 2002). Section 5 describes the economic concepts underlying the relationship between I&E reductions and estimating the recreational benefits associated with those reductions. Section 6 describes the site-calibrated RUM used to estimate the recreational benefits associated with HBGS's I&E reductions.

Step 3b: Commercial Benefits

Commercial benefits from I&E reductions accrue to commercial fishermen as increased profit attributable to the higher catch per unit effort (CPUE) associated with increases in fish populations and/or to fish consumers in the form of lower prices. The ability of commercial fishermen to realize *sustained* increased profits depends on the responsiveness of market prices to higher CPUE. Market extremes determine the upper and lower bounds on commercial

[5] RUMs are recognized in the Department of the Interior (DOI) regulations (43 *CFR* §11.83) as an appropriate method for quantifying recreation service losses in natural resource damage claims. Currently, the RUM is the most widely used model for quantifying and valuing natural resource services. RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985), as well as more recently in environmental and resource economics.

benefits. In competitive markets, prices adjust instantly and benefits accrue to consumers. In restricted markets, prices do not change and commercial benefits are maximized in the form of producer surplus at price times quantity (P * Q). Estimating the commercial benefits of I&E reductions involves consideration of the fishery's relevant market conditions. Section 5 describes the economic concepts underlying the relationship between I&E reductions and changes in commercial fishing benefits for alternative market conditions. Section 6 describes the market conditions for the species associated with the HBGS I&E impacts and presents the methods and results associated with evaluating changes to the fishery resulting from I&E reductions at the HBGS.

Step 3c: Nonuse Benefits

Uncaught recreational fish and forage fish do not have a traditional use value and are therefore categorized as having potential nonuse value. Nonuse values are the values that people may hold for a resource independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist.

The 316(b) rule requires that the benefits assessment consider the nonuse benefits associated with reductions in I&E (§ 125.95(b)(6)(ii)). Currently, the only methods available for estimating nonuse values are survey-based techniques that ask respondents to value, choose, rate, or rank natural resource services in a hypothetical context. The reliability of this approach for evaluating nonuse impacts is questionable. For example, because of conceptual and empirical challenges associated with measuring nonuse values, which are further described in Appendix B, the EPA decided in the final rule that "…none of the available methods for estimating either use or nonuse values of ecological resources is perfectly accurate; all have shortcomings" (EPA 2004a, p. 41,624). More importantly, EPA determined that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004a, p. 41,624).

Therefore, for assessing the nonuse benefits of I&E reduction at an individual facility, the rule states the following:

> When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information (EPA 2004a, p. 41,648).

Specifically, the rule directs that nonuse benefits should be monetized "in cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function in a facility's waterbody or watershed" (EPA 2004a, p. 41,648). Otherwise, monetization is unnecessary and the analysis should contain a qualitative assessment of nonuse benefits.

Section 5 contains a detailed description of the economic concepts underlying the relationship between reductions in I&E and assessing the nonuse benefits associated with those reductions.

Section 6 then presents the rationale for conducting a qualitative evaluation of HBGS's nonuse benefits and presents the results of that evaluation.

Step 4: Quantify Uncertainty in Benefits

As part of conducting a cost-benefit analysis, the rule requires that a benefits assessment include uncertainty analysis but does not specify methods (see EPA 2004a, p. 41,647). In statistical analysis, the term *uncertainty* refers to the quantifiable imprecision in estimates. Benefit estimates are most useful when uncertainty is quantified and its causes are clearly identified.

As recommended by EPA, Step 4 uses a Monte Carlo analysis to quantify the effects of uncertainty on benefits. The Monte Carlo analysis combines uncertainty in input parameters with the benefits-estimation model to quantify uncertainty in 316(b) compliance benefits. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and then combines the estimates. The resulting combination of the various inputs creates an estimate of compliance benefits. Section 6 contains a detailed explanation of Step 4 and presents its analysis and results.

3
RECREATIONAL AND COMMERCIAL FISHERIES

AES Huntington Beach L.L.C. Generating Station (HBGS) lies within the southeastern portion of the City of Huntington Beach at 21730 Newland Street (Figure 3-1) in the coastal part of Orange County, California. HBGS draws cooling water from the Pacific Ocean through an intake structure located about 1,500 feet offshore (MBC and Tenera 2007).

Figure 3-1
Location of the Huntington Beach Generating Station

More than 3 million people live in Orange County: of those, more than 195,000 live in Huntington Beach. Cities located within 20 miles of Huntington Beach include Anaheim (population 332,000), Long Beach (population 475,000), Newport Beach (population 78,000), and Santa Ana (population 343,000) (City of Huntington Beach 2006; U.S. Census Bureau 2007a).

The Huntington Beach Generating Station is located just across Pacific Coast Highway (inland) from the Huntington State Beach, and the intake and discharge structures for the generating station are just offshore the state beach. The state beach is a little over two miles in length, extending north from the Santa Ana River mouth past the generating station to Beach Boulevard. At Beach Boulevard, the state beach borders the Huntington City Beach. Over 11 million people visit the beaches of Huntington Beach annually.

The Orange County Health Care Agency and its Ocean Water Protection Program test bacteriological samples and review the results daily for the presence of disease-causing organisms. Ocean and bay water closures, postings, and health advisories are issued as conditions warrant. Portions of Huntington Harbour, Huntington City Beach, and Huntington State Beach have been closed to body-contact recreation when sewage spills and leaks occur (Orange County Health Care Agency 2007; California Regional Water Quality Control Board, Santa Ana Region 2002).

Fishery research has demonstrated that some fishery stocks can fluctuate independently of the generating station operations. One recent case is that of white seabass (*Atractoscion nobilis*) a highly prized gamefish that once supported a large recreational and commercial fishery (Allen et al. 2007). White seabass is the largest resident sciaenid (croaker/drum) within the Southern California Bight, and as such, it functions as a higher trophic level predator within the nearshore ecosystem. Much of its diet consists of queenfish, white croaker, anchovies, Pacific sardines, and California market squid (Cailliet et al. 2000). I&E at HBGS have the potential to constrain white seabass populations directly through entrainment (impingement), or indirectly through entrainment (impingement) of common prey species. Both instances have been documented at HBGS. MBC and Tenera (2007) reported that an estimated 347,306 white seabass larvae were entrained and an additional 60 individuals were impinged.

Allen et al. (2007) observed that both recreational and commercial landings had declined precipitously since the 1970s. Commercial catch generally fluctuated between 100 and 400 metric tons (mt) for most of the 20th century, but declined to 10 percent or less of the historic catch from 1980 on. Similar patterns were seen in recreational landings, which declined from a peak of 0.13 fish per angler in 1949 to 0.001 fish per angler in 1978. In 1994, the California Department of Fish and Game enacted a nearshore commercial gillnet ban, effectively removing the majority of commercial fishing pressure from the adult spawning aggregation sites. This, in conjunction with strong recruitment classes in 1994 and 1998, sparked resurgence in the white seabass population levels. Despite the increased commercial restrictions, both commercial and recreational landings returned to near historic levels. In 2002, the commercial fishery landed approximately 219 mt. More importantly, the recreational fishery landed an estimated 360 mt in 2001. It should be noted that the recreational fishery, unlike the commercial fishery, is still permitted to fish adult spawning aggregation sites.

Mean daily cooling water flow at HBGS declined from a peak of more than 90 percent in 1982 to less than 40 percent from 1987–2001, coinciding with much of the period of depressed white seabass stocks. From 2002–2005, mean daily cooling water flow at HBGS has been greater than 50 percent. In this analysis, it is assumed that I&E were proportional to cooling water flow throughout this period. Based on these data, if I&E acted as a constraining factor on white seabass populations, a reciprocal increase in the white seabass population parameters would be expected in relation to flow levels. No evidence exists to support this. The data show, however, that white seabass populations fluctuated relatively independently of HBGS operations. Commercial landings have fluctuated between approximately 150 and 250 mt annually from 2001–2005, a period of increased operation at HBGS (Allen et al. 2007). Recreational landings have declined since their peak in 2001, although this may relate to overfishing. Allen et al. (2007) reported that while landings for commercial and recreational fisheries in 2002 were both approximately 220 mt, the mean length for commercially landed white seabass was substantially larger than that of recreational catches. This indicates that the recreational fishery harvested substantially more individuals, potentially from spawning aggregation sites.

The empirical data concerning the white seabass fishery suggest that while they were subject to I&E, as were their prey species, their populations fluctuated independently of plant operations. The resource, and its associated economic products, would largely feel no effect of modifications to the HBGS cooling water system. The following text provides detailed information on the recreational and commercial fisheries.

Recreational Fishery

The California Fish and Game Commission (1998) notes the richness and diversity of California's marine life, stating that "[t]housands of species of marine plants, crustaceans, mollusks, other invertebrates, fish, seabirds, and marine mammals use an astonishing diversity of habitats." At least 30 public fishing piers in southern California provide opportunities for anglers to land popular game fish from ocean waters. Additionally, shore-based fishing is popular from public access points, and boat ramps provide opportunities for boat anglers.

About 300 varieties of fish and shellfish are native to California (California Seafood Council 1997). Table 3-1 lists many of the fish and invertebrates inhabiting the Pacific Ocean off the coast of Huntington Beach. None of these species are included on the U.S. Fish and Wildlife Service's (USFWS's) or California's listings of endangered and threatened species (USFWS 2007; California Department of Fish and Game (DFG) 2006a).

Table 3-1
Fish and Invertebrates Inhabiting the Pacific Ocean off Huntington Beach

Fish of the Pacific Ocean at Huntington Beach			
Arrow goby	Combfishes	Pacific butterfish	Shield-backed kelp crab
Barred sand bass	Deepbody anchovy	Pacific electric ray	Shiner perch
Barred surfperch	Diamond turbot	Pacific hake	Shovelnose guitarfish
Basketweave cusk-eel	English sole	Pacific littleneck	Smoothhead sculpin
Bat ray	Fantail sole	Pacific mackerel	Spanish shawl
Bay ghost shrimp	Garibaldi	Pacific rock crab	Speckled sanddab
Bay goby	Giant kelpfish	Pacific sanddab	Specklefin midshipman
Bay pipefish	Giant sea bass	Pacific sardine	Spiny brittlestar
Bigmouth sole	Graceful rock crab	Pacific staghorn sculpin	Spotfin croaker
Black croaker	Grass rockfish	Painted greenling	Spotted cusk-eel
Black perch	Halfmoon	Pile perch	Spotted sand bass
Black surfperch	Horn shark	Plainfin midshipman	Spotted turbot
Blackeye goby	Hornyhead turbot	Pubescent porcelain crab	Striped shore crab
Blacksmith	Jack mackerel	Purple-striped jelly	Stubby dendronotus
Blackspotted bay shrimp	Jacksmelt	Pygmy poacher	Thick-clawed porcelain crab
Blind goby	Jellyfish	Queenfish	Thornback
Blue rockfish	Innkeeper worm	Red rock crab	Topsmelt
Bocaccio	Intertidal coastal shrimp	Red rock shrimp	Tube blennies
Brown rockfish	Kelp bass	Ribbon worm	Tuberculate pear crab
Cabezon	Kelp blennies	Ridgeback rock shrimp	Tubesnout
California aglaja	Kelp greenling	Rock wrasse	Turbot
California barracuda	Kelp pipefish	Rockpool blenny	Two-spotted octopus
California clingfish	Labrisomid blennies	Roughcheek sculpin	Vermillion rockfish
California corbina	Leopard shark	Round herring	Walleye surfperch
California grunion	Longjaw mudsucker	Round stingray	Warty sea cucumber
California halibut	Market squid	Rubberlip seaperch	White croaker
California headlightfish	Masking crab	Sanddab	White seabass
California lizardfish	Mexican lampfish	Salema	White seaperch
California needlefish	Mussel blenny	Salp	Xantus swimming crab
California petricola	Northern anchovy	Sand crab	Yellow rock crab
California sheephead	Northern lampfish	Sargo	Yellow shore crab
California scorpionfish	Nudibranch	Sea star	Yellow snake eel
California spiny lobster	Ochre starfish	Senorita	Yellowfin croaker
California tonguefish	Olive rockfish	Shadow goby	Yellowfin goby
Cheekspot goby	Opaleye	Sheep crab	Yellowleg shrimp
Chub mackerel	Pacific barracuda		

Source: MBC Applied Environmental Sciences and Tenera Environmental (2007)

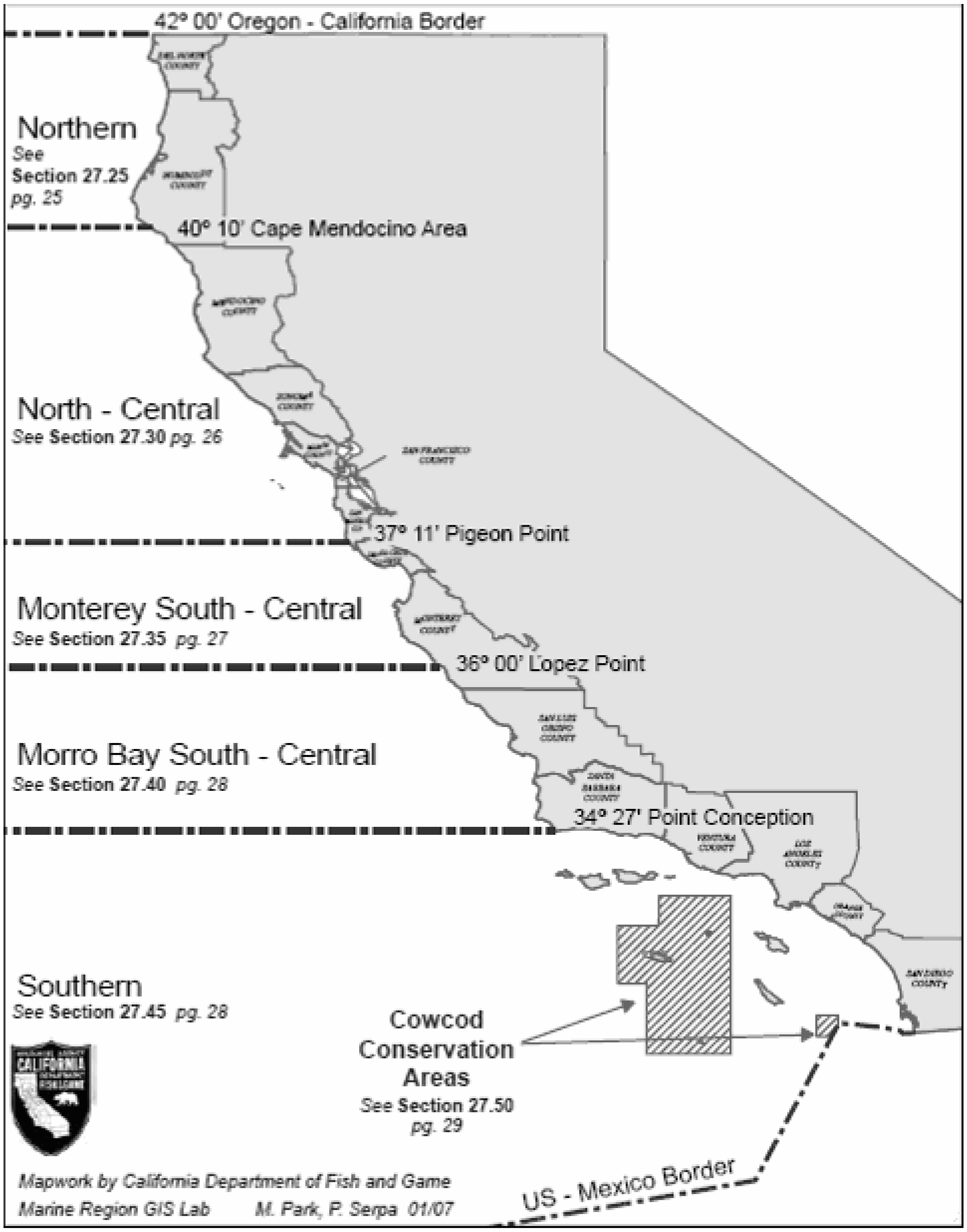
California offers angler recognition programs for ocean fishing, as described below. The angler recognition programs for ocean fishing records comprise both angling and diving categories.

- Ocean Fishing Record Program—A diver or angler catching a state-record fish must land the fish/shellfish unaided. The fish must be weighed on a scale certified by a government agency and in the presence of two witnesses unknown to the angler or diver. A biologist must identify the catch (California DFG, Marine Region 2007a).
- California Fishing Passport Program—The passport lists 150 different species of freshwater and saltwater finfish and shellfish that inhabit waters throughout California. Participating anglers catch and document all of the different species listed, receiving a stamp for each one (California DFG 2007a).

Huntington Beach offers an attractive venue for fishing tournaments. For example, the largest surf fishing tournament ever held on the Pacific Coast—Albackore's Gulp! Only West Coast Fall Surf Slam—took place on Saturday, October 7, 2006 at Huntington Beach. More than 300 anglers participated. On April 14, 2007, the Albackore Sportfishing Gear Spring Surf Slam fishing tournament was held at Huntington Beach. That tournament featured catch-and-release fishing for surfperch, croaker, and halibut. On August 25, 2007, the Huck Finn Fishing Derby for children was held at Huntington Beach (Jackson 2006; Huntington Beach Events.com 2007).

California grunion provides a unique recreational fishery near Huntington Beach and other California beaches from Point Conception south. For two to six nights after the full and new moons during the spring and summer months, grunion leave the water at night to spawn on the beach. Spawning begins after high tide and continues for several hours. Grunion may be taken by sport fishers (with a valid fishing license) using their hands only (Stockteam.com 2007).

The California Fish and Game Commission and the Pacific Fishery Management Council have established six groundfish management areas in California's ocean waters, each with a different set of regulations tailored to meet regional needs. Groundfish include all species of rockfish, cabezon, and greenlings; lingcod; leopard shark; Pacific sanddab; ocean whitefish; California sheephead; California scorpionfish; and federal groundfish: rock sole, sand sole, butter sole, curlfin sole, rex sole, and flathead sole, dover sole, English sole, petrale sole, arrowtooth flounder, starry flounder, spiny dogfish, soupfin shark, big skate, California skate, longnose skate, ratfish, rattail, codling, Pacific cod, Pacific whiting, sablefish, and thornyheads. The Southern Management Area includes Huntington Beach and substitute fishing sites in California' ocean waters (Figure 3-2). See Appendix C for a summary of the recreational groundfish regulations for 2007 in the Southern Management Area (California DFG, Marine Region 2007b).



Source: California DFG, Marine Region (2007b)

Figure 3-2
Groundfish Management Areas in the Pacific Ocean off the California Coast

This figure shows that the ocean waters near Huntington Beach and substitute saltwater fishing sites are located in the Southern Management Area.

Substitute Fishing Sites

The value of any particular fishery impact is related to both the level of the impact and the quality of available substitute sites. Anglers can choose from many other sites near Huntington Beach when they want to fish in saltwater. Attractive substitute sites provide opportunities for saltwater fishing and other recreation, such as:

- Dana Point, where anglers can fish from a pier, launch a boat, or take a fishing charter. Anglers can catch California halibut, corbina, diamond turbot, jacksmelt, opaleye, croaker; spotted sand bass, and many other fish. State-record corbina and yellowfin croaker have been landed from Dana Point Harbor (Jones undated).
- Long Beach, where anglers can fish from a pier, launch a boat, or take a fishing charter, whale watching tour, or harbor tour. Anglers can catch barracuda, bocaccio, bonito, calico and sand bass, queenfish, rockfish, sculpin, yellowtail, and many other fish. An angler caught a state-record pile perch on February 26, 2007 at Long Beach (Sportfishingreport.com 2007; California DFG, Marine Region 2007a).
- Marina del Rey, where anglers can participate in fishing derbies; take a fishing charter, cruise, or whale-watching tour; or enjoy one of the many special events. Marina del Rey has the largest marina on the West Coast. Anglers can catch barracuda, calico and sand bass, dorado, halibut, marlin, rockfish, and many other fish at Marina del Rey (Los Angeles County Department of Beaches and Harbors undated).
- San Diego Bay, where anglers can enjoy fishing, boating, charters, and adjacent parks. Anglers can catch albacore; bluefin, big-eyed, and skipjack tuna; barracuda; bat ray; bonito; calico bass; California corbina; flounder; halibut; shark; and many other fish. Anglers caught state-record thresher shark and skipjack tuna from San Diego Bay (California DFG, Marine Region 2007a; San Diego Sportfishing Council undated).

Table 3-2 compares Huntington Beach and other saltwater fishing sites. See Appendix C for a list of additional saltwater fishing sites near Huntington Beach. Appendix C also lists site characteristics for Huntington Beach and the additional sites.

Table 3-2
Comparison of Huntington Beach and Other Fishing Sites

Water Bodies	Saltwater Bass	Bonito	Corbina	Halibut	Shark	Tuna	Boat Ramp(s)	Noteworthy Facts
Saltwater								
Huntington Beach	•	•	•	•	•	•	•	Adjoins Huntington Beach State Park and Bolsa Chica Ecological Reserve. Anglers caught state-record jack mackerel and bat ray at Huntington Beach.
Dana Point	•	•	•	•	•		•	Anglers caught state-record corbina and yellowfin croaker at Dana Point Harbor.
Long Beach	•	•	•	•			•	Angler caught state-record pile perch on February 26, 2007.
Marina del Rey	•			•		•	•	Largest marina on the West Coast; WaterBus during the summer; near Aubrey Austin, Chace, and Admiralty Parks and North Jetty Walkway.
San Diego Bay	•	•	•	•	•	•	•	Anglers caught state-record thresher shark and skipjack tuna from San Diego Bay.

Sources: DeLorme (2005); Jones (undated); Sportfishingreport.com (2007); California DFG, Marine Region (2007a); Los Angeles County Department of Beaches and Harbors (undated); San Diego Sportfishing Council (undated)

No fish consumption advisories based on chemicals have been issued for Huntington Beach or for substitute fishing sites at Santa Monica Pier, Venice Pier, Venice Beach, Marina del Rey, Redondo Beach, Emma/Eva oil platforms, Laguna Beach, Fourteen Mile Bank, Catalina (Twin Harbor), and Dana Point. Consumption advisories for some species of sport fish have been issued for substitute fishing sites in ocean waters because of elevated DDT and PCB levels, as listed in Table 3-3 (California DFG 2007b).

Table 3-3
Fish-Consumption Advisories for Southern California Coastal Waters

Site	Fish	One Meal[a] Every Two Weeks	One Meal a Month	Do Not Consume
Point Dume/Malibu offshore	White croaker			•
Malibu Pier	Queenfish		•	
Short Bank	White croaker	•		
Redondo Pier	Corbina	•		
Point Vicente Palos Verdes—Northwest	White croaker			•
White's Point	Kelp bass	•[b]		
	Rockfishes	•[b]		
	Sculpin	•[b]		
	White croaker			•
Los Angeles/Long Beach harbors, especially Cabrillo Pier	Black croaker	•[b]		
	Queenfish	•[b]		
	Surfperches	•[b]		
	White croaker			•
Los Angeles/Long Beach breakwater (ocean side)	Black croaker		•[b]	
	Queenfish		•[b]	
	Surfperches		•[b]	
	White croaker		•[b]	
Belmont Pier Pier J	Surfperches	•		
Horseshoe Kelp	Sculpin		•[b]	
	White croaker		•[b]	
Newport Pier	Corbina	•		

[a] A meal for a 150-pound adult is about 6 ounces. Calculate 1 ounce of consumption for each 20 pounds of body weight (Office of Environmental Health Hazard Assessment 2003).

[b] Consumption recommendation applies to all listed species combined at the site (Office of Environmental Health Hazard Assessment 2003).

Additionally, the Office of Environmental Health Hazard Assessment (OEHHA) provides general guidance for fish consumption (2003). The general advisories caution consumers to eat smaller fish of legal size rather than large fish, which are likely to have higher levels of contaminants. Mussels are quarantined from May 1 through October 30 in California and should not be eaten.

OEHHA also refers consumers to the U.S. EPA (2007) advisory for women who are pregnant or might become pregnant, nursing mothers, and young children. The EPA advisory cautions them not to eat shark, swordfish, king mackerel, or tilefish because those fish contain high levels of mercury.

Angler Characteristics

Recreational fishing values are related to the number and characteristics of anglers in the recreational market. Recreational anglers need no license to fish from California piers or during the two free fishing days offered annually, when all other fishing regulations still apply. During 2007, California's free fishing days were June 9 and September 22 (California DFG 2007c; California DFG, Marine Region 2007b).

Otherwise, recreational anglers aged 16 or older must have a basic fishing license to take any kind of fish, mollusk, invertebrate, amphibian, or crustacean from California waters. The license is valid for the calendar year. A basic fishing license also entitles an angler to fish in the ocean north of Point Arguello, Santa Barbara County. Besides the basic fishing license, anglers fishing in the Huntington Beach area or at substitute sites may also need:

- An Ocean Enhancement Stamp for ocean fishing south of Point Arguello, except when fishing under the authority of a one- or two-day sport fishing license
- A Steelhead Fishing Report and Restoration Card when fishing for steelhead in anadromous waters
- A Sturgeon Fishing Report Card when fishing for sturgeon (California DFG 2007c; California DFG, Marine Region 2007b).

The USFWS conducts the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation every five years. Among other information, the survey collects data on anglers and the types of fish that they catch. We use data from the 2001 survey (updated during 2003) because it is the most recent survey with complete data. Table 3-4 estimates the number of anglers who fished during 2001 as summarized in the report for California (USFWS 2003).[6]

Table 3-4
Estimates of Fishing in California during 2001

Category	California
Number of residents who fished during 2001	2.389 million
Percentage of residents who fished during 2001	7.05%[a]

[a]Anglers may fish from public fishing piers in California without a license.

Source: USFWS (2003)

[6] During 2001, 6.51 percent of Californians bought a fishing license (2,206,382 of 33,871,648 residents) (American Sportfishing Association 2007; U.S. Census Bureau 2007b).

The USFWS reports statistics on fishing in saltwater separately from fishing in freshwater bodies.[7] Table 3-5 summarizes the number of anglers and days spent fishing in California water bodies during 2001. Table 3-6 lists the estimated days that anglers fished for selected species in California water bodies during 2001 (USFWS 2003).

Table 3-5
Fishing Reported in California during 2001

Category	Saltwater	Freshwater
Number of anglers	0.932 million	1.877 million
Days spent fishing	8.371 million	19.685 million
Average number of fishing days per angler	9 days	11 days

Source: USFWS (2003)

Table 3-6
Estimated Days that Anglers Fished for Selected Species in California Water Bodies during 2001

Species	Number of Days Spent Fishing in Saltwater Bodies (in thousands)	Number of Days Spent Fishing in Freshwater Bodies (in thousands)
Trout	—	9,901
Black bass	—	4,121
Salmon	833	3,735
Striped bass	3,552	—
Other saltwater fish	2,964	—
White bass, striped bass, striped bass hybrids	—	2,945
Catfish, bullheads	—	2,918
Any kind of fish	2,138	1,909
Crappie	—	1,076
Flatfish (flounder, halibut)	1,013	—
Panfish	—	998
Other freshwater fish	—	714
Mackerel	434	—
Shellfish	379	—

Source: USFWS (2003). Note that anglers could list more than one species.

[7] See Appendix D for regulations and opportunities related to freshwater fishing near Huntington Beach.

Commercial Fishery

The California Fish and Game Code, Division 6, Part 3, Sections 7600–14105 and Title 14, California Code of Regulations govern commercial fishing in California waters. Federal regulations affect coastal pelagic species (jack mackerel, market squid, northern anchovy, Pacific mackerel, and Pacific sardine), groundfish, highly migratory species, and salmon. Tribal fishing does not affect the coastal waters near Huntington Beach (National Marine Fisheries Service [NMFS] Northwest Regional Office 2007a, 2007b; NMFS Southwest Regional Office 2007a, 2007b).

The California DFG requires licenses for all commercial fishermen and fishing vessels. In 2007, there were nearly 5,000 licensed commercial fishermen in the state and over 3,000 registered commercial vessels (California DFG 2007d). California DFG also issues permits to take certain species of fish or use certain gear types for commercial purposes. For example, the Department issues ocean enhancement stamps (required for landing white seabass south of Point Arguello) and commercial fishing salmon stamps (required when taking salmon commercially).

A commercial fishing license issued in California may contain provisions that

- establish the amount and size of species that may be taken
- designate the areas where the licensee is permitted to fish
- specify the season and the depths where the licensee may fish commercially
- specify the methods and gear that the licensee may use
- specify other terms, conditions, and restrictions.

Additionally the California DFG designates several fisheries as limited entry/restricted access fisheries. These determinations are based on extant fish populations as well as the pressure they receive. Those that are dwindling are restricted, with some permits being transferable and others non-transferable. Table 3-7 lists California's limited entry/restricted access fisheries.

California's coastal waters are divided into commercial fishing districts 6–20 (Figure 3-3). The coastal waters near Huntington Beach are part of District 19B (California DFG 2007a, 2007f). However, I&E impacts from HBGS may also affect commercial species in the other portions of the larger District 19.

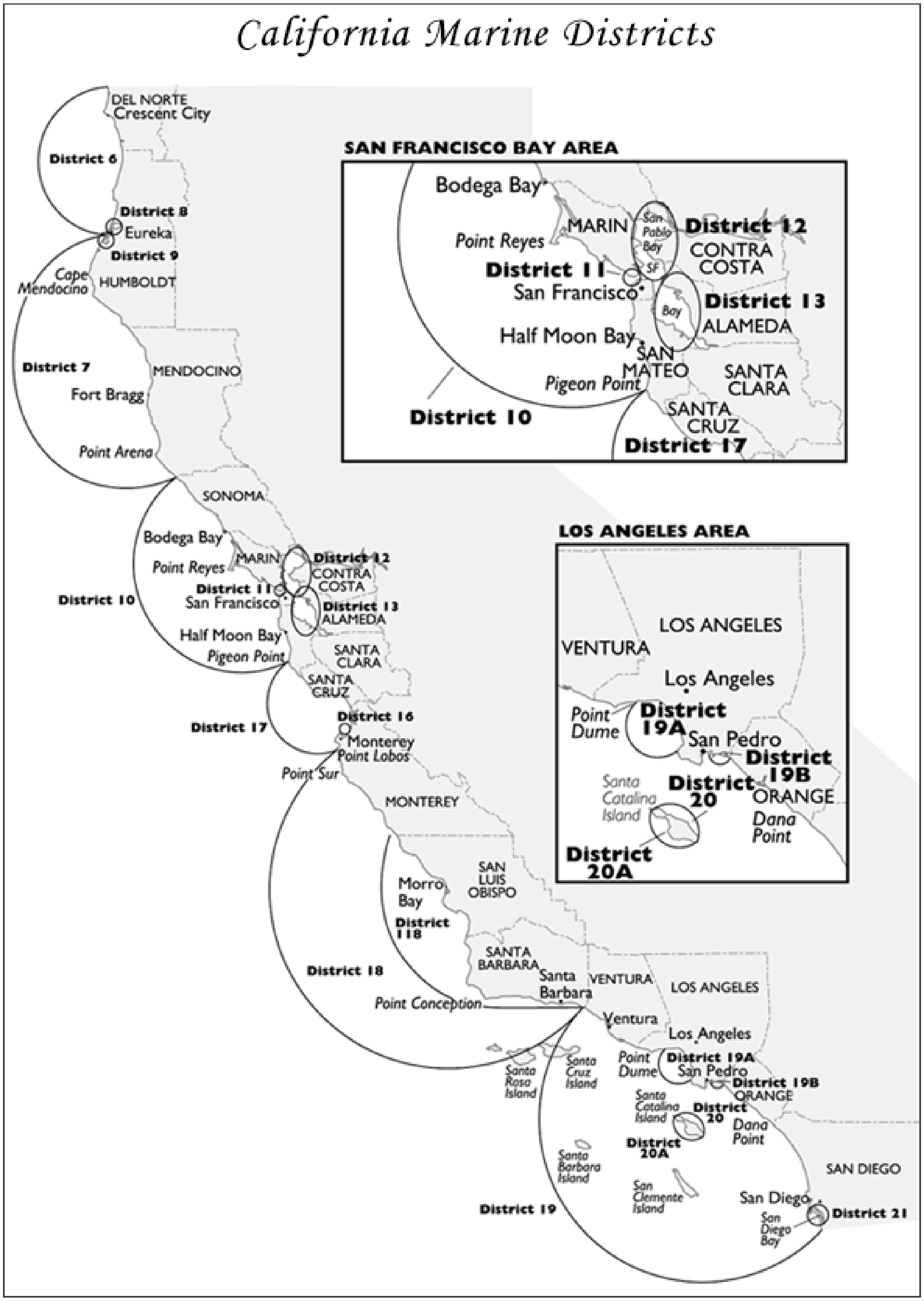
Table 3-7
Limited Entry/Restricted Access Fisheries of California

Type of Limited Entry/Restricted Access	Transferable	Non-Transferable
Herring Stamp		
Lobster Operator		
Market Squid Vessel	•	
Market Squid Vessel		•
Market Squid Brail	•	
Market Squid Brail		•
Market Squid Light Boat	•	
Market Squid Light Boat		•
Nearshore Fishery Permits		
North Coast Region	•	•
North-Central Coast Region	•	•
South-Central Coast Region	•	•
South Coast Region	•	•
Nearshore Fishery Trap Endorsements		
North-Central Coast Region	•	•
South-Central Coast Region	•	•
South Coast Region	•	•
Nearshore Fishery Bycatch Permit		
Northern Pink Shrimp Trawl Vessel	•	
Northern Pink Shrimp Trawl Vessel		•
Salmon Vessel		
Sea Cucumber Diving		
Sea Cucumber Trawl		
Sea Urchin Diving		
Southern Rock Crab Trap		
Spot Prawn Trap Vessel—Tier 1		
Spot Prawn Trap Vessel—Tier 2		
Spot Prawn Trap Vessel—Tier 3		

Source: California DFG (2007f)

Both the California DFG and the federal government regulate catch limits and fishery closures to help reduce overfishing in the California waters of the Pacific Ocean (72 *Fed. Reg*. 85 24543; California DFG 2007f, 2007g; International Pacific Halibut Commission 2007; NMFS Northwest Regional Office 2007c; National Oceanic and Atmospheric Administration 2006, 2007; Pacific Fishery Management Council 2006). Table 3-8 lists catch limits and closure dates by species and district for 2007–2008.

Table 3-9 lists the weight and dollar value of the commercial catch landed at ports in the Los Angeles area during 2006. The weight and dollar value of the commercial catch from ports near Los Angeles fluctuated from 2000 through 2006, as Figure 3-4 shows, reaching low points in 2003 (landings) and 2004 (value).



Source: California Fish and Game Commission (1998)

Figure 3-3
Commercial Fishing Districts of Coastal California

Table 3-8
Catch Limits and Closure Dates for Commercial Fisheries in District 19: 2007–2008

Species	District	Catch Limit	Closure Dates
Bigeye tuna	All		August 1–September 11, 2007
Cabezon	All	59,300	March 1–April 30, 2007
California halibut	Halibut trawl grounds		March 15–June 15, 2007
Chinook salmon	6, 7, 10, 17, 18, 19		October 1, 2007–April 30, 2008
Coho salmon	6, 7, 10, 17, 18, 19		All year
Coonstripe shrimp (trapping)	All		November 1, 2007–April 30, 2008
Dungeness crab	All districts except 6, 7, 8, 9		July 1–November 14, 2007
Greenling	All	3,400	March 1–April 30 and August 1–December 31, 2007
Nearshore fishery[a]	South of 40°10′		March 1–April 30, 2007
Pacific halibut	6, 7, 10, 11, 16, 17, 18, 19	31.7% X (1,340,000 lb. – 25,000 lb.) California and Oregon	November 1–December 31, 2007
Pacific sardine	All	152,564 metric tons Pacific coast	
Pink shrimp (trawling)	6, 7, 10, 17, 18, 19		November 1, 2007–March 31, 2008
Red sea urchin	All		April 1, 6–8, 13–15, 20–22, 27–29; May 4–6, 11–13, 18–20, 25–27; June 1–3, 7–10, 14–17, 21–24, 28–30; July 1, 4–8, 11–15, 18–22, 25–29; August 2–5, 9–12, 16–19, 23–26, 30–31; September 1–2, 7–9, 14–16, 21–23, 28–30; October 5–7, 12–14, 19–21, 26–28, 2007
Ridgeback prawn (trawling)	6, 7, 10, 17, 18, 19		June 1–September 30, 2007
Sea cucumber	Halibut trawl grounds		March 15–June 15, 2007
Sheephead	All	75,200	March 1–April 30, 2007
Skipjack tuna	All		August 1–September 11, 2007
Spiny lobster	18, 19, 20A, and part of 20		March 20–October 2, 2007
Spot prawn (trapping)	18, south of Point Arguello, 19, 19A, 20, 20A, 21		November 1, 2007–January 31, 2008
Surfperch	All		May 1–July 31, 2007
White seabass	All districts south of Point Conception		March 15–June 15, 2007
Yellowfin tuna	All		August 1–September 11, 2007

[a]The nearshore fishery consists of black rockfish, black-and-yellow rockfish, blue rockfish, brown rockfish, cabezon, calico rockfish, California scorpionfish, California sheephead, China rockfish, copper rockfish, gopher rockfish, grass rockfish, greenlings of the genus Hexagrammos, kelp rockfish, monkeyface eel, olive rockfish, quillback rockfish, and treefish.

Sources: California DFG (2007f, 2007g); California DFG, Marine Region (2007c, 2007d); 72 *Fed. Reg*. 85 24543; International Pacific Halibut Commission (2007); NMFS Northwest Regional Office (2007c); National Oceanic and Atmospheric Administration (2006, 2007); Pacific Fishery Management Council (2006)

Table 3-9
Commercial Catch Landed at Ports near Los Angeles: 2006

Fish/Shellfish	Dollar Value	Weight in Pounds
Market squid	$20,392,649	81,806,330
Pacific sardine	$3,244,992	59,043,970
California spiny lobster	$2,465,904	266,140
Pacific bonito	$1,359,972	4,885,920
Spot prawn	$906,099	83,035
Pacific mackerel	$800,619	12,594,563
Swordfish	$769,060	201,730
All other species	$3,041,551	6,512,958
Totals	**$32,980,846**	**165,394,646**

Source: California DFG (2006b)

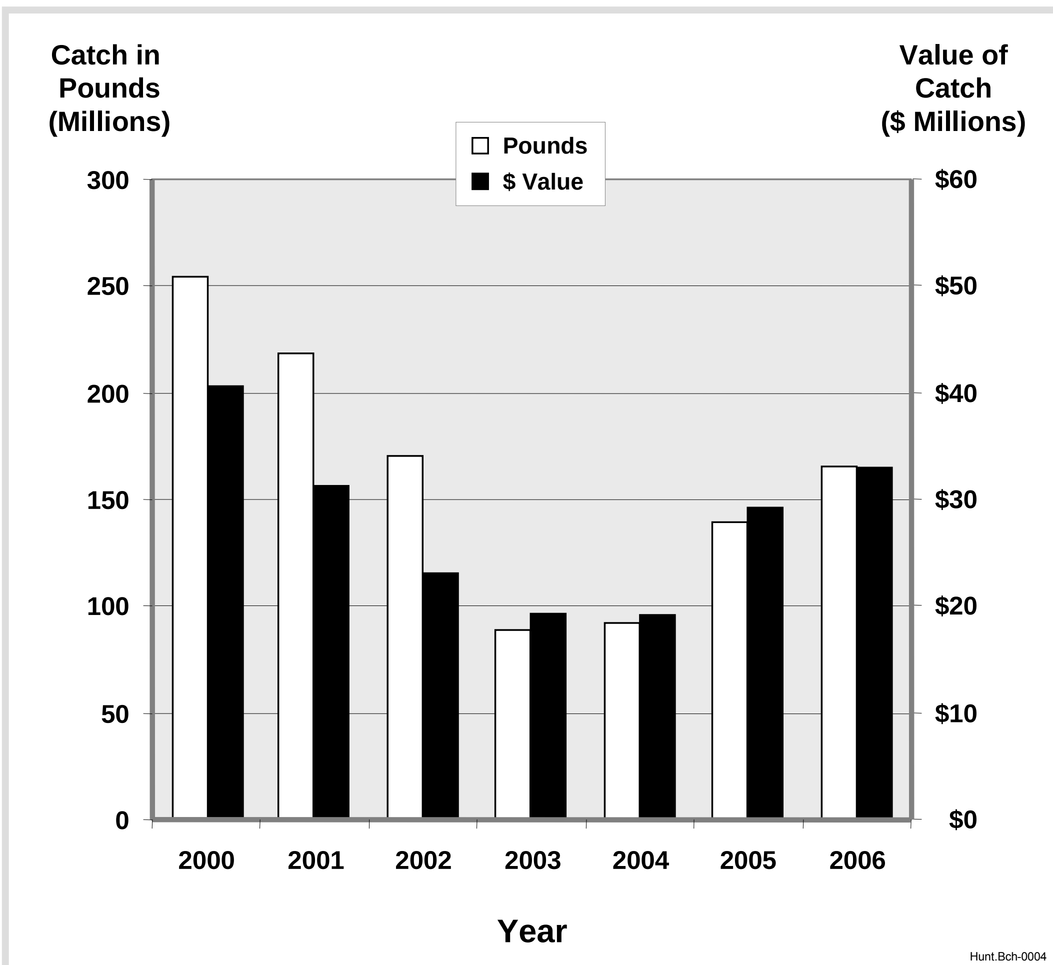


Figure 3-4
Pounds and Values of Commercial Catch Landed at Ports near Los Angeles, 2000–2006
This figure shows the weight and dollar value of commercial fish landings at ports near Los Angeles.

4
CHANGES IN CATCH

Age-structured population models are the best-recognized quantitative framework for the representation and evaluation of populations. Such models are often used for analysis of human demographics (Pollard 1973) and renewable resources (Getz and Haight 1989). Leslie (1945) developed the representation of a linear discrete population model as a matrix equation, now commonly referred to as the Leslie matrix population model. This model is frequently used in fisheries management and has long been an important component of professional judgment (PJ) 316(b) assessments under 1977 draft guidance (Akçakaya, Burgman, and Ginzburg 2002; Public Service Electric and Gas Company [PSEG] 1999; U.S. Environmental Protection Agency [EPA] 2002).[8]

In the assessment of I&E impacts, the advantages of population models include acceptability, correctness, and the ability to refine with improved information. However, these advantages are somewhat offset by significant data requirements. Development of a statistical model that estimates population effects requires I&E data, as well as population data over time. Approaches that employ the age-structure formulation in a dynamic simulation are less data intensive.[9] For example, life history and I&E estimates are sufficient when using simulations that represent part of the population. In situations where there is limited information about species life history, transfers using life history parameters, such as survival and fecundity, of similar species are sometimes employed. Because these approaches rely on dynamic simulation, specification errors can compound. This can lead to dramatic errors when minor differences between species are extrapolated through time.

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[8] Fishery managers use the Leslie matrix in various applications. For example, the Shark Population Assessment Group of the National Oceanic and Atmospheric Administration (2006) uses the Leslie matrix to represent the population dynamics of sharks through demographic methods and to assess the status of shark stocks through stock assessment methodology. Sabaton et al. (1997) use a mathematical model to represent long-term change in a trout population under different river management scenarios. Their model describes the structure of a population divided into age classes based on the Leslie matrix. Hein et al. (2006) use an age-structured Leslie matrix model to determine which removal method most effectively reduced the population of invasive rusty crayfish in an isolated lake in Wisconsin. Carlson, Cortés, and Bethea (2003) simulated Leslie matrices to study the life history and population dynamics of the finetooth shark in the northeastern Gulf of Mexico.

[9] We use the term dynamic simulation to refer to a mathematical simulation that models changes over time using the difference equations of population dynamics.

Unfortunately, life history and population information for impinged and entrained species at HBGS is scarce. Despite this drawback, the conversion of impingement and entrainment impacts to fishery impacts in this assessment employs a dynamic population assessment approach. When life history information is unavailable, transferred parameters are employed.[10] Potential problems with compounding errors are addressed with adjustments based on mathematical simulation techniques. Here a distinct advantage of using models with known properties and fishery implications is that adjusted and transferred parameters can be combined with species specific information in a manner that has specific implications for observable population-level outcomes. This allows calibration based on bounds selected through empirical or even anecdotal information. This approach also supports the identification of cost-effective data sources to improve model accuracy.

Without population data, estimated annual impacts can be projected through these models to identify numeric (not percentage) impacts. With population information, percentage impacts can be identified. In either case, fishery impacts can be evaluated through specification of recreational and commercial mortality rates. With limited information, the reasonable specification of relative mortality rates (recreational, commercial, natural) is sufficient to identify timing and amount for recreational and poundage for commercial fishery impacts. With more information, the I&E assessment methodology could be synchronized with existing fishery models.

Under certain conditions, reductions in early life stage survival are reflected in equivalent changes in populations (Newbold and Iovanna 2007a, 2007b). The associated mathematics, as well as some preliminary simulations, identify the conditions under which reductions in early life-stage mortality lead to equivalent changes in expected catch (i.e., a 2-percent reduction in early life stage survival is associated with a 2-percent reduction in steady-state recreational catch rates and a 2-percent reduction in steady-state commercial catch rates). The direct extrapolation of changes in survival rates to equivalent changes in catch rates over a sampled impact area is an approach that has been supported by California regulatory agencies.

The approach taken here is to calibrate fishing mortality rates from life-history tables such that numeric changes estimated from population dynamic models are equivalent to percentage changes in catch rates implied by reductions in early life-stage survival rates.[11] For example, if biological sampling indicates a 1-percent reduction in early life-stage survival over an area with an annual recreational harvest of 1,000 fish the life-history table is calibrated so that it forecasts a steady-state reduction of 10 fish. This approach has the advantage of consistency with existing methodologies and mathematical rigor. The details and mathematical assumptions of this approach are detailed further in this text.

[10] Using transferred parameters has been generally characterized as benefits transfer, the use of existing information designed for one context to address policy questions in another. This approach is commonly used in practical policy analysis when it is generally prohibitively expensive or impossible to implement original studies (see Desvousges, Johnson, and Banzhaf 1998).
[11] In two cases (commercial anchovies and commercial rock crab), severe violations of underlying assumptions invalidate this approach and it is not applied.

The Leslie Matrix

The mathematical representation of the Leslie matrix is:

$$\underbrace{\begin{pmatrix} N_{1,t+1} \\ N_{2,t+1} \\ N_{3,t+1} \\ \vdots \\ N_{A,t+1} \end{pmatrix}}_{\substack{\textbf{Estimated} \\ \textbf{Population at} \\ \textbf{Time t+1}}} = \underbrace{\begin{pmatrix} \overbrace{S_0 f_1 \quad S_0 f_2 \quad \cdots \quad S_0 f_A}^{\textbf{Fecundity}} \\ \begin{matrix} S_1 & 0 & \cdots & 0 \\ 0 & S_2 & 0\ldots & 0 \\ \vdots & 0 & \vdots & \vdots \\ 0 & \cdots & S_{A-1} & 0 \end{matrix} \end{pmatrix}}_{\textbf{Transition Matrix}} \underbrace{\begin{pmatrix} N_{1,t} \\ N_{2,t} \\ N_{3,t} \\ \vdots \\ N_{A,t} \end{pmatrix}}_{\substack{\textbf{Initial} \\ \textbf{Population at} \\ \textbf{Time t}}} \qquad \textbf{(4-1)}$$

This representation consists of a population vector and a transition matrix. $N_1 ... N_A$ is the population vector (on the far right of Equation 4-1). The population vector represents the age-structured population of a single stock at time t. Using a population of queenfish as an example, $N_{1,t}$ would be the number of age one queenfish in the population at time t, $N_{2,t}$ would be the number of age twos in the population at time t, through all the life stages for queenfish.

The transition matrix (in the middle of Equation 4-1) contains two types of information. The first type of information is survival rates, represented by the S_ns. Survival rates include both natural mortality (M) estimates and fishing mortality (F) estimates. The survival rate can be calculated for each life-stage transition by applying Baranov's catch equation (C=FN(average) or $C=\frac{F}{Z}AN_0$) to standard mortality tables (Ricker 1975). In this development, survival is an exponential relationship of M and F:

$$\text{Survival (S)} = e^{-(M+F)} \qquad \textbf{(4-2)}$$

Survival rates in the transition matrix represent the probabilities that a fish in a population will survive to the next life stage. Applied at the population level, these survival probabilities are the percentage of one life stage that survives to the next.

The second type of information contained is the transition matrix is fecundity, represented by f_ns. Fecundity is the average number of eggs laid annually by each female of a particular age-class. For example, the f_1 in the matrix above represents the average number of eggs laid by an age one female.

As the equality condition indicates, multiplying the age-structured population vector at time t by the transition matrix returns the age-structured population vector at time t + 1. Thus, with knowledge of a population's structure and the transition matrix, it is possible to predict the population's structure in the next time period. Proceeding in an iterative way allows simulation of populations for future periods.

Process for Determining Fishery Impacts at HBGS

This section presents the methodology employed to determine the fishery impacts associated with I&E at HBGS. Our process began by reviewing the annual estimates of I&E provided by MBC and Tenera (2007). This report contains annual estimates of impinged and entrained species that represent about 90 percent of the total organisms impinged or entrained. To account for I&E impacts associated only with Units 1 and 2, we divide the annual entrainment estimates by 2. Table 4-1 below contains the annual I&E estimates used in the benefits assessment.

Table 4-1
Annual I&E Impacts at HBGS for Units 1 and 2

Species	Annual Impingement	Annual Entrainment (Larvae)
CIQ gobies	0	56,593,417
northern anchovy	2,193	27,174,509
spotfin croaker	49	34,850,795
queenfish	35,847	8,904,932
white croaker	4,903	8,812,632
black croaker	65	3,564,064
salema	46	5,848,480
blennies	3	3,582,757
diamond turbot	0	2,721,559
California halibut	21	2,510,584
shiner perch	4,045	0
sand crab megalops[a]	N/A	34,897
California spiny lobster[b]	32	0
market squid[b]	7	0
rock crab	5,820	3,205,586
nudibranch[a]	65,150	0
two spotted octopus[b]	61	0
purple-striped jelly[b]	53	0

Source: MBC and Tenera (2007)

[a] See the discussion of forage species below.

[b] Due to the low frequency of impingement, and the paucity of life history parameters for invertebrates, these species are not considered further.

For each species in Table 4-1, our review included a determination of whether species-specific life history parameter information was available. When precise information was not available, a transfer and calibration process was applied. Table 4-2 identifies the sources of the life history parameters used in this assessment. Transfer species are selected on the basis of biological similarity (i.e., lifespan, size) with consultation of fishery experts.

Table 4-2
Source of Life History Parameters by Species

Impinged and Entrained Species at HBGS	Fecundity			Mortality	
	Species	Eggs per Year	Source	Species	Source
CIQ gobies	goby	1,538	MBC and Tenera (2007)	gobies	EPA (2004b), Table B1-17
northern anchovy	anchovy	20,000 to 320,000	MBC and Tenera (2007)	anchovy	EPA (2004b), Table B1-2
spotfin croaker	white croaker	800 to 37,200	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
queenfish	queenfish	5,000 to 90,000	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
white croaker	white croaker	800 to 37,200	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
black croaker	white croaker	800 to 37,200	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-13
salema	salema	21,600	Muncy (1984)	other forage	EPA (2004b), Table B1-39
blennies	blennies	1,265	MBC and Tenera (2007)	blennies	EPA (2004b), Table B1-5
diamond turbot	Atlantic winter flounder	600,000	EPRI (2005)	flounder	EPA (2004b), Table B1-15
California halibut	California halibut	5.5 million	MBC and Tenera (2007)	California halibut	EPA (2004b), Table B1-7
shiner perch	shiner perch	5 to 20 young	MBC and Tenera (2007)	surfperch	EPA (2004b), Table B1-35
sand crab	sand crab	100,000	MBC and Tenera (2007)	other commercial crab	EPA (2004b), Table B1-23
graceful rock crab	graceful (slender) crab	681,000	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-23
yellow rock crab	yellow crab	3.3 million	MBC and Tenera (2007)	drum/croaker	EPA (2004b), Table B1-23
Pacific rock crab	Pacific (brown) crab	1.8 million	MBC and Tenera (2007)	other commercial crab	EPA (2004b), Table B1-23

The remainder of this section describes the process used to generate estimates of fishery impacts using queenfish as a specific example. This species is both impinged and entrained at HBGS, and the species-specific life history parameters are limited. Although species-specific fecundity information is available, mortality information is not. We considered several sources of information to determine the survival rates of queenfish: EPA's Section 316(b) Phase II Final Rule Regional Analysis for California (EPA 2004b) and MBC and Tenera (2007). Neither report contains a specific life history table for queenfish. However, EPA includes queenfish in the drum/croaker group. Based on this information, and with support from fishery experts from MBC and Tenera, this assessment employed croaker life history parameters for queenfish.

EPRI's life history table for croaker includes daily mortality rates by life stage, but does not differentiate between natural and fishing mortality. EPA, on the other hand, includes both natural and fishing mortality rates for each life stage. For this assessment fishing mortality rates are calibrated based on reported local catch rates.

Figure 4-1 describes the approach for assessing harvest impacts associated with I&E in a data-poor environment. As indicated in the figure, the first step integrates transfer information from other species and species-specific information with professional judgment to identify the survival and fecundity components of the transition matrix. In the second step, the specified life history information is evaluated for empirical validity, using implications for long run growth rates. If the long run population growth rate is not consistent with empirical and anecdotal information, professional judgment and calibration are used to adjust the specification of survival parameters. In the third step, specified survival rates are replaced with fishing mortality rates to calculate fishing deaths. In the fourth step, the harvest changes are developed based on calibration to local fishery harvest information. For recreational species, the results are expressed as a number of fish. For commercial species, the results reflect additional pounds of fish harvested. These four steps are illustrated in the following sections.

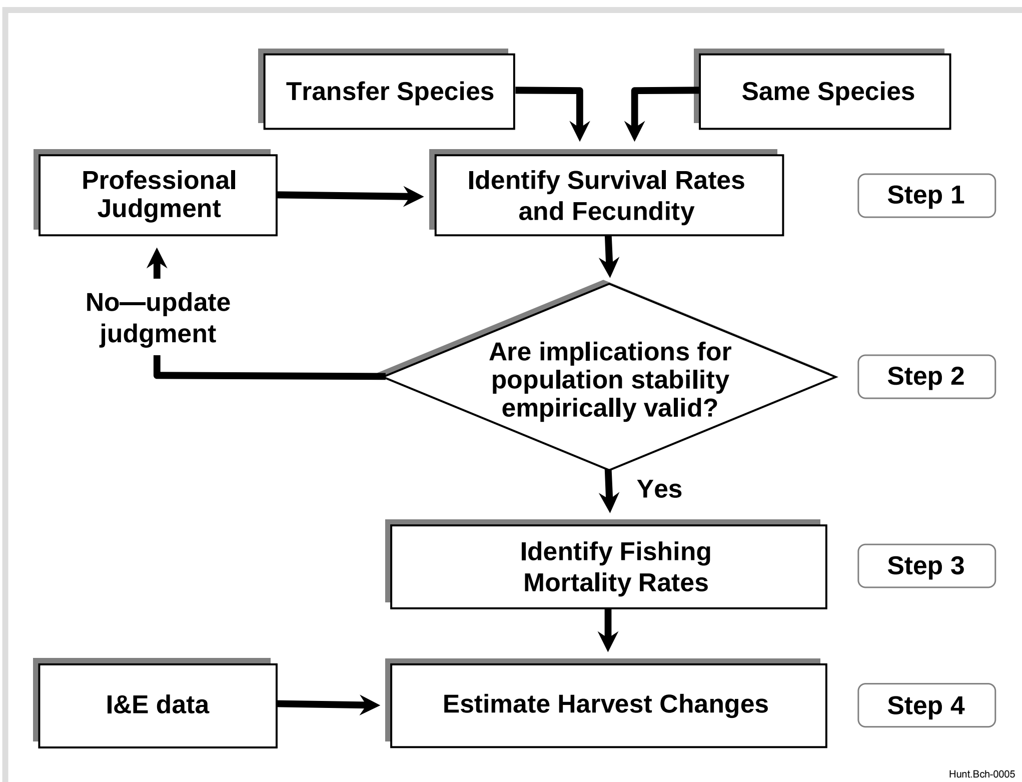


Figure 4-1
Population Dynamic Framework to Support Fishery Harvest Assessment in Data-Poor Environment

When no population or life-history estimates are available, the approach depicted in this figure demonstrates the application of a population dynamic framework to support the assessment of impacts to fishery harvest.

Step 1—Develop Transition Matrix

In a data-poor situation, the survival and regeneration components of a population dynamic model are developed using the best available information and professional judgment. The transition matrix is constructed so that the number in a specific cell is the probability an age-class member will survive to the next age-class. In Figure 4-2 below, age one fishes will have a 0.657 probability of surviving to become age two fishes. Applied at the population level, these survival probabilities are the percentage of one life stage that survives to the next.

	Eggs	Larvae	Juvenile	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Eggs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Larvae	0.6065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile	0	9.952m	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 1+	0	0	0.03405	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 2+	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0

Figure 4-2
A Basic Leslie Transition Matrix with Survival Probabilities

When a population at time t is multiplied by the above transition matrix (Equation 4-1), a proportion of the age ones will survive the year and transition to age twos at time t+1. The following example demonstrates how to calculate the survival rate (S) for the transition from an age three queenfish to an age four queenfish using mortality values from EPA mortality tables. The age three-to-age-four transition is used as an example because this is the earliest life stage of queenfish that includes fishing mortality. For this species, the natural and fishing mortality parameters are the same when applying equation 4-2.

$$\text{Survival (S)} = e^{-(0.21 + 0.21)} = 0.657 \qquad \textbf{(4-3)}$$

A population regenerates by spawning. Regeneration can be represented in the transition matrix by including stage-specific fecundity in the top row of the transition matrix. The top row of the transition matrix represents the number of eggs expected from the spawn of mature females.

The *AES Huntington Beach L.L.C. Generating Station Entrainment and Impingement Study Report* (MBC and Tenera 2007) includes reproduction information specific to queenfish. The fecundity information in this section is drawn from MBC and Tenera's report. The fecundity of queenfish for each mature adult (age two fishes and above) is expected to lay between 5,000 and 90,000 eggs. This information is incorporated by specifying annual egg laying for each female as demonstrated in Figure 4-3.

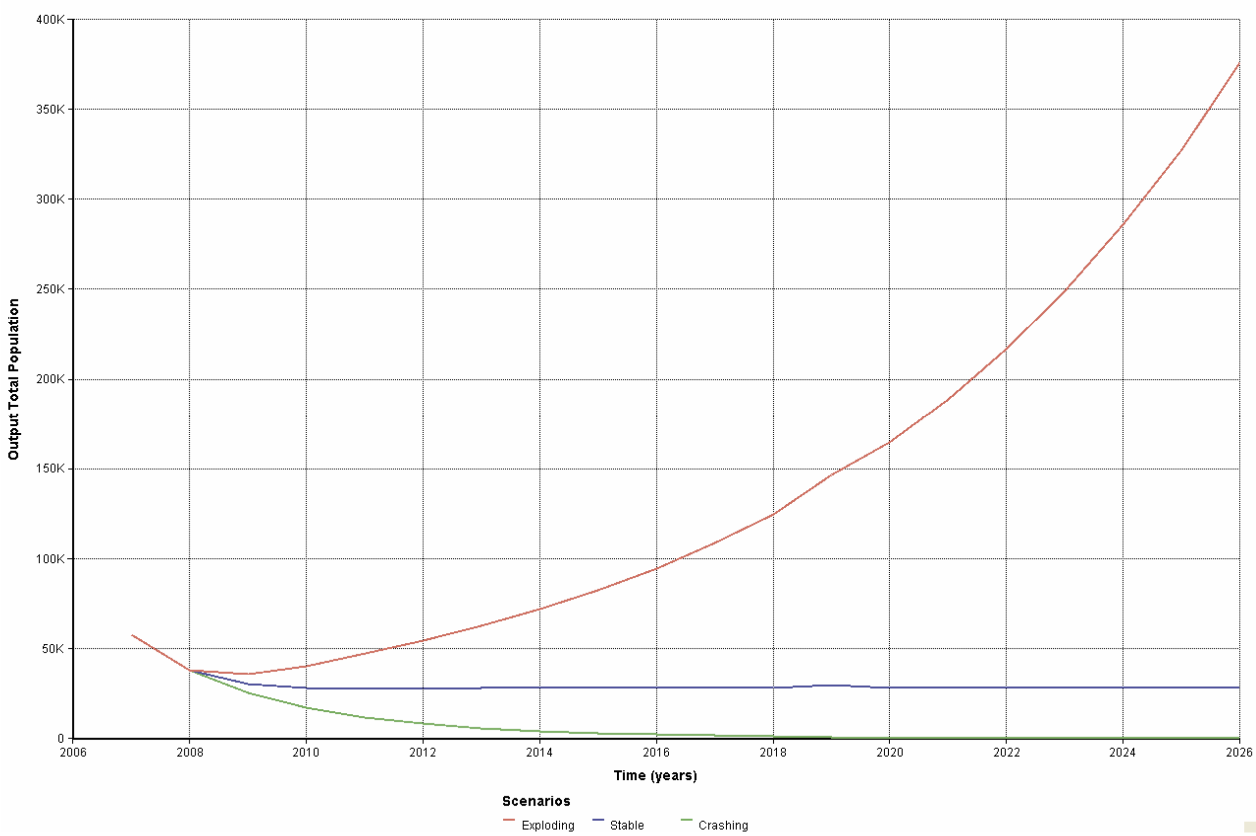
	Eggs	Larvae	Juvenile	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Eggs	0	0	0	0	5000	13K	21K	29K	37K	45K	53K	61K	69K	77K	90K	0
Larvae	0.6065	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Juvenile	0	9.952m	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 1+	0	0	0.03405	0	0	0	0	0	0	0	0	0	0	0	0	0
Age 2+	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.657	0

Figure 4-3
Transferred Queenfish Transition Matrix with Regeneration[12]

Step 2—Calibrate Transition Matrix

After specifying the transfer-based transition matrix, it is calibrated based upon information available about the population. Once the classification of the population's growth behavior is determined, it can be used to calibrate the simulation model. For this assessment we consider that transfer-based simulations of population growth will indicate that populations are crashing, decreasing, stable, increasing, or exploding. Figure 4-4 below depicts simulations of populations that are exploding, stable, and crashing.

[12] The model is based on females. Changes estimated for females are adjusted to reflect males.



Example 1: An Exploding Population
Example 2: A Steady-State Population
Example 3: A Crashing Population

Figure 4-4
Simulations of Steady-State Population Changes Based on Transferred Information

After the initial Leslie transition matrix is configured with mortality rates, survival rates, and fecundity, simulated population growth behaviors are used to calibrate the life history specification to fine-tune the population's modeled growth or contraction. For example, a population that is assumed stable is calibrated to a long-run population growth of 1.[13] This means that each member of the population is replaced so that the size of the population remains constant over time.

Because most survival uncertainty is associated with early life stages (Quinlan and Crowder 1999), the calibration is applied prior to age one fishes. For example, if the actual population is a steady-state population but the simulation based on the transferred life history table is exploding, then a calibration modification is implemented to decrease the probability of survival to age one. By increasing the mortality of the pre-age one life stages, the calibration limits the growth of the population. This calibration can be tuned until the projected simulation behavior or growth rate

[13] The population growth rate is identified by examining the dominant eigenvalue of the transition matrix. An eigenvalue is the sum of squared values in the column of a factor matrix. The dominant eigenvalue (E_d) for the transition matrix is equivalent to the population growth rate, where: $E_d > 1$ increasing, $E_d = 1$ stable, and $E_d < 1$ decreasing.

match the expected behavior for the population. Doing so minimizes the likelihood of compounding error problems associated with dynamic simulations using uncalibrated transfer parameters.

Figure 4-5 depicts the growth rate of queenfish population based on the croaker transfer parameters. Initially it indicates an exploding population (green). Based on professional judgment, we determined that a more appropriate specification is a stable population, depicted in red. A growing population is depicted for illustrative purposes in blue.

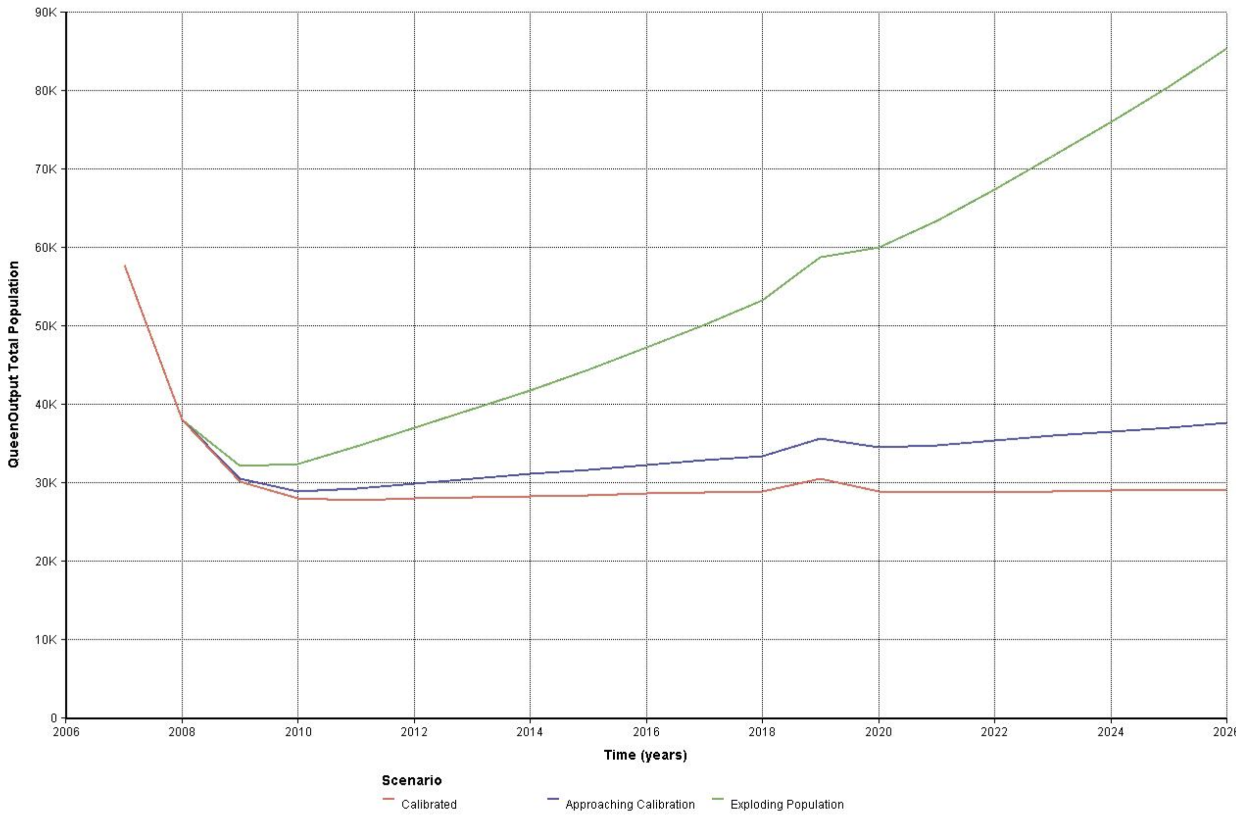


Figure 4-5
Calibration of Transferred Life History Specification for Queenfish

Step 3—Determine Recreational and Commercial Harvest Rates

An important advantage of age-structured population modeling for estimating I&E impacts is the information that survival rates imply for recreational and commercial catch. It is possible to structure the transition matrix to decompose death outcomes into commercial, recreational and natural. A dynamic simulation with specified fishing mortality rates by age can be used to identify numeric changes in catch for each age class and future year. The equations below demonstrate how the components of survival are represented in a typical life history table, where "rate" can be interpreted as the probability of advancing to another stage in the next year.

Total Death Rate = 1 – Total Survival Rate **(4-4)**

Natural Death Rate	=	M/(M+F) * Total Death Rate	**(4-5)**
Fishing Death Rate	=	F/(M+F) * Total Death Rate	**(4-6)**
*Commercial Death Rate	=	% of Commercial Fishing Mortality * Fishing Death rate	**(4-7)**
*Recreational Death Rate	=	(1 – % of Commercial Fishing Mortality) * Fishing Death rate	**(4-8)**

Deconstructed in this manner, the age-structured population modeling approach can provide a great deal of information about commercial and recreational impacts. For example, a species like anchovies that is commercially fished but not recreationally fished could have an upper bound impact identified by specifying all deaths as commercial catch. Representing all mortality as fishing mortality provides an upper bound for catch changes. For species that are fished commercially and recreationally, all death can be specified as fishing death and the distribution of commercial versus recreational catch can be used in sensitivity analysis. If empirical, anecdotal, or professional judgment indicates that the species is not overfished, the percentage of death that is commercial catch would be adjusted downward. Species that are fished recreationally are considered in a similar fashion. Expected value estimates for species that are fished recreationally and commercially can be identified by applying ratios from aggregated creel and harvest information to harvest rates. With respect to the approach employed in this assessment, proportional changes in expected catch over a geographic area are calibrated to equal sub-adult entrainment rates as identified in the I&E report (MBC and Tenera 2007).

Returning to the queenfish (age three fishes) as an example, the fishing death rates originally specified are:

Total Survival Rate	=	$e^{-(0.21+0.21)}$	=	0.657	**(4-9)**
Total Death Rate	=	1 – 0.657	=	0.343	**(4-10)**
Natural Death Rate	=	0.21/0.42 * 0.343	=	0.1715	**(4-11)**
Fishing Death Rate	=	0.21/0.42 * 0.343	=	0.1715	**(4-12)**
Comm. Death Rate	=	0.309 * Fishing Death rate	=	0.05299	**(4-13)**
Recr. Death Rate	=	0.691 * Fishing Death rate	=	0.1185	**(4-14)**

Figure 4-6 below is the calibrated queenfish transition matrix developed earlier with additional rows that accommodate the decomposition of mortality rates. Note that age three fishing mortality rates are highlighted.

	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Age 1+	0	0.3199	0.3536	0.3872	0.4209	0.4546	0.4882	0.5219	0.5556	0.5893	0.6229	0.6566	0
Age 2+	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0.657	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0.657	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0.657	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0.657	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0.657	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0.657	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0.657	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0.657	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0.657	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0.657	0
Count Caught Rec	0	0	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0.1185	0
Count Caught Comm	0	0	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0.05299	0
Count Died Naturally	0.343	0.343	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0.1715	0

Figure 4-6
Queenfish Transition Matrix with Commercial and Recreational Fishing Mortality

A review of local recreational and commercial harvest is used to calibrate the life history table. Local commercial fishing data indicates that queenfish is not commercially fished. Accordingly, the commercial mortality rate is calibrated to zero.

Under certain conditions, equilibrium catch impacts from population dynamic models are roughly equivalent to fishery impacts (Newbold and Iovanna (2007a). These include high early life stage mortality rates, high fecundity, and evenly distributed fishing and I&E pressure.[14] Figure 4-7 depicts the final calibrated Leslie transition matrix.

	Age 1+	Age 2+	Age 3+	Age 4+	Age 5+	Age 6+	Age 7+	Age 8+	Age 9+	Age 10+	Age 11+	Age 12+	Age 13+
Age 1+	0	0.3199	0.3536	0.3872	0.4209	0.4546	0.4882	0.5219	0.5556	0.5893	0.6229	0.6566	0
Age 2+	0.657	0	0	0	0	0	0	0	0	0	0	0	0
Age 3+	0	0.657	0	0	0	0	0	0	0	0	0	0	0
Age 4+	0	0	0.7298	0	0	0	0	0	0	0	0	0	0
Age 5+	0	0	0	0.7298	0	0	0	0	0	0	0	0	0
Age 6+	0	0	0	0	0.7298	0	0	0	0	0	0	0	0
Age 7+	0	0	0	0	0	0.7298	0	0	0	0	0	0	0
Age 8+	0	0	0	0	0	0	0.7298	0	0	0	0	0	0
Age 9+	0	0	0	0	0	0	0	0.7298	0	0	0	0	0
Age 10+	0	0	0	0	0	0	0	0	0.7298	0	0	0	0
Age 11+	0	0	0	0	0	0	0	0	0	0.7298	0	0	0
Age 12+	0	0	0	0	0	0	0	0	0	0	0.7298	0	0
Age 13+	0	0	0	0	0	0	0	0	0	0	0	0.7298	0
Count Caught Rec	0	0	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0.09007	0
Count Caught Comm	0	0	0	0	0	0	0	0	0	0	0	0	0
Count Died Naturally	0.343	0.343	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0.1801	0

Figure 4-7
Queenfish Transition Matrix with Calibration

[14] By evenly distributed fishing and I&E pressure, we mean that the area of I&E impacts and fishing impacts are similar. For brown rock crab and anchovy, this assumption is violated and the calibration is made virtually impossible. Uncalibrated fishing mortality parameters are employed for these species.

Step 4—Estimate Changes in Harvests

Under these assumptions and following geographic areas and entrainment rates as listed in the I&E report, the equilibrium change in recreational catch of queenfish is approximately 270[15] fish annually. Employing these assumptions, and consistent with methodologies previously approved by California regulators, recreational harvest rates are calibrated such that the number of queenfish lost to the recreational harvest is equal to the number implied by percentage impacts.

Identifying numeric changes in catch for each species and year is accomplished by summing recreational catch for each year over age-classes. Figure 4-8 depicts the estimated change in recreational catch of queenfish associated with a 90-percent reduction in I&E at HBGS that began in 2006.

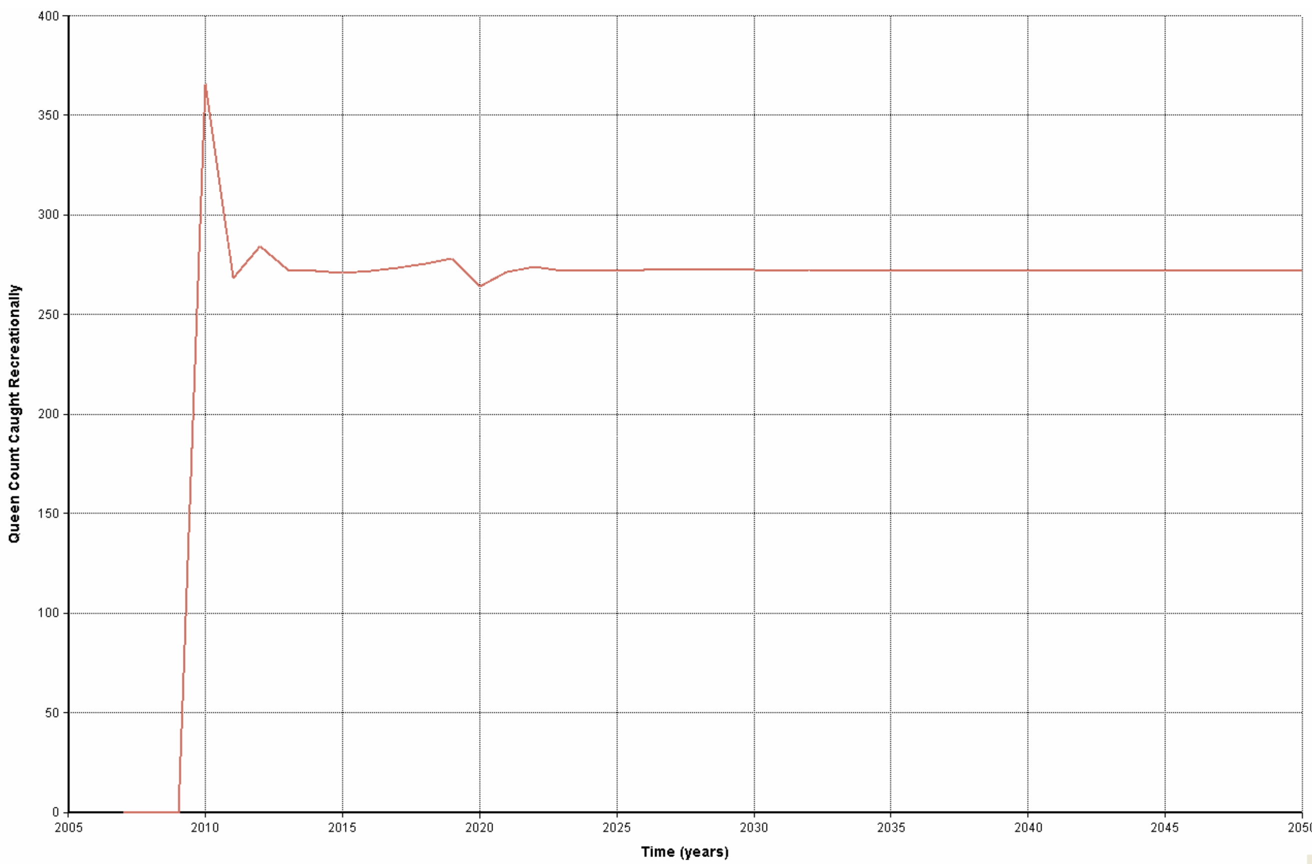


Figure 4-8
Change in Recreational Catch of Queenfish by Year

[15] The calibration is done for entrainment only. Impingement rates are added to the dynamic model after calibration occurs.

Incorporating Forage Species

Because commercial and recreational anglers do not target them, forage fish such as gobies are considered to have indirect economic benefits. In this context, indirect-use benefits arise from the role forage species play in supporting game fish populations. Indirect-use benefits can be calculated by evaluating the degree of energy transfer that occurs through the consumption of gobies and other forage fish by game fish. However, this approach requires knowing whether and to what degree limited availability of forage species constrains the populations of commercial and recreational species. There are two general situations:

1. Lack of forage fish does not constrain populations of commercially and recreationally valuable species.
2. Lack of forage fish does constrain populations of commercially and recreationally valuable species.

Valuation in the first instance is straightforward. When forage fish availability does not constrain commercial and recreational populations, impingement and entrainment of forage fish does not impact game fish populations and indirect use values are zero. When the lack of forage species availability does constrain commercial and recreational populations, forage losses are greater than zero, but can potentially be valued using trophic transfer. For purposes of this assessment, we have assumed that populations of harvested species are constrained and incorporate them through a trophic transfer methodology.

Incorporating forage species into this assessment begins with the same process outlined above in Figure 4-1. We first evaluate the available information on survival and fecundity for the forage species. When species-specific information is not available, we use the transfer data identified above in Table 4-2. However, the process departs from the figure at Step 3. Rather than focusing on fishing mortality rates, we evaluate natural mortality rates, which include consumption by other species.

Literature on trophic transfer rates suggests that a trophic transfer efficiency of 10 percent across all species is reasonable. For example, Pauly and Christensen (1995) compiled 140 estimates of trophic transfer efficiency from 48 trophic models of aquatic ecosystems. Pauly and Christensen found that although the range of values was very wide, the mean value was 10 percent and only a few of the values were 20 percent or higher. This finding also is bolstered by more recent work with bioenergetics models that support a value of 10 percent (PSEG 1999). Similarly, the EPA used a 10 percent transfer rate in its final rule (EPA 2004b). However, this approach apparently assumes that all the lost forage production would have been consumed by harvested species. In fact, it is likely that a large portion of the forgone production is consumed by intermediate predators and *then* by harvested species. In addition, it is also likely that a much lower proportion of forage fish are actually consumed by predators. Thus, the assumption that harvested species *directly* consume *all* forage biomass likely leads to an overestimate of the harvested gains.

Forage species evaluated for Huntington Beach include nudibranchs, sand crabs, blennies, gobies, and salema. However, no sportfish consume nudibranchs. Cephalaspidea (also known as headshield slugs and bubble shells) and navanax, a brightly colored sea slug, prey on nudibranchs. Other potential predators avoid attacking nudibranchs because of their color (Wägele and Klussmann-Kolb 2005; Sheckler 1999; Judd 1998). Accordingly, we estimate no impacts to recreational or commercial fisheries associated with the impingement of nudibranchs.

For the other affected forage species, their predators include sportfish:

- Sportfish prey on gobies, particularly arrow goby. Lane and Hill (1975) note that California halibut is probably the major predator of arrow goby. Other predators of arrow goby include cabezon, California corbina, diamond turbot, leopard shark, queenfish, staghorn sculpin, walleye surfperch, and white croaker. Sharks and rays prey on yellowfin goby. California halibut and other finfish prey on longjaw mudsucker, another goby.
- The California Energy Commission (undated) note that California halibut and other large predators may prey on salema.
- Octopus, kelp bass, and cabezon prey on blennies (Feder, Turner, and Limbaugh 1974; Cephbase 2003).
- The barred surfperch preys on sand crabs, which makes up 90 percent of the barred surfperch's diet (LIMPETS undated).

For purposes of this assessment, we assume that all gobies, blennies, salema, black croaker, and shiner perch are converted to California halibut through a 10 percent trophic transfer. Similarly, we convert biomass of sand crabs to surfperches.

Results

This section contains the results of the dynamic population impacts for the impinged and entrained species at HBGS. Based on the discussion of forage fish above, these results reflect the population impacts only for harvested species. For recreational species, the impacts are expressed in numbers of fish. For commercial species, the impacts are expressed in pounds of fish.

The following tables contain the results for the forgone recreational harvests of impinged species, recreational harvests of entrained species, commercial harvests of impinged species, and commercial harvests of entrained species. The time of benefits is specified as though technology is installed during 2008 and operated for 20 years.

Table 4-3
Forgone Harvest of Recreational Species Impinged and Entrained at HBGS
(Number of Fish)

Year	White Croaker	Queenfish	California Halibut	Spotfin Croaker	Diamond Turbot
2008	0.0	0.0	0.0	0.0	5.3
2009	0.0	0.0	0.0	0.0	8.2
2010	115.1	538.3	0.0	2.5	8.7
2011	86.7	395.0	0.0	2.0	8.7
2012	95.5	418.9	0.0	2.2	8.4
2013	92.5	401.0	48.0	2.2	8.6
2014	93.6	400.5	40.8	2.2	8.6
2015	93.8	398.9	34.8	2.2	8.6
2016	94.5	400.1	36.8	2.3	8.6
2017	95.2	402.3	37.5	2.3	8.6
2018	96.1	405.4	37.1	2.3	8.6
2019	97.0	409.1	37.1	2.4	8.6
2020	91.2	388.9	37.3	2.1	8.6
2021	93.9	400.0	37.3	2.2	8.6
2022	94.4	403.1	37.3	2.2	8.6
2023	94.1	400.4	37.4	2.2	8.6
2024	94.2	401.1	37.4	2.2	8.6
2025	94.1	400.6	37.5	2.2	8.6
2026	94.2	400.7	37.5	2.2	8.6
2027	94.2	400.7	37.6	2.2	8.6

Table 4-4
Forgone Harvest of Commercial Species Impinged and Entrained at HBGS
(Pounds of Fish)

Year	White Croaker	California Halibut	Northern Anchovy	Rock Crab
2008	0.0	0.0	0.0	0.0
2009	0.0	0.0	0.0	0.0
2010	33.7	0.0	7.0	0.0
2011	31.1	0.0	7.2	0.6
2012	36.9	0.0	7.4	0.6
2013	39.3	13.2	7.6	0.6
2014	42.1	15.4	7.3	0.6
2015	44.0	16.5	7.4	0.6
2016	45.8	19.3	7.4	0.6
2017	47.2	20.6	7.4	0.6
2018	48.4	21.7	7.4	0.6
2019	49.6	22.9	7.4	0.6
2020	42.5	23.6	7.4	0.6
2021	44.8	24.2	7.4	0.6
2022	44.7	24.9	7.4	0.6
2023	45.0	25.4	7.4	0.6
2024	45.1	25.9	7.4	0.6
2025	45.2	26.3	7.4	0.6
2026	45.3	26.7	7.4	0.6
2027	45.3	27.0	7.4	0.6

5
FISHERY VALUATION OVERVIEW

The California coastal waters near Huntington Beach support a range of commercial and recreational fishing. Considering the impacts of reduced I&E on species abundance and composition, we expect human welfare to improve. Increases in the abundance and changes in the composition of fish species proximate to the HBGS may be expected to change the levels of commercial and recreational fishing in the area as fishers take advantage of the improved fishing opportunities. Individuals who stand to gain from these changes include consumers and producers of commercially important fish species harvested in the ecosystem and recreational fishers. These relationships are depicted in Figure 5-1 below.

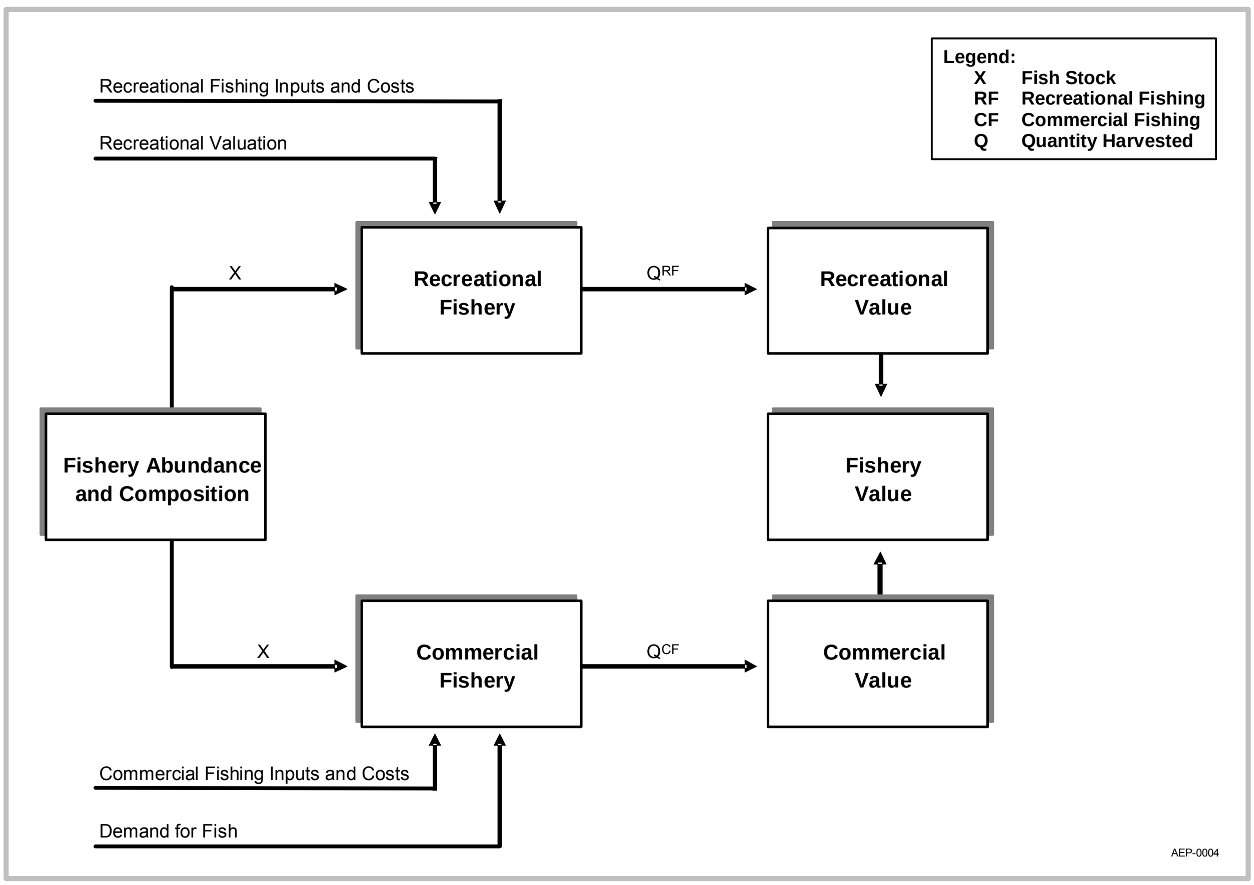


Figure 5-1
Relationship between Fishery Abundance and Value

Fisheries are dynamic environments where organisms are borne, reproduce, and die. Some of these fish will die as a result of harvesting by commercial and recreational fishers. The implications of I&E on this process can be illustrated in a simple biomass growth and population model developed by Schaefer (1954, 1957). This model recognizes that most fish stocks follow a population-dependent growth pattern, as illustrated in Figure 5-2. The growth in fish stock is on the vertical axis, and the size of the fish population on the horizontal axis.

In Schaefer's model, over some population range, the biomass size will grow at an increasing rate. However, beyond some point the carrying capacity of the ecosystem becomes compromised, reducing the species growth rate. With this growth, the population size eventually reaches the carrying capacity of the ecosystem. This is illustrated in Figure 5-2 by the inverted U-shaped function. Without harvesting, the population size will be X which is a natural or stable equilibrium.[16]

I&E and fishing add an outside influence on the population size. Point B represents the results of overharvesting and I&E impacts on the fish population. With reduced I&E, commercial and recreational fishing is the only source of harvesting so the population grows to A_s.

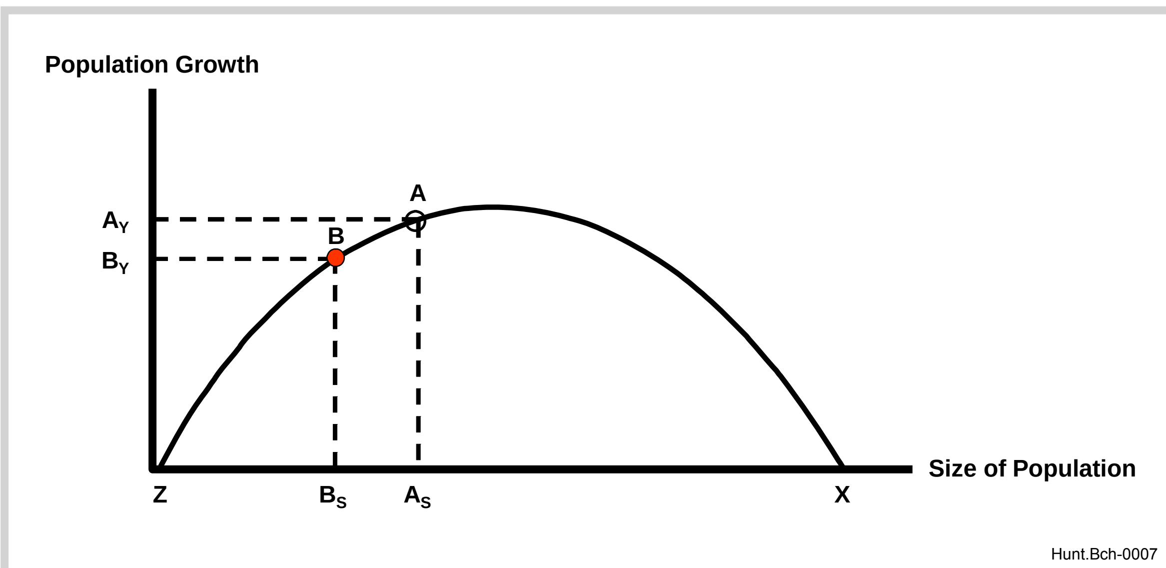


Figure 5-2
I&E and Fishing Impacts on Fish Population and Growth

This section of the report describes the fishery valuation methodologies used to measure the economic benefits of reducing losses. Economic benefits are the monetized values of the improvements in human welfare. In the national benefits valuation for the 316(b) rule, EPA introduced several relevant classifications of economic benefits, including:

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[16] X represents a stable equilibrium because if the fish population exceeds X, natural mortality rates increase such that the fish population returns to the natural equilibrium. If the population is less than X growth will push it back to X. Z is the minimum viable population or the point of extinction.

- Market-based benefits
- Nonmarket, direct-use benefits
- Nonmarket, indirect-use benefits
- Nonmarket, nonuse benefits.

Market-based benefits are those that can be measured through markets. An increase in the commercial harvest of fish is the most relevant example of a market-based benefit in the 316(b) context. Nonmarket, direct-use benefits reflect improvements in ecosystem services that are directly used by humans but not traded in a traditional market. An increase in recreational catch associated with reductions in I&E is the primary example of the direct-use benefits applicable to 316(b). Indirect-use benefits are those benefits that accrue to users of a resource indirectly. For example, forage fish provide a food source to harvested fish. Thus, when game fish populations are constrained by lack of forage, an increase in forage fish populations can indirectly provide an economic benefit to anglers. This occurs because the increased food source supports larger sport fish populations, increasing recreational catch. Finally, nonuse benefits are those that are completely independent of any past, present, or future use of the resource, encompassing the concepts of altruism, bequest or existence motives.

Both the commercial and recreational fisheries depend on the determinants of supply and demand to establish price and quantity. The abundance of fish within the fishery is an important factor for the value of the fisheries. For example, in the commercial fishery, a decline in abundance means commercial fishermen will expect to catch fewer fish with the same amount of effort (i.e., commercial fishing inputs and costs). The higher cost of catching fish will result in smaller harvests for commercial fishermen. The reduction in harvested fish will reduce the value of the commercial fishery.

In the recreational fishery, decreased catch rates at some sites leads to less satisfaction with trips to those sites. In addition, some recreational anglers choose to fish elsewhere and take trips of lower value. Others substitute lower-valued activities.

In economic theory, changes in society’s well-being result from changes in the value of environmental services. Consumer and producer surplus are the primary methods for measuring changes in well-being. However, the appropriate method depends on the type of change measured. For example, when the catch rates for fish increase, it would be reasonable to assume that both recreational and commercial fishermen will catch more fish. However, these two effects are measured differently. For recreational fishing, the angler consumes leisure time, or recreation, and he or she may consume the fish that are caught. Changes in consumption flows are measured using consumer surplus. On the other hand, commercial fishermen supply labor that is used to produce a good, or in this case, fish. Commercial fishermen catch fish with the intention of selling them to make money. When production flows are affected by a change in environmental services, producer surplus measures the welfare change.

Recreational Fishery—Consumer Surplus

The concept of individual demand for a good or service is the basis for economic valuation for the recreational fishery. The demand function for any good describes the maximum quantity a person would be willing to purchase at each price for a given time period. Alternatively, the demand function also shows the person's maximum willingness to pay (WTP) for each quantity supplied.

Figure 5-3 shows a demand curve for recreational fishing trips. V_1 is the marginal value people attach to trip T_1, that is, the additional value people experience from taking one more trip (T_1). The downward slope of the curve indicates that individuals are willing to pay less for each additional trip. Thus, the first trip has a higher value than the fifth.

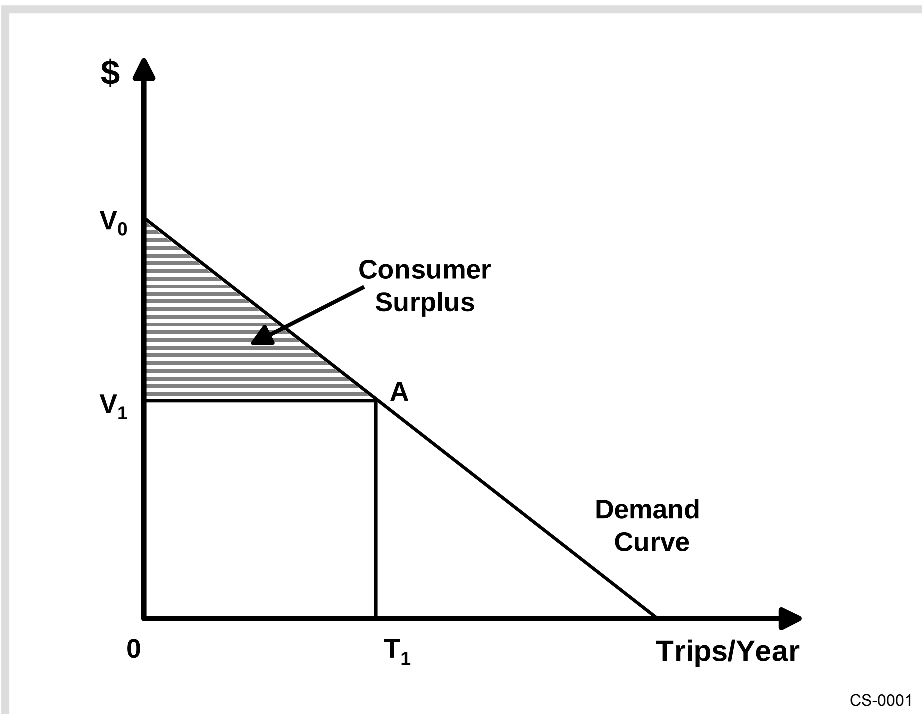

Figure 5-3
The Demand Curve and Consumer Surplus

The area V_1AT_10 shows the individual expenditure on recreational fishing trips. Because the height of the demand curve measures a person's maximum WTP for each fishing trip, the total WTP for all fishing trips between zero and T_1 is the entire area under the demand curve: total expenditures plus the triangle V_1V_0A. The triangle V_1V_oA is the difference between what people actually pay for a recreational fishing trip and the amount they are willing to pay for each trip individually. The value of this triangle is called consumer surplus, and it is the dollar measure of the satisfaction, or utility, people receive from consuming a good or service, beyond what they pay for it.

For a nonmarket service like recreational fishing, the price represents the cost of taking the trip. This price may include transportation costs, the opportunity cost of time, entrance fees, and other trip-related costs. The price of a good itself does not represent consumer welfare. Rather, the surplus value a consumer retains, the difference between what a consumer is willing to pay and what a consumer has to pay (cost) must be measured to determine the consumer's welfare. Consumer surplus is widely accepted as the appropriate measure of the social value of environmental goods (Zerbe and Dively 1994).

For a recreational fishery, the benefit measure appropriate for benefit-cost analysis is the increase in consumer surplus provided by additional trips to the site that occur as a result of a reduction in I&E losses. A reduction in I&E at a facility will lead to an improvement in fish catch at a site, which increases people's enjoyment of (and hence value for) the site, increasing the value of the site's services at each visitation level. This increase in value causes the outward shift in the demand curve shown in Figure 5-4. Thus, the benefit of the improvement in fish catch is measured as an increase in consumer surplus represented by the shaded area in Figure 5-4. Summed over all individuals, it is a measure of the aggregate gain in social well-being.

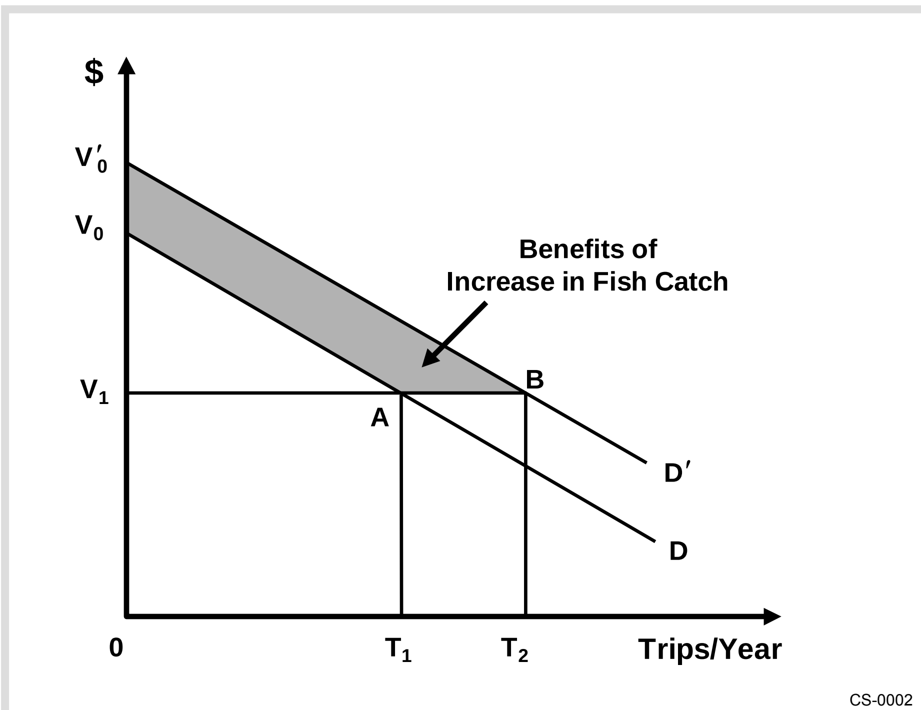

Figure 5-4
Increase in Consumer Surplus from Reduction in I&E

The RUM is the best available tool for measuring changes in consumer surplus for recreation services. Resource economists have long used RUMs in policy applications (Bockstael, Hanemann, and Strand 1986; Bockstael, McConnell, and Strand 1991; Feenberg and Mills 1980; Caulkins, Bishop, and Bouwes 1986; Bockstael, Hanemann, and Kling 1987; Morey, Shaw, and Rowe 1991), and the EPA endorses the use of RUMs for 316(b) applications (69 [131] *Fed. Reg.*

41658 July 9, 2004).[17] The RUM is based on welfare theory and posits that individuals make choices that maximize their utility, subject to constraints. It uses anglers' actual choices to model the factors that influence the site an angler chooses to visit. To the extent that the angler trades off factors such as distance to the site against the quality of the fishing opportunity, we can model the relative influence of these variables as revealed by anglers' decisions. Incorporating the relevant substitute sites, the RUM can then evaluate the importance of site characteristics at each of these sites to determine the site's value to anglers.

Fishing sites are made up of different characteristics. The characteristics of each fishing site, such as fish catch rate, presence of facilities like a boat ramp or lighted fishing pier, and distance to the site from the angler's home, distinguish one site from another. Fishing sites are similar to other goods and services in this respect. For example, different cars have characteristics that distinguish them from one another. Likewise, banking services differ in minimum balance requirements, interest rates, and fees.

Anglers choose the "best" site and fish at the site with the combination of characteristics that gives them the most satisfaction. The "best" site may differ for each angler, depending on the distance to the site. The decision to travel to a site is also affected by time and angler income. Again, choosing a fishing site is similar to choosing among other goods. When choosing a bank, for example, Joe wants to open an account at the bank closest to his house. Mary is willing to travel farther to a bank that offers free checking. Anglers have preferences for fishing sites as well. Joe does not want to travel far from home to fish. Mary prefers to visit a site where she can launch her boat, even if it is farther from home.

The focus on site characteristics, such as catch rates, permits us to isolate the benefits of I&E reductions on recreational fishing. All other site characteristics are held constant. The better the characteristics of a site are, the higher the probability that an angler will choose that site, which is reflected in a higher value for the site. RUMs can be used to estimate both the distribution of trips among various sites and the total satisfaction received from a given set of fishing opportunities.

To determine how much total angler satisfaction would increase from reducing I&E at HBGS, we measure the attractiveness of coastal fishing sites based on current catch rates (based on the current level of I&E). We then recalculate the model to reflect the higher catch rates that anglers would experience at coastal fishing sites with reduced I&E. The difference in angler satisfaction between the two scenarios corresponds to the benefits from reducing I&E at HBGS.

In addition to the direct-use benefits that are measured through the RUM, our assessment also includes indirect-use benefits associated with increases in forage fish. As described earlier, an increase in numbers of forage fish can indirectly benefit anglers and commercial fishermen through an increase in the numbers of harvested species that feed on the forage fish. Our methodology explicitly accounts for this effects. Thus, the increase in catch rate described in our

[17] RUMs are also widely accepted in other areas of the economics profession. RUMs have been used in transportation (Beggs, Cardell, and Hausman 1981; Hensher 1991), housing (McFadden 1997), and electricity demand estimation (Cameron 1985).

RUM reflects both the direct-use benefits and the indirect-use benefits. Section 6.1 describes the RUM results.

Commercial Fishery—Producer and Consumer Surplus

For many markets, producer surplus is used to measure changes in welfare when it is production, and not consumption, that is affected by the change in environmental services. To determine producer surplus, we must look at the supply curve instead of the demand curve. A supply curve, as shown in Figure 5-5, illustrates how much of a good a producer will supply at each market price.[18] In this case, the supply curve shows the amount of fish a commercial fisherman will supply at each market price. To maximize profits, producers choose to produce to a point where the marginal cost of producing the last unit is equal to the price received for that unit in the marketplace. Thus, the supply curve represents the marginal cost of producing each unit.

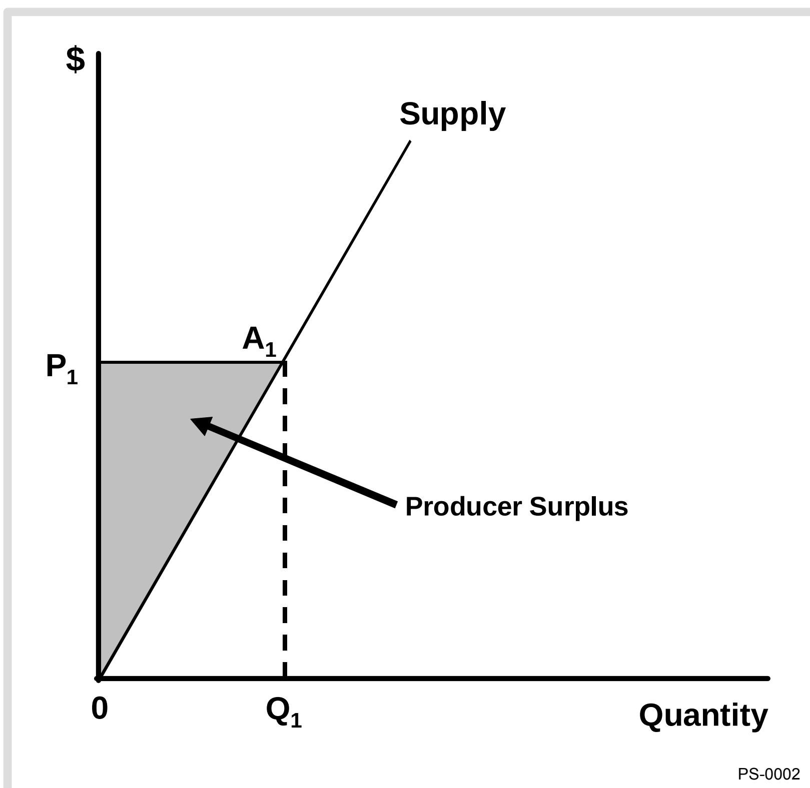

Figure 5-5
The Supply Curve and Producer Surplus

In a competitive market, no individual producer can affect the market price, making producers "price-takers." Thus, the price is determined exogenously and shown in the figure as P_1. At price P_1, the producer is willing to produce Q_1 units. Selling the Q_1 units at price P_1 generates

[18] In this simplified discussion, we assume that producers know what the market price is when they make their supply decisions. Of course, the actual situation is more complex.

revenue represented by the rectangle of $0Q_1A_1P_1$. Because the supply curve represents the marginal cost of production for each unit, the area under the supply curve up to Q_1 represents the costs of production for Q_1 units. The remaining triangle, $0A_1P_1$, is the producer surplus, which represents the amount of revenue received that exceeds the marginal cost of production.

A decrease in the cost of production causes the supply curve to shift to the right. The marginal cost of producing each unit is now lower. Figure 5-6 illustrates this shift: S_1 shows the original supply curve and S_2 shows the curve after the decrease in production costs. Because individual producers are price-takers and cannot change the market price, it remains at P_1. However, with the new supply curve S_2, a producer can choose to supply more units, shown by Q_2. The resulting increase in producer surplus is the area bounded by $0A_1A_2Q_1$.

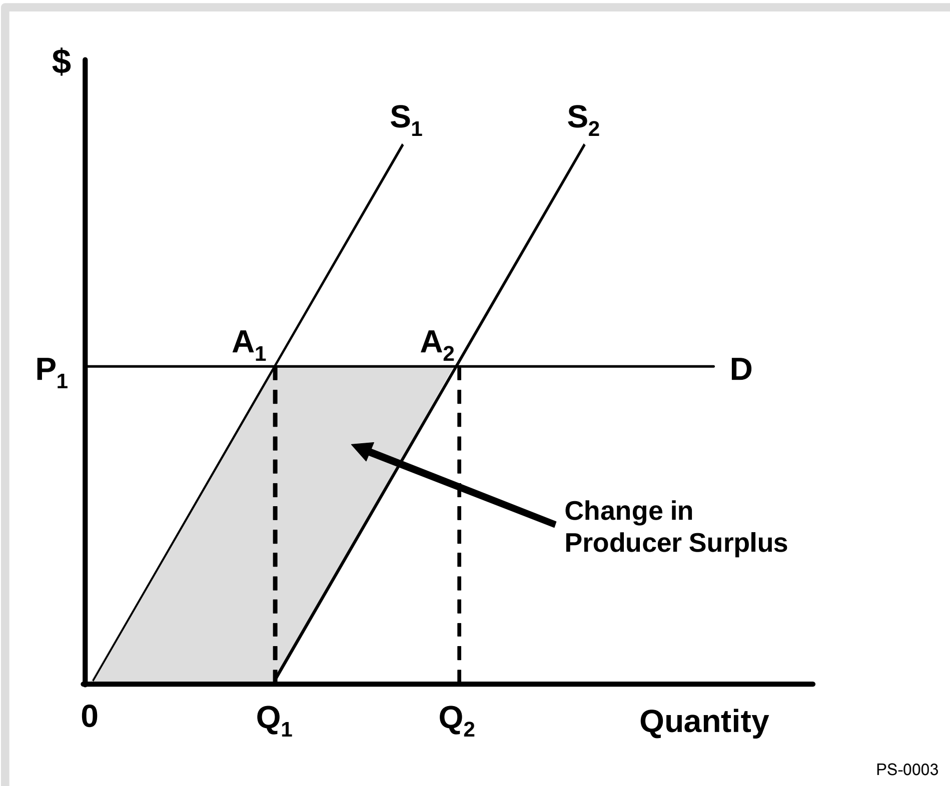

Figure 5-6
Change in Producer Surplus from a Supply Shift

Commercial fishing differs from the typical markets presented in Figures 5-5 and 5-6. Specifically, fisheries belong to a class of resources termed *common property*. By tradition and because of the high cost of rationing their use, these resources are not privatized but are either overseen by government (e.g., nearshore fisheries) or left unregulated (e.g., ocean fisheries). Like some other common property resources (e.g., forests, pastures), fisheries are also, as characterized by Tietenberg (2006), an interactive resource because their species population is jointly determined by both the biological conditions and by the actions taken by society. Thus, a potential problem these resources face is overuse.

When access to a common property fishery is open to anyone, individuals and organizations will enter the business of harvesting fish as long as their expected profits are positive. The result is that many open access fisheries and other resources are exploited beyond economically sustainable harvest levels. Governments world-wide have addressed what Garrett Hardin (1968) labeled as “The Tragedy of the Commons” through a variety of rules and regulations designed to curb overfishing in the resources under their aegis.

Many states and other governmental agencies may require a license or permit to fish commercially. Although the permitting process may not be onerous, it can present a minor and temporary barrier to entry. For some species, harvest quotas may also be established by the relevant regulatory agency to protect certain species from overfishing. For all of these reasons, a particular fishing market may not react in the way that Figures 5-5 and 5-6 describe.

Commercial benefits from I&E reductions accrue primarily to commercial fishermen as increased profit due to the higher catch per unit effort (CPUE) associated with increases in fish populations. The ability of commercial fishermen to realize *sustained* increased profits depends on the responsiveness of market prices to higher CPUE. The tendency for producer surplus to reach zero in the long-run is a well-known foundation of microeconomic theory (Mansfield 1988). However, producer surplus elimination through competition depends upon price changes. It may be possible to have some long-run producer surplus if there are market restrictions such as quotas or regulations.

Market extremes determine the upper and lower bounds on commercial benefits. In competitive markets, prices adjust instantly and there are no benefits. In restricted markets, prices may not change.

Consider first the case where the fishery is an open access fishery. In an open access fishery, new entrants are expected as long as the price of anticipated catch exceeds the cost of entry. The entry of new suppliers (or increased effort of existing suppliers) tends to reduce the stock of fish, raising the cost of catching fish for all participants. Suppliers will continue to enter as long as expected profits are above the normal rate of return for this class of investment. Entry ceases when the price and average cost of harvesting fish are equated at the industry level. At this point, producer surplus is eliminated. Thus, once all adjustments are made, markets reach equilibrium and there is no producer surplus.

This situation is shown in Figure 5-7. Here, the original long-run supply curve is horizontal and producer surplus (represented by the area between the price line and supply curve) is zero. As the stock of fish increases because I&E is reduced, the cost of catching fish drops. Because a supply curve represents costs, permanent lower per fish harvest costs can be depicted by a downward shift in the long-run supply curve (LRS_1 to LRS_2). When all anglers face lower harvest costs, they compete to sell additional fish by lowering prices. This leads to a decrease in long-run equilibrium price (P_1 to P_2). Once competition has caused prices to adjust, there is no producer surplus. Thus, in a competitive situation, benefits do not accrue to commercial anglers. The advantage this sector gains due to lower costs is completely offset by lower prices.

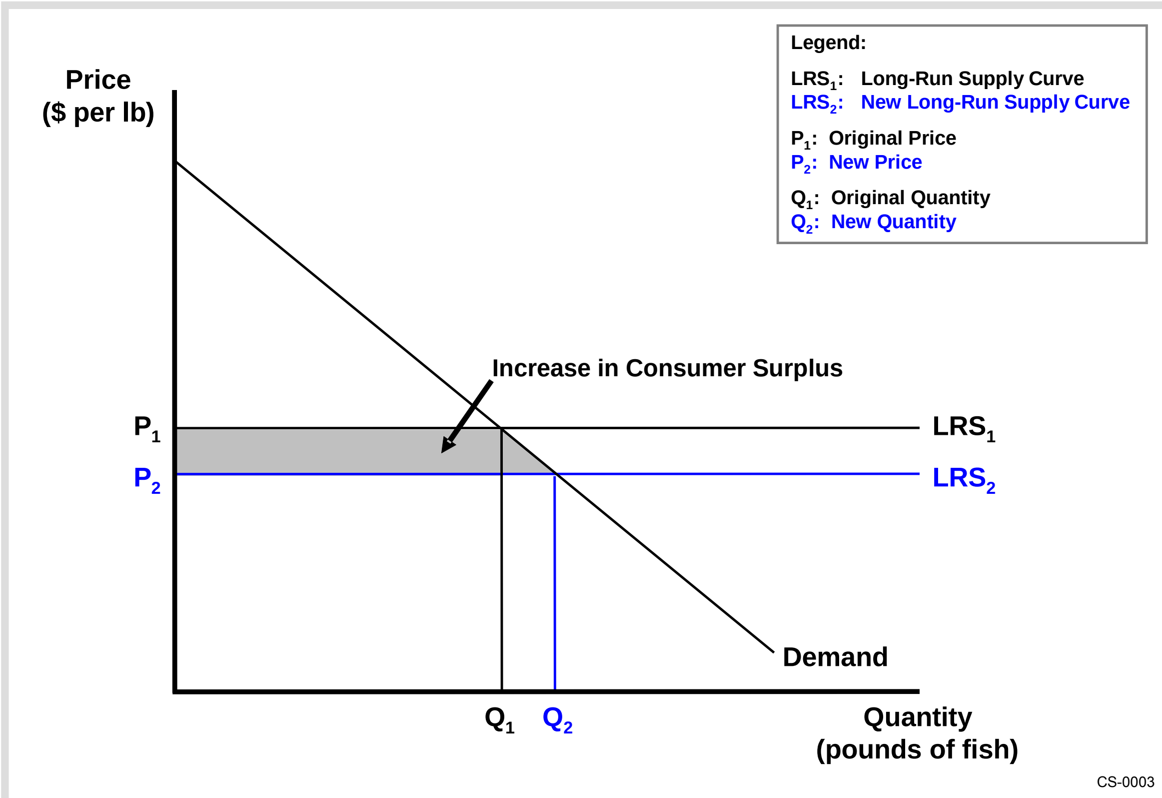

Figure 5-7
Commercial Fish Market with Open Access

However, there is a societal benefit to lower harvest costs, which accrues to fish consumers. Consumers benefit through lower market prices. This benefit can be estimated by calculating the increase in *consumer* surplus that is associated with lower harvest costs. Consumer surplus is the difference between what consumers are willing to pay (as represented by the demand curve) and market price. The change in consumer surplus associated with lower costs in a competitive market is the shaded area depicted in Figure 5-7.

The increase in consumer surplus CS can be calculated mathematically by:

$$\Delta CS = [(P_1 - P_2) * Q_2] - [0.5(P_1 - P_2) * (Q_2 - Q_1)] \qquad \textbf{(5-1)}$$

Inputs to this calculation are existing price and quantity, expected change in quantity, and expected change in price. The change in quantity is already developed through expected reductions in I&E and resultant catch improvements. In order to estimate the change in the long-run equilibrium price, we use the price elasticity of demand for fish. Price elasticity of demand is also called simply elasticity or own price elasticity. It refers to the percent change in quantity associated with a percent change in price. For example, if the price elasticity of demand is –1.5 and the percentage change in quantity is 1%, then the estimated percentage change in price would be:

$$e = \frac{\%DQ}{\%DP} \quad \textbf{(5-2)}$$

$$\%DP = \frac{\%DQ}{e} = \frac{1}{(-\ 1.5)} = -\ 0.67\%$$

This information can be used to calculate the new price level and estimate the change in consumer surplus.

Now consider a model of fish stock improvement under a fishery regime that restricts output. In this model, the government sets a quota on the quantity of commercial stock sold and the quota is the equilibrium quantity (Q_1). As shown in Figure 5-8, there is no initial long-run producer surplus. As the reduction in I&E leads to an increase in the commercial stock, the long-run supply curve shifts down from LRS_1 to LRS_2. However, the quantity supplied remains at Q_1 (the quota level) and the corresponding equilibrium price remains at P_1. In this situation, there would be an increase in producer surplus because the equilibrium price exceeds average costs. The producer surplus is the difference between production costs and price (the shaded area of Figure 5-8) or $(P_1 - P_2) * Q_1$. In this manner, existing price and quantity information can be combined with price elasticity of demand estimates to anticipate changes in producer surplus when there are market restrictions.

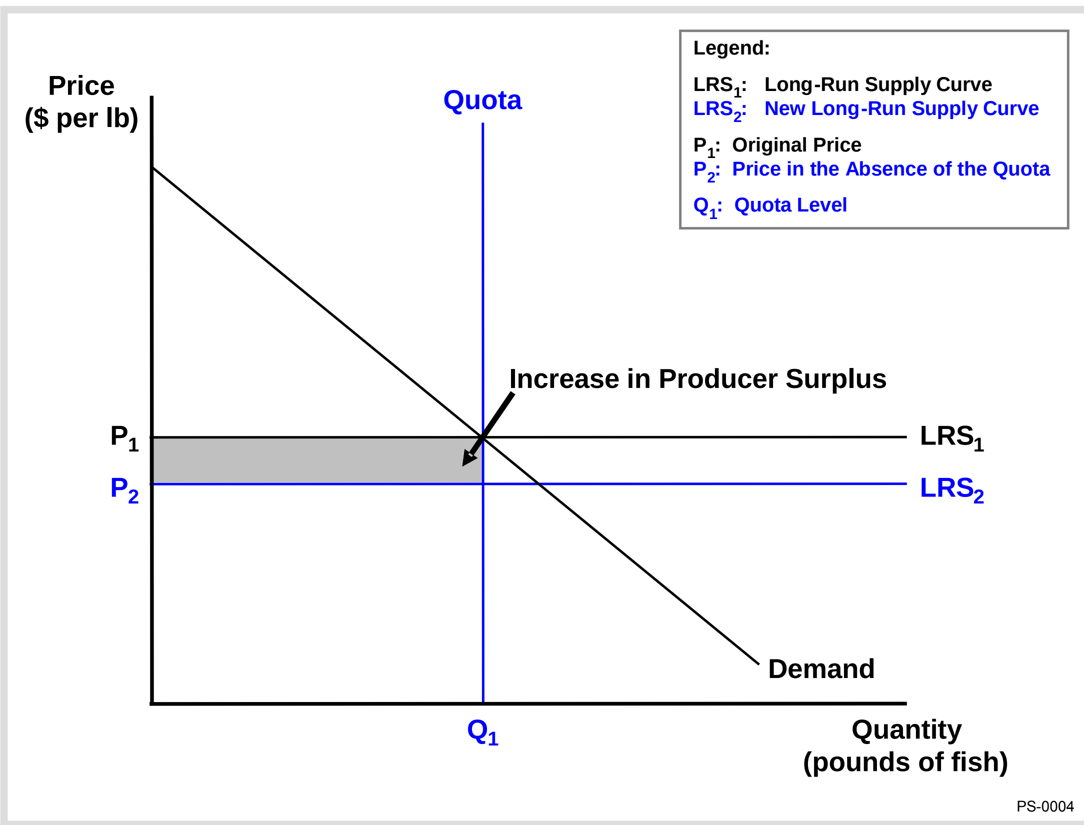

Figure 5-8
Commercial Fish Market (with a Quota)

In terms of the commercial species impinged and entrained at HBGS, none of them is subject to harvest quotas (see Sections 3 and 4 above). However, the California DFG limits access to several of the affected fisheries. Therefore, these fisheries near HBGS reflect neither of the market extremes presented in Figures 5-7 and 5-8.

For purposes of this assessment, we assume that all commercial fishing benefits accrue to consumers. We contend that this position is more conceptually correct than either of the extremes presented. The primary reason for this is that producer surplus is a transitory state that will be eroded through entry and eventually transferred to consumers in the form of lower prices. Moreover, the data necessary to accurately measure producer surplus are not publicly available.

Accordingly, we estimate potential benefits to commercial fisheries near HBGS by computing consumer surplus changes in light of likely demand elasticities. The gain in consumer welfare will depend on original consumption rate, Q_1, the size of the harvest cost decrease, and the responsiveness of consumer demand to the lower price.[19] For markets that are more national or global in nature, we expect a more elastic response to price changes. This occurs because comparable fish are available from more substitute sources. For local markets, we would expect to see less response to a price change because there are fewer alternative sources for comparable fish, compared to larger markets.

Unitary elasticity indicates that price and quantity change by equal proportions but in opposite directions. A review indicates that assuming unitary elasticity (–1) is appropriate for many commercial fish species (Wessells and Anderson 1992; Wessells and Wilen 1994; DeVoretz and Salvanes 1997). Our analysis, the details of which are described in Section 6 below, considers a range of demand elasticities from –0.01 to -–3.00 and varies by the nature of the market for each affected species.

Nonuse Values

Nonuse values are the values that people may hold for a resource independent of their use of the resource. That is, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. As the EPA rule points out, the economic literature commonly refers to these two components of nonuse values as “bequest” (or “altruistic”) values and “existence” values, respectively (EPA 2004b, p. A9-3).

The EPA provides the following list of nonuse values in its final rule guidance (EPA 2004b, p. A9-3):

- Intergenerational equity
- Stewardship
- Altruism

[19] Since demand curves slope downward this will be a negative number. For example, if the elasticity of demand (ή) is -2, a 10 percent reduction in price will occasion a 20 percent increase in quantity demanded. The elasticity of demand is thus bounded 0< ή < -∞.

- Option value
- Historical/cultural value
- Philanthropy
- Existence
- Bequest
- Vicarious consumption.

Thus, when considering nonuse values, we must discern how a potential increase in the numbers of fish improves human welfare, in the specific ways that EPA identifies with the list above. These improvements in human welfare must be beyond the direct-use and indirect-use benefits associated with recreational and commercial fishing and avoid double-counting.

Moreover, the conceptual framework and challenges associated with properly valuing the potential nonuse benefits can be illustrated through the economic concept of rivalry (Tietenberg 2006).[20] Many goods can only be consumed once by a single person. These goods are termed rival goods. Food is an example of a rival good. An apple eaten by one individual cannot be eaten by another person. Therefore the consumption of food by one person eliminates the possibility that the food can be consumed by another. Goods whose consumption does not imply depletion are called nonrival. A typical example might be a public waterbody. For nonrival goods like public waterbodies, at reasonable levels of use, one person's use of the resource does not diminish the ability of other people to use it.

The importance of differentiating between rival and non-rival goods in assessing the potential nonuse benefits becomes apparent when evaluating the potential societal benefits associated with protecting an additional fish. The nonrenewable nature of use benefits realized by recreational anglers significantly diminishes the likelihood of both existence and bequest motivations for nonuse values. Use of the resource reduces the stock of fish, which is purportedly increased through reduced I&E impacts. Once these benefits have been realized, they are no longer available to others. In this instance, nonuse valuation predicated upon existence or bequest motivations seems at odds with the presence of recreation use values. Thus, the nonuse benefits outlined by EPA (see the bullet list above) can be applied only to the uncaught fish that are harvested recreationally or commercially. Additional fish harvests, and the forage biomass, have been accounted for in the use values. Their rival nature makes nonuse benefits for these fish unavailable to nonusers.

The 316(b) rule requires that the benefits assessment consider the nonuse benefits associated with reductions in I&E (EPA 2004a, p. 41,647). However, because of conceptual and empirical challenges associated with measuring nonuse values, which are further described in Appendix B, the Agency decided in the final rule that "…none of the available methods for estimating either use or nonuse values of ecological resources is perfectly accurate; all have shortcomings" (EPA 2004a, p. 41624). More importantly, EPA determined that "none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule,

[20] See Desvousges et al (2005) for additional details on this topic.

and has thus decided to rely on a qualitative discussion of nonuse benefits" (EPA 2004a, p. 41624).

Therefore, in the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E:

> Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference (SP) methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
>
> In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, nonuse benefits should be monetized. (EPA 2004a, p. 41,647–41,648).

Thus, in cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not required.

6
ECONOMIC BENEFIT ESTIMATES

Economic benefit categories considered include commercial, recreational, and nonuse. This portion of the report provides details on the quantification of recreational fishery benefits and a qualitative discussion of potential nonuse benefits.

Recreational Fishing Benefits

As described in the previous section, random utility models (RUMs) provide the best method for valuing I&E reduction impacts on recreational fishing. However, conducting an original RUM study can require extensive primary data collection.

In this analysis, we use the results of an existing recreational fishing model to develop estimates of the recreational fishing benefits associated with I&E reductions at the HBGS. Using the valuation results of one study and applying them to another scenario is called "benefits transfer." The economics literature has established criteria to be fulfilled for benefits transfer studies (EPA 2000; Brookshire and Neill 1992; Smith 1992; Desvousges, Naughton, and Parsons 1992; McConnell 1992; Boyle and Bergstrom 1992; Desvousges, Johnson, and Banzhaf 1998). These criteria are termed similarity and soundness.

For use in valuation, the first criterion, similarity, or "fit," recognizes that transferred values from existing studies can be relevant only if these values measure the quantity of interest in the current study. For example, the value of a brand-new luxury SUV should not be identified by the blue book value of a ten-year-old compact car. For this analysis, a transfer study should include a similar fishing experience to that offered by the coastal waters near Huntington Beach. To maximize similarity, this analysis employs a site-calibrated transfer of an existing RUM model. This approach allows capturing important site-specific compensating behavioral responses without requiring survey data collection. The accuracy of this methodology is limited only by the analyst's ability to calibrate a previously estimated preference function to a different population using appropriate economic methodologies (Smith, van Houtven, and Pattanayak 2002).

The second criterion, scientific soundness, refers to the overall quality of a study and is widely recognized as a primary criterion for applying the results from one study to another situation. The quality encompasses all aspects of a study, such as the data, the methodology, the survey protocols, and the analysis technique. This criterion effectively asks whether the original study is sufficiently sound to pass scientific muster. If the results were not based on reliable data, rigorous protocols, and valid analyses, then the results are not reliable and should not be used.

For this assessment, we have conducted a site-calibrated benefits transfer with the California region RUM (CRR) developed by the EPA for its California Regional case study (EPA 2004b). These models rely upon data from the 2000 Marine Recreational Fisheries Statistics Survey (National Marine Fisheries Service [NMFS]). These data were collected on-site by interviewing anglers at the conclusion of their fishing trips, and via telephone. The California case study contains separate models for shore anglers and boat anglers. The models acknowledge that anglers who fish south of Point Conception may have different preferences for target species and catch rate improvements than those who choose fishing sites farther north. Thus, we believe that the CRR models are sufficiently similar for use as a site-calibrated benefits transfer.

The CRR also satisfies the soundness criterion. The underlying data reflect more than 11,000 fishing trips in California coastal waters. The data are collected using rigorous protocols consistent with survey research guidelines. These recreational fishing models are consistent with the RUM framework described in Section 5. The models are rigorous, perform well, and reflect results that are consistent with expectations.

The CRR, however, is not without some limitations as a transfer study. Because it is not a published study, it has not been through an independent, peer-review process. While unpublished studies are not necessarily unsound, published studies have been scrutinized by peers who raise potential quality problems in their initial reviews, which often results in a strengthening of the technical merits of published studies. An evaluation of published studies does not identify a more suitable study. For example, Kling and Herriges (1995) develop a basic RUM for southern California marine anglers that includes travel cost, an aggregate catch rate (for all species combined) and a variable for fishing mode (beach, pier, private boat, or charter boat). Kling and Thomson (1996) describe multiple RUMs for marine fishing in southern California. However, they do not provide the coefficients of the site characteristics, which is critical for the site-calibrated transfer. Moreover, both published studies are also based on data from the 1980s and may not reflect current angler preferences accurately.

Another possible limitation of the CRR as a transfer study is that the separate models for shore fishing and boat fishing would not address cross-mode substitution possibilities. For example, if catch rate improvements were such that shore anglers would prefer to become boat anglers, then these models would not capture that switch. However, given the specifics of this assessment, we do not believe this phenomenon would result from I&E reductions, particularly those of the type and magnitude here. Pier angling, which accounts for the vast majority of shore-based angling in southern California (California DFG 2006c), does not require a fishing license while all forms of boat angling do. Moreover, owning or renting a boat from which to fish requires additional expenditures. Thus, switching from pier/shore fishing to boat fishing would require additional expenditures. Given the small percentage increases in catch rates that are predicted to result from reducing I&E at HBGS, we do not believe the inability to account for mode-switching introduces bias in our results.

Similarly, the design of the models would not predict whether anglers would change their target species in response to increased catch rates. Again, given the specifics of this assessment, we do not believe that this limitation is significant in our assessment. Based on the 2000 NMFS data that the EPA summarizes in its California case study, only 21 percent of the southern California anglers target the species impacted by I&E at HBGS (queenfish, croakers, shiner perch, California halibut and diamond turbot). Thus, it seems unlikely that reducing I&E at HBGS would result in large numbers of anglers changing their target species.

As a related matter, the EPA model does not explicitly model the anglers who take trips on charter or "party" boats. According to California DFG (2006c), in 2005, charter boat trips accounted for 44 percent of boat-based trips and 19 percent of all fishing trips in Southern California. However, in this analysis we, with the authors of the EPA analysis, intend to apply the results of the boat model to these charter boat trips. Kling and Thomson (1996) evaluated welfare estimates for various fishing modes and generally found that per-trip gains for private boat trips were usually larger than were comparable gains for party boat trips. Thus, our strategy is more likely to lead to an overestimate of benefits rather than an underestimate.

In addition, the EPA models do not include a participation component. That is, the models would not predict a change (presumably an increase) in the number of anglers or in the number of trips taken by current anglers as a result of the reduction in I&E. Again, we do not find this limitation particularly meaningful for this particular assessment. Given that catch rates are predicted to increase only a small percentage (see below), we do not believe that this limitation unduly biases our results.

Similarly, the EPA models are based only on single-day trips and do not explicitly model multiple-day trips. Multiple-day trips present a challenging issue in recreational modeling because multiple-day trips are often multi-purpose trips, potentially overstating the assignment of travel costs to the fishing activities. We intend to value multi-day trips by treating them as multiple single day trips. That is, a two-day fishing trip would be counted as two single-day fishing trips. EPA cites unpublished studies that reveal that multi-day anglers have higher trip values than do single-day anglers for east coast and Midwestern sites. If this result holds for marine fishing in southern California, then it is possible that our results may underestimate benefits associated with reduced I&E at HBGS. The extent of that underestimate depends on the relative proportion of multiple days trips and the marginal difference in per trip values associated with catch rate improvements for the bottom and flat fish species that are affected by I&E at HBGS.

Moreover, the on-site data collection likely introduces avidity bias into the results because anglers who fish more often are more likely to be interviewed. Although analysts typically adjust for avidity bias by weighting their models, the EPA models have not made these adjustments. In terms of the potential effect of avidity bias in our assessment, the results may be unrepresentative only if the more avid anglers have different preferences for trading off increased travel distance for increased catch. If the relative trade-offs for avid anglers and less frequent anglers are similar, then the avidity bias in the data is not likely to unduly affect this assessment.

A 50-mile radius from Huntington Beach was used in the calibration to reflect local angling activity near the Huntington Beach Generating Station. The 50-mile radius reflects a reasonable distance for a single-day trip to the site and is likely to include the majority of coastal marine anglers who fish near Huntington Beach. In fact, EPA (2004b) reveals that the average, one-way travel distance for southern California marine anglers is 24 miles. Because we include anglers who may travel more than twice that distance, we believe our approach captures the majority of the anglers potentially impacted by I&E reductions at HBGS.

The valuation approach employed by multiple-site travel cost models is based on predictions of changes in recreational activities and valuation of those changes. In this case, we evaluate how augmenting the annual harvest at coastal fishing sites near Huntington Beach (across all relevant anglers) would affect the consumer surplus for the potentially affected anglers. The simulation captures substitution among sites. This adds a critical level of realism that tends to mitigate loss estimates and increase estimates of gains relative to models that ignore substitution possibilities. Important factors unique to a site that influence the amount of substitution include site location and population distributions.

In this assessment, calibration to reflect the availability of substitute sites considers substitute angling opportunities within a 200-mile coastal range. If the typical angler travels up to 50 miles to his fishing site, that means anglers at the outer edge of the 50-mile radius from Huntington Beach may choose to fish at another site 50 miles in the opposite direction. Thus, to identify the geographic area that contains the relevant substitute sites, we include coastal fishing sites within 100 miles north and 100 miles south from Huntington Beach. The geographic range corresponds roughly to the Santa Barbara-Ventura County line and the southern edge of San Diego County (the U.S.-Mexican border). Figure 6-1 depicts the geographic range of potentially affected anglers and the most relevant substitute sites.

Figure 6-1
Affected Population and Substitute Sites

This figure shows the 50-mile radius where potentially affected anglers live and the 200-mile range of potential substitute sites for those angers.

The 100-mile range is generally consistent with, but somewhat more conservative, than the 140-mile range that the EPA uses in the California Regional study (EPA 2004b). However, in that study, the EPA wanted to capture potential substitution between marine sites in central and northern California and marine sites in central and southern California as the study was a state-wide study. Because our focus here is specifically on substitution opportunities for trips taken near Huntington Beach, we believe that this slightly smaller geographic is appropriate. Moreover, a larger area introduces more substitution possibilities, which can dilute the benefit estimates.

We compiled a list of coastal fishing sites from the *Southern and Central California Atlas and Gazetteer* (DeLorme 2005). This source indicates the location (including latitude and longitude) of fishing piers, public beaches, and boat ramps along the coast. Our research revealed 31 fishing piers, 57 public beaches from which shore fishing is possible, and 36 boat ramps within the 100-mile range. Appendix E provides a detailed listing of the relevant coastal fishing sites.

California DFG conducts annual on-site assessments of angling pressure along the California coast (California DFG 2006c), by county groupings. The "Southern" Coast includes marine sites in Los Angeles, Orange, and San Diego Counties, all of which are within the relevant geographic range identified in Figure 6-1 above. The "Channel" County grouping includes Santa Barbara and Ventura Counties. Although Ventura County is within the relevant area, Santa Barbara County is not. To estimate the portion of these trips that occur within Ventura County, we use the site characteristics of sites within the county to estimate visitation probability. In the CRR study, the number of trips is divided by target species and mode of fishing. These trips are multiplied by the probability that an angler will visit a particular site to determine the number of trips to each site.

The distance traveled to a site is one of the most important site characteristics in a RUM. It directly influences the travel cost to each site for each angler. A critical factor for the site-calibrated benefits transfer is distance from each anglers' residence (Zip code) to each of the relevant coastal fishing sites.[21] These distances are calculated using the most recent version of a popular transportation routing software called PC*Miler. The EPA California models use the estimated travel cost, rather than distance. For the calibrated RUM, travel costs from each of the zip codes to each of the relevant sites are calculated to be consistent with the EPA models. Specifically, travel costs reflect both direct costs and travel time costs. Direct costs are calculated by multiplying the round-trip miles by the standard per mile reimbursement (GSA 2006). The costs of travel time were also calculated to be consistent with the EPA models. The average hourly wage of each zip code within the 50-mile radius was calculated by dividing household income from the U.S. Census by 2000 work hours per year and escalated to 2006 dollars. Travel speed was assumed to average 50 miles per hour. The round-trip time estimate (round trip distance divided by speed of travel) was multiplied by one-third of the average hourly wage rate to reflect the opportunity cost of time. The travel cost included in the model is sum of the direct travel cost and the travel time costs.

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[21] The 50-mile radius from Huntington Beach is "as the crow files." The distances calculated for the site-calibrated benefits transfer are the road distances that anglers would actually drive, based on PC*Miler estimates.

For purposes of this assessment, the expected catch rate at each site is an important site characteristic because it is the site characteristic that may be enhanced by a reduction in I&E at the HBGS. In this case, we evaluate how augmenting the annual catch (including fish subsequently released) at coastal fishing sites would affect the consumer surplus for the affected anglers. We determine existing catch rates for the relevant fishing sites based on the same species groups evaluated in the EPA California models, allowing for differences in boat and shore modes (EPA 2004b). Table 6-1 contains that information, based on the species groupings needed for the RUM.[22]

Table 6-1
Estimated Catch by Species Groups for Coastal California Sites under Current Conditions (Fish per Angler per Hour)

Species/Species Group	Boat	Shore
Small game	0.192	0.418
Striped bass	0.002	N/A
Bottom fish	0.145	0.730
Flatfish	0.096	0.227
Big game	0.057	N/A
Salmon	0.009	N/A
Sea basses	0.231	0.353
Other species	0.104	0.267
Other small fish	0.080	0.615
No target	0.238	0.569
Jacks	0.065	N/A

Source: EPA (2004b)

Our next task is to determine at which sites anglers will experience increases in catch if I&E were reduced. For the impinged and entrained species, we researched whether information was available on the typical range (in miles) of the affected species but faced a paucity of data. Therefore, we assume that the relevant fish species would stay within the Southern California Bight and would be caught there.

Section 4.4 above contains the details of the augmented harvest of recreational fish I&E. For each year in the assessment, we grouped the increase in recreational harvest to correspond to the species groupings used in the RUMs, as shown in Table 6-1 above. We also aggregated the I&E impacts together for valuation purposes. To determine the portions of the augmented catch that would be experienced by boat anglers and shore anglers, we used the catch rates above in Table 6-1 as weights. For example, shore anglers catch roughly twice as many small game fish as do

[22] See EPA (2004b) for a listing of the various species within the species groups. All of the recreational species impinged and entrained at HBGS are in the flatfish and bottom fish groups.

boat anglers. Thus, approximately two-thirds of the increased harvest of small game fish was allocated to shore anglers and approximately one-third of it was allocated to boat anglers. Within the defined geographic area, the increased catch is distributed evenly across all trips. That is, each boat or shore site gets an equal share of the increased catch.

Table 6-2 contains the expected equilibrium changes in catch for the relevant sites. Because I&E at HBGS affect only species in the bottom and flatfish groups, no other catch rates are affected.

Table 6-2
Expected Changes in Catch by Species Groups for the First Impacted Year

Species/Species Group	Boat	Shore
Bottom fish	0.0001	0.0003
Flatfish	0.00001	0.0002

The statistical model used in estimating a RUM is the conditional logit. The conditional logit evaluates a specific outcome conditional on the available alternatives. In fishing models, the conditional logit evaluates the selection of a particular fishing site based on the characteristics of that site and the characteristics of other fishing sites. The output from the conditional logit is the vector of coefficients for each site characteristic. Each coefficient reflects the importance of that site characteristic in the site choice decision. Maximum likelihood estimation is used to estimate the values of the coefficients in the conditional logit. Given the characteristics of all options available to the anglers, the conditional logit estimates coefficients that maximize the likelihood that we would observe the anglers' actual choices.

To understand maximum likelihood techniques, picture the site choice decision as a hill. There are many points on the surface of the hill, but only one point on the top. Many different combinations of the relative importance for site characteristics could reflect site choice decisions, but only one combination of coefficients most accurately reflects anglers' actual decisions. Maximum likelihood estimation moves step by step up the hill using different combinations of coefficients for the site characteristics, trying to best fit the importance of the characteristics to actual behavior. The final coefficients are those that maximize the likelihood that the observed site choice decisions are predicted by the model.

Table 6-3 presents the coefficients from the CCR models. The travel cost parameter has been previously discussed. It is negative, indicating that additional time or travel expenses decrease angler utility when all other site features are held constant. The marina/dock variable and the jetty variable indicate whether those features exist at the site. In the shore model, we would expect anglers to prefer sites with piers but avoid sites with boat ramps. In the boat model, we would expect boat anglers to avoid sites with piers. However, the negative sign on the marina/dock variable is counterintuitive. The EPA hypothesizes that the negative sign reflects insufficient data. We add that it could also indicate congestion at ramps, to the extent that queuing at boat ramps reduces trip satisfaction.

The remaining variables in Table 6-3 reflect the catch rate variables for the southern California models. It is worthwhile to note that the species group catch rates correspond to anglers targeting the species. For anglers without a target species, the catch rate reflects all fish caught. The logical interpretation of these coefficients relates the catch rate coefficients to the travel cost coefficient. Because each coefficient reflects the relative importance of that characteristic, the results in Table 6-3 tell us the additional costs anglers are willing to incur to catch one more fish of each species.[23]

Table 6-3
Coefficients in the EPA California Models

Variable	Boat Model		Shore Model	
	Estimated Coefficient	t-statistic	Estimated Coefficient	t-statistic
Travel Cost	–0.0524	–73.39	–0.0827	–49.67
SQRT ($Q_{small\ game}$)	1.5578	12.10	1.9067	7.33
SQRT ($Q_{striped\ bass—North}$)	3.3437	7.82	1.9558	9.89
SQRT ($Q_{jacks—South}$)	11.9676	25.00	N/A	N/A
SQRT ($Q_{sea\ basses—South}$)	0.5443	5.51	0.1873	0.57
SQRT (Q_{bottom})	1.8420	15.58	0.7824	5.24
SQRT ($Q_{flatfish—North}$)	2.7179	12.71	2.4743	5.00
SQRT ($Q_{flatfish—\ South}$)	4.4960	21.81	1.6156	6.98
SQRT ($Q_{big\ game—North}$)	2.9221	5.51	N/A	N/A
SQRT ($Q_{big\ game—South}$)	1.5820	10.27	N/A	N/A
SQRT ($Q_{salmon—North}$)	5.5201	23.88	N/A	N/A
SQRT($Q_{salmon—South}$)	4.2645	5.63	N/A	N/A
SQRT ($Q_{sturgeon—North}$)	17.3385	10.21	N/A	N/A
SQRT ($Q_{other—North}$)	N/A	N/A	3.0937	5.28
SQRT ($Q_{other—South}$)	1.4604	2.30	1.7437	1.50
SQRT ($Q_{other\ small\ fish}$)	N/A	N/A	1.1416	6.63
SQRT ($Q_{no\ target}$)	0.4074	10.22	0.5255	8.23
Marina/Dock	N/A	N/A	–0.2206	–3.86
Marina/Dock— North	0.4235	10.17	N/A	N/A
Marina/Dock— South	–1.1688	–17.40	N/A	N/A
Pier/Jetty	–0.7106	–23.30	0.4777	12.81

Source: EPA (2004b)

The calibrated RUM uses the information in Tables 6-1, 6-2, and 6-3 to estimate the current value of consumer surplus, based on the current level of I&E. To simulate the value of consumer surplus based on I&E reductions at HBGS, we augment catch rates to reflect the conclusions of the population analyses in Section 4. This increased catch rate for affected coastal fishing sites in southern California is incorporated into the calibrated RUM while all other site characteristics for these sites are held constant. In addition, all sites characteristics, including the catch rates,

[23] Dividing the expected catch coefficient by the travel cost coefficient reveals the marginal value of additional catch by species. This calculation reveals marginal values rather than average values because substitution effects can lead to additional costs associated with catching the fish.

are held constant for the remaining sites. Angler behavioral responses to the changes in expected catch are identified by simulation. The calibrated RUM is re-run and provides an estimate of consumer surplus. Subtracting the original consumer surplus (with current levels of I&E) from the revised consumer surplus (with reduced levels of I&E) provides the potential benefits to recreational anglers that are uniquely attributable to I&E reductions at HBGS. This procedure is repeated for each year in the assessment. Table 6-4 depicts the change in trips to sites where catch is expected to increase.

Table 6-4
Change in Number of Trips to Sites with Increase in Expected Catch

Year	Bottom Fish	Flatfish
2007	0	0
2008	0	4.6
2009	0	7.1
2010	179.1	7.6
2011	132.1	7.7
2012	141.1	7.3
2013	135.4	49.3
2014	135.6	43.1
2015	135.2	37.8
2016	135.8	39.6
2017	136.6	40.2
2018	137.6	39.9
2019	138.9	39.9
2020	131.7	40.0
2021	135.4	40.0
2022	136.5	40.1
2023	135.7	40.1
2024	135.9	40.1
2025	135.8	40.2
2026	135.8	40.2
2027	135.8	40.3

Commercial Fishing Benefits

Commercially important species caught from California's marine waters may be sold locally or shipped to foreign markets. Most reach the market fresh, but some are frozen, particularly

California spiny lobster and California halibut. Northern anchovy, queenfish, shiner perch, and white croaker are used as baitfish. Northern anchovy also are used as animal feed and fertilizer; in fact, only a limited number of northern anchovy are used for human food.

As described in Section 5, we estimate benefits to commercial fishing by positing demand elasticity and the time period over which producer surplus is eroded. Elasticity varies by the type of market. Thus, commercial benefits are linked to the dynamic framework in a conceptually appropriate manner. Table 6-5 provides background information on commercially harvested species, as well as the economic specification employed to evaluate economic impacts.

Table 6-5
Market and Uses for Commercial Fish

Commercial Species	Geographic Extent of Market	Fresh, Frozen, or Canned	Used for Nonfood Purposes	Used for Bait	Specified Demand Elasticity
Northern anchovy	Much of the frozen product goes to Europe and Asia	Canned, fresh, frozen	Fish meal and oil, soluble protein for animal consumption; fertilizer	Yes	-1.0 to -3.0
California halibut	Fresh product is sold locally Much of the frozen product goes to Europe and Asia	Fresh (filleted), frozen	None	No	-0.01 to -1.0
California spiny lobster	Fresh product is sold locally Sold to the European Union (especially Spain) and to Japan	Fresh, frozen	None	No	-0.01 to -1.0
Commercial crabs	Sold in fresh fish markets	Fresh	None	No	-0.01 to -1.0
Diamond turbot	Local	Fresh	None	No	-0.01 to -1.0
Queenfish	Local	Fresh	None	Yes	-0.01 to -1.0
Shiner perch	Local	Fresh	None	Yes	-0.01 to -1.0
White croaker	Fresh product is sold in Los Angeles and Orange Counties	Fresh	None	Yes	-0.01 to -1.0

Sources: California Department of Fish and Game (2003; 2007f); Chetrick (2006); Hackett and Krachey (2001); Pomeroy and Dalton (2005); Radtke and Davis (2000)

In order to predict the impact of an increase in harvest on market prices, we need to identify the geographic extent of the relevant market(s) for each affected commercial species. We follow the logic described above for the geographic area over which recreational catch will increase. We assume that the market for the increased catch is contained within the ports in Los Angeles County in the Bight and the ports in Orange County. These ports include:

- San Pedro
- Los Angeles
- Terminal Island

- Wilmington
- Long Beach
- Seal Beach
- Huntington Beach
- Newport Beach
- Balboa Beach
- Dana Point

The California DFG compiles commercial catch data by species and by port that includes pounds harvested and dockside price (California DFG 2006b). For 2006, we use these data to estimate the potential consumer surplus gains, as described in Section 5 above, for the commercial harvest increases that may result from reducing I&E at HBGS. Table 6-6 below contains the results.

Table 6-6
Benefits to Commercial Fisheries near HBGS

Year	White Croaker	California Halibut	Northern Anchovy	Rock Crab
2008	0.0	0.0	1.5	0.0
2009	0.0	0.0	1.1	0.0
2010	32.7	0.0	1.1	0.0
2011	30.2	0.0	1.1	0.7
2012	35.9	0.0	1.2	0.7
2013	38.1	64.8	1.2	0.7
2014	40.8	75.7	1.1	0.7
2015	42.7	80.8	1.2	0.7
2016	44.4	94.7	1.2	0.7
2017	45.8	101.2	1.2	0.7
2018	47.0	106.5	1.2	0.7
2019	48.1	112.6	1.2	0.7
2020	41.2	115.8	1.2	0.7
2021	43.5	118.8	1.2	0.7
2022	43.4	122.0	1.2	0.7
2023	43.6	124.7	1.2	0.7
2024	43.8	127.0	1.2	0.7
2025	43.8	129.1	1.2	0.7
2026	43.9	131.1	1.2	0.7
2027	43.9	132.8	1.2	0.7

Quantification of Uncertainty in Benefits

EPA requires that a benefits assessment include uncertainty analysis but does not specify methods (EPA 2004a, p. 41,647). In statistical analysis, the term *uncertainty* refers to the statistical reliability of estimates. Benefit estimates are most useful when the causes of uncertainty are clearly identified and quantified. This section discusses uncertainty in benefit estimates and the approach taken to quantify the uncertainty associated with the benefits of reducing I&E at HBGS.

There are numerous sources of uncertainty that may lead to imprecision or bias in benefit estimates in this analysis. Following Finkel (1990), uncertainty can be classified into two general types (EPA 2002):

- The first is structural uncertainty, which reflects limited understanding of the appropriate model and relationships among model parameters. Structural uncertainty is an unresolved issue that is inherent in this assessment and all such evaluations that require simplifying complex natural processes.
- The second is parameter uncertainty, which reflects imprecision in the specific numeric values of model parameters.

Structural uncertainties will generally lead to inaccuracies, rather than imprecision, in economic and biological impact estimates (EPA 2004a). EPA does not offer support for this contention. However, in practice, the ability to evaluate such uncertainties is limited. Accordingly, the uncertainty analysis conducted for this effort focuses primarily on parameter uncertainty.

This analysis employs a Monte Carlo analysis to quantify the effects of uncertainty on benefits. The Monte Carlo analysis combines uncertainty in input parameters with the benefits estimation model to quantify uncertainty in 316(b) compliance benefits. The approach takes specified distributions for each variable input, randomly selects a value from each distribution, and then combines the estimates within the framework of the site-calibrated benefits transfer and 316(b) compliance requirements. The resulting combination of the various inputs creates an estimate of compliance benefits.

The Monte Carlo analysis repeats this process of drawing from the various input distributions 1,000 times, each time drawing randomly from the designated ranges of values for calculating economic benefits in a 316(b) framework. Each repetition produces a different estimate of compliance benefits. The resulting distribution of outcomes from the 1,000 draws produces the range of potential 316(b) compliance benefits that explicitly addresses uncertainty.

Figure 6-2 provides an illustrative example. The figure shows that several different components determine the economic benefits associated with reductions in I&E. The illustration shows that there is a distribution associated with each component and the distributions may have different properties. For example, the distribution on the travel cost per trip may be a typical bell curve, whereas the distribution associated with catch rates may be more skewed to the right.

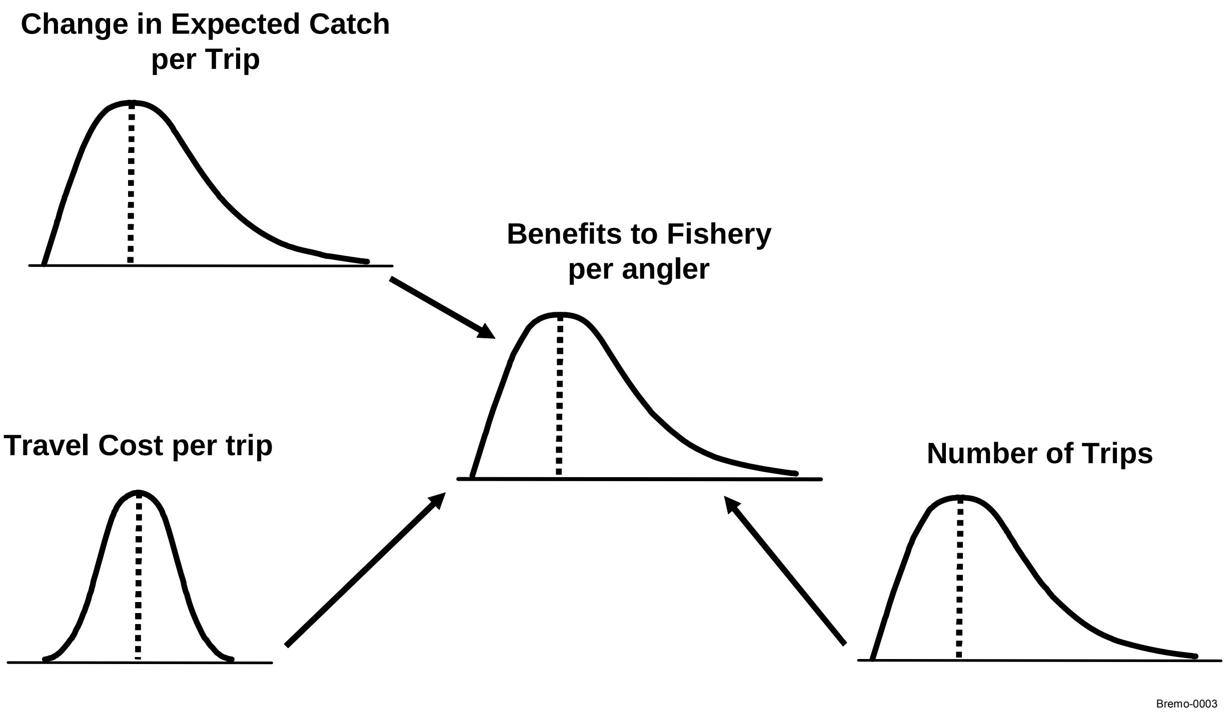

Figure 6-2
Illustration of Monte Carlo Analysis of Recreational Fishing Benefits

As Figure 6-2 shows, the Monte Carlo analysis draws from each element influencing economic benefits to determine the distribution of economic benefits. For example, in one draw, the analysis may draw a low estimate from the distribution of catch rates, but then draw a high estimate from the number of trips and a mid-level estimate from the travel cost per trip. Putting all three of these estimates together produces one estimate of economic benefits. The analysis then draws a value for each component again. This time it may draw a mid-level estimate from each element. The process is repeated 10,000 times to produce the distribution of economic benefits.

Qualitative Assessment of Nonuse Benefits

Section 5.2 revealed the circumstances under which nonuse benefits should be quantified. In the final Phase II Rule, EPA noted that

> In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species; to the sustainability of populations of important species of fish, shellfish, or wildlife; or to the maintenance of community structure and function in a facility's waterbody or watershed, monetization is not necessary. (EPA 2004a, p. 41,647–41,648).

The I&E data presented earlier in Section 4 reveal that no threatened and endangered species are affected by the CWIS at Huntington Beach Generating Station (see Section 3). Accordingly, we adopt a qualitative discussion of nonuse benefits.

The original concept of nonuse values is credited to Krutilla (1967), who argued that individuals do not have to be active consumers of unique, irreplaceable resources in order to derive value from the continuing existence of such resources. He wrote that “when the existence of a grand scenic wonder or a unique and fragile ecosystem is involved, its preservation and continued availability are a significant part of the real income of many individuals” (p. 779).

Krutilla’s argument has two crucial components. First, nonuse values are related to unique resources. Second, nonuse values are related to the continuing existence of a resource. Thus, it follows that common resources that suffer from limited injury do not generate significant nonuse values.

This perspective has pervaded the economic literature in the years since Krutilla introduced it. The economic literature emphasizes the relationship between nonuse values and both the uniqueness of the resource in question and the irreversibility of the loss or injury (Freeman 1993). Freeman summarizes this relationship as follows:

> …economists have suggested that there are important nonuse values in …preventing the global or local extinction of species and the destruction of unique ecological communities. In contrast, resources such as ordinary streams and lakes or a subpopulation of a widely dispersed wildlife species are not likely to generate significant nonuse values because of the availability of close substitutes (p. 162).

As Freeman’s text indicates, common resources (i.e., resources that are not unique) that do not experience irreversible losses are not likely to generate significant nonuse values, if any at all. These principles indicate that there are not meaningful nonuse effects, those uniquely associated with the uncaught sport fish, resulting from reducing I&E at the Huntington Beach Generating Station.

As previously noted, the I&E data for HBGS demonstrate that no threatened or endangered species are affected. This is important because of the relationship between the uniqueness of the resource, the irreversibility associated with changes to the resource, and the extent of potential nonuse values. Because there are no threatened and endangered species associated with I&E at HBGS, the species being impinged and entrained are not unique resources and the effect on these resource is not irreversible. Therefore, the nonuse benefits associated with reducing I&E at the plant are small, if anything at all. Accordingly, no additional evaluation is recommended.

Summary of Economic Benefits

The annual economic benefits of reducing impingement at all units by 13 percent and entrainment at Units 1&2 by 90 percent are based on the dynamic fishery modeling and economic impact methodologies described earlier. Mean quantitative estimates of impacts, decomposed by species and category (recreational, commercial, forage), are depicted in Table 6-6.[24]

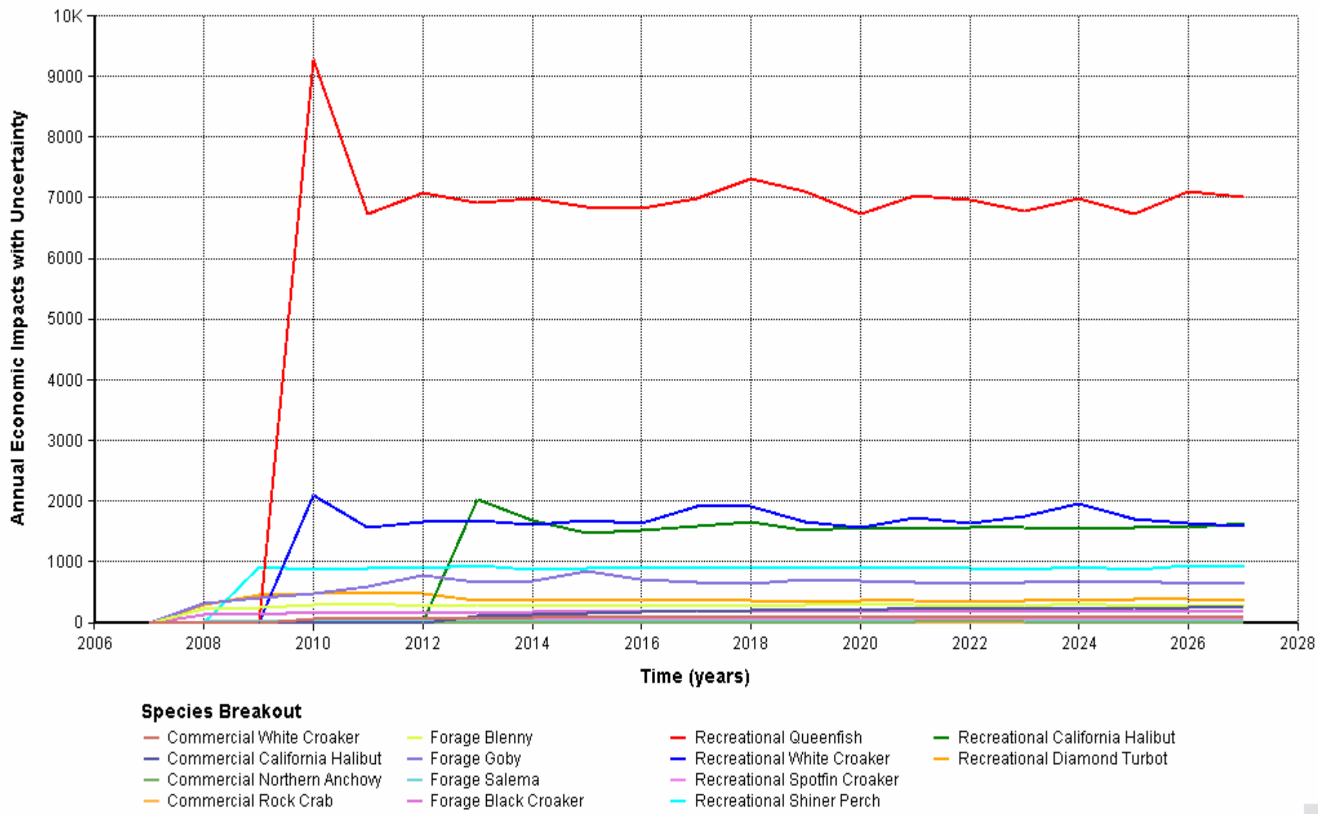

Figure 6-3
Mean Annual Economic Benefits by Species and Category

[24] Quantitative estimates of nonuse are not included for reasons stated previously.

Parameter uncertainty (as opposed to model uncertainty) manifests in supply impacts and demand responses.[25] Biological uncertainty (i.e., change in the supply of fish) in this model is incorporated via mathematical calibration of population dynamic models to equilibrium conditions. Economic uncertainty (i.e., the change in value associated with the change in supply of fish) is incorporated via transferred statistical significance parameters (recreational) and mathematical bounding based on professional judgment (commercial).[26] With these caveats, and with methodologies reflecting the uncertainty discussion earlier in Section 6, upper (95 percent) and lower (5 percent) bounds on the total annual economic impact are depicted in Figure 6-4.

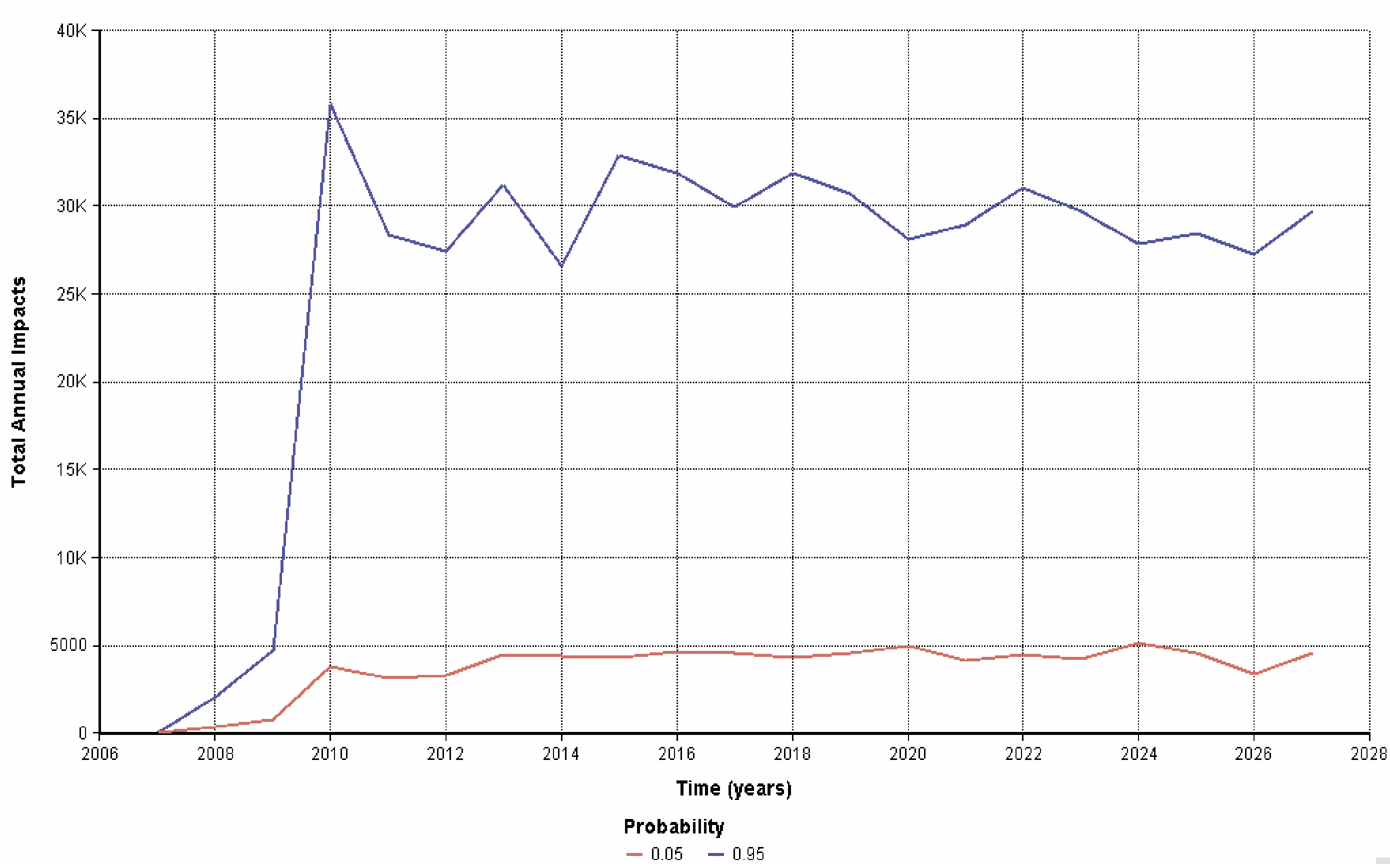

Figure 6-4
Upper and Lower Bound of Total Annual Benefit

[25] Model uncertainty (the inaccuracy associated with the model specification) and sampling uncertainty (the degree to which extrapolated I&E counts reflect actual dynamic annual impacts) are not addressed here.
[26] Uncertainty is incorporated statistically by specifying uniform distributions between upper and lower bounds for commercial benefit parameters.

Both economic theory and requirements of the Phase II Rule indicate that the type (recreational, commercial, use) and timing of dollar-valued benefits influence their relative value. Present-value concepts provide the mathematical structure for equilibrating these values. Here, consistent with Phase II Rule requirements, recreational benefits are discounted at 3 percent and commercial benefits (including that generated from recaptured forgone productivity attributable to forage loss) are discounted at 7 percent. Impacts are quantified as if the I&E reduction began in 2007 and continues for 25 years.[27]

The timing of biological impacts exhibits an appropriate lag.[28] This feature is common to dynamic population models and reflects the time taken to transition between life stages. Economic benefits associated with the change in catch do not occur with a lag. Thus, the model presumes that commercial and recreational anglers adjust their behavior in the same year catch changes. The extent to which this assumption is incorrect and resultant estimates are biased has not been evaluated. However, mitigating relationships exist. For example, relatively small behavioral changes (i.e., changes in trips) associated with relatively small changes in catch such as those seen here mean that much of the value comes from current trips where a behavioral response is not required. Conversely, large changes in expected commercial and recreational catch in particular areas are likely to be communicated rapidly. The public nature of 316(b) proceedings would tend to enhance this effect.

With respect to the incorporation of uncertainty in present value calculations, uncertainty is not monetarily valued.[29] Consistent with the philosophy that the estimates provided here are developed with the intention of meeting regulatory as opposed to policy goals, discount rates are specified as certain, known parameters. In fact, true social discount rates are not constant in that they are both time period and context specific.[30]

Under this specification, the expected value (mean) of the net present value is $158,600. Upper (95 percent) and lower (5 percent) are $254,000 and $94,000. The annualized (NPV/20) benefits associated with I&E reductions range from $4,719 to $12,700 with a mean estimate of $7,928.

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[27] In dynamic models, impacts can persist for a limited period. The 25-year cut-off is computationally tractable and viewed as offsetting to the start specification as instantaneous.

[28] For a more detailed discussion and numerical example of catch timing impacts on value, see Bingham, Desvousges, and Mohamed (2003).

[29] Viewing uncertainty in economic benefits as a form of risk similar to the risk associated with any financial instrument or business endeavor theoretically allows conversion of uncertain future benefit to a certain current value. Theoretically means that the methodologies are available. However, identification of required parameters is difficult without markets.

[30] The appropriate discount rate for environmental impacts with potentially dramatic effects (global warming, nuclear waste) has been studied extensively under the rubric "deep discounting." For policy decisions, interdependence of choices and limited resources dictate that such cases impact discount rates across programs. Thus, the relative discount rate across distant dramatic changes (i.e., global warming) and small changes (i.e., I&E reductions) is properly calculated as a result of a choice between two, rather than used as input to choose between the two.

7
REFERENCES

1. Akçakaya, H. R., M. A. Burgman, and L. Ginzburg. 2002. Applied Population Ecology Principles and Computer Exercises Using RAMAS: Second Edition. Available at http://www.ramas.com/contents.htm. Retrieved on March 22, 2007.
2. Allen, L. G., D. J. Pondella, II, and M. A. Shane. 2007. Fisheries independent assessment of a returning fishery: Abundance of juvenile white seabass (*Atractoscion nobilis*) in the shallow nearshore waters of the Southern California Bight. 1995-2005. Fish. Res. 88:24-32.
3. American Sportfishing Association. 2007. Number of license buyers per state, 2001–2005. Available at http://www.asafishing.org/asa/statistics/participation/fishlicense_2001_05.html. Retrieved on September 13, 2007.
4. Beggs, S., S. Cardell, and J. Hausman. 1981. Assessing the potential demand for electric cars. Journal of Econometrics 17(1):1-19.
5. Bingham, M. F, W. H. Desvousges, and A. F. Mohamed. 2003. Comments on Benefit Estimation of EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability: Final Report. Prepared for The Utility Water Act Group, June 2. Triangle Economic Research, Durham, NC.
6. Bockstael, N. E., W. M. Hanemann, and C. L. Kling. 1987. Estimating the value of water quality improvements in a recreational demand framework. Water Resources Research 23(5):951-960.
7. Bockstael, N. E., W. M. Hanemann, and I. E. Strand, Jr. 1986. Measuring the Benefits of Water Quality Improvements Using Recreation Demand Models. Report to the U.S. Environmental Protection Agency. University of Maryland, College Park, MD.
8. Bockstael, N. E., K. E. McConnell, and I. E. Strand. 1991. Recreation. In Measuring the Demand for Environmental Quality, J. B. Braden and C. D. Kolstad, eds. Elsevier Science Publishers B.V., North Holland.
9. Boyle, K. J., and J. C. Bergstrom. 1992. Benefit transfer studies: myths, pragmatism, and idealism. Water Resources Research 28(3):657-663.
10. Brookshire, D. S., and H. R. Neill. 1992. Benefit transfers: conceptual and empirical issues. Water Resources Research 28(3):651-655.
11. Cailliet, G. M., E. J. Burton, J. M. Cope, L. A. Kerr, R. J. Larson, R. N. Lea, D. VenTresca, and E. Knaggs. 2000. Project summary. In Biological Characteristics of Nearshore Fishes of California: Final Report. Available at http://www.dfg.ca.gov/marine/lifehistories/index.asp#summary. Retrieved on December 11, 2007.

12. California Department of Fish and Game. 2003. 5. Rock crabs. Available at http://www.dfg.ca.gov/marine/status/report2003/rockcrabs.pdf. Retrieved on October 25, 2007.
13. California Department of Fish and Game. 2006a. Threatened and endangered fishes. Available at http://www.dfg.ca.gov/wildlife/species/t_e_spp/fish.html. Retrieved on July 30, 2007.
14. California Department of Fish and Game. 2006b. Table 20PUB—poundage and value of landings by port, Los Angeles area during 2006. Available at http://www.dfg.ca.gov/mrd/landings06/table20pub.pdf. Retrieved on October 12, 2007.
15. California Department of Fish and Game. 2006c. California recreational fisheries survey 2005 annual review. Available at http://www.dfg.ca.gov/marine/crfs_pfmc0306.pdf. Retrieved on October 11, 2007.
16. California Department of Fish and Game. 2007a. Welcome to the California fishing passport web site. Available at http://www.dfg.ca.gov/fishingpassport/. Retrieved on September 27, 2007.
17. California Department of Fish and Game. 2007b. Public health advisories on fish consumption. Available at http://www.dfg.ca.gov/marine/fishcon1.asp. Retrieved on September 14, 2007.
18. California Department of Fish and Game. 2007c. 2007–2008 California Freshwater Sport Fishing Regulations. Available at http://www.dfg.ca.gov/regulations/07-08-inland-fish-regs.pdf. Retrieved on July 31, 2007.
19. California Department of Fish and Game. 2007d. Commercial fishing licenses and permits. Available at http://www.dfg.ca.gov/licensing/pdffiles/cf_items_10yr.pdf. Retrieved on October 11, 2007.
20. California Department of Fish and Game. 2007e. Trophy black bass certificate program. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/TBB/index.asp. Retrieved on September 27, 2007.
21. California Department of Fish and Game. 2007f. Commercial Fishing Laws and Licensing Requirements: 2007. Available at http://www.dfg.ca.gov/marine/pdfs/commercialdigest2007.pdf. Retrieved on August 7, 2007.
22. California Department of Fish and Game. 2007g. California Law: California Fish and Game Code. Available at http://www.leginfo.ca.gov/cgi-bin/calawquery?codesection=fgc&codebody=&hits=20. Retrieved on August 8, 2007.
23. California Department of Fish and Game, Marine Region. 2007a. Record ocean sportfish. Available at http://www.dfg.ca.gov/marine/faqtrph3.asp. Retrieved on September 27, 2007.
24. California Department of Fish and Game, Marine Region. 2007b. *2007 Ocean Sport Fishing Regulations*. Available at http://www.dfg.ca.gov/marine/oceanfish2007.pdf. Retrieved on July 31, 2007.
25. California Department of Fish and Game, Marine Region. 2007c. State managed commercial fisheries: cabezon, greenlings and sheephead (CGS). Available at http://www.dfg.ca.gov/Mrd/cgs.html. Retrieved on August 8, 2007.

26. California Department of Fish and Game, Marine Region. 2007d. Popular features. Available at http://www.dfg.ca.gov/MRD/index_regs.html. Retrieved on August 9, 2007.

27. California Energy Commission. Undated. Biological resources. Available at http://www.energy.ca.gov/sitingcases/elsegundo/documents/applicants_files/afc_cd-rom/VOLUME%201A/5.6.pdf. Retrieved on October 23, 2007.

28. California Fish and Game Commission. 1998. California's marine life management act. Available at http://www.fgc.ca.gov/mlma/introduction.html. Retrieved on September 18, 2007.

29. California Office of Environmental Health Hazard Assessment. 2003. Fish: site-specific advisory information. Available at http://www.oehha.ca.gov/fish/so_cal/index.html. Retrieved on August 6, 2007.

30. California Regional Water Quality Control Board, Santa Ana Region. 2002. Order No. R8-2002-0014, waste discharge requirements for sewage collection agencies in Orange County within the Santa Ana region. Available at http://www.swrcb.ca.gov/rwqcb8/pdf/sso/ssostaffrpt.pdf. Retrieved on September 14, 2007.

31. California Seafood Council. 1997. Facts in brief. Available at http://ca-seafood.ucdavis.edu/facts/industry.htm. Retrieved on September 19, 2007.

32. California State Coastal Conservancy. 2000. Wetland profile: Anaheim Bay. Available at http://images.google.com/imgres?imgurl=http://www.wrpinfo.scc.ca.gov/coast/wetland_images/historic/seal_beach_hist.gif&imgrefurl=http://www.wrpinfo.scc.ca.gov/coast/dbs/profile.asp%3FSITEID%3D22&h=884&w=559&sz=57&hl=en&start=1&um=1&tbnid=RMCBuQ0dWmiRDM:&tbnh=146&tbnw=92&prev=/images%3Fq%3D%2522shipping%2Bchannel%2522%2B%252B%2B%2522Huntington%2BBeach%2522%2B%252B%2BCalifornia%26svnum%3D10%26um%3D1%26hl%3Den%26sa%3DN. Retrieved on September 17, 2007.

33. Cameron, T. A. 1985. A nested logit model of energy conservation activity by owners of existing single family dwellings. The Review of Economics and Statistics 67(2):205-211.

34. Carlson, J. K., E. Cortés, and D. M. Bethea. 2003. Life history and population dynamics of the finetooth shark (carcharhinus isodon) in the northeastern Gulf of Mexico. Fishery Bulletin 101(2):281–292. Available at http://fishbull.noaa.gov/1012/06carlso.pdf. Retrieved on March 22, 2007.

35. Caulkins, P. P., R. C. Bishop, and N. W. Bouwes, Sr. 1986. The travel cost model for lake recreation: a comparison of two methods for incorporating site quality and substitution effects. American Journal of Agricultural Economics 68(2):291-297.

36. CephBase. 2003. Cephalopod prey in the wild. Available at http://www.cephdev.utmb.edu/preydb/preydb.cfm. Retrieved on October 23, 2007.

37. Chetrick, J. 2006. Trends in U.S. and world lobster production, imports, and exports. Available at http://www.fas.usda.gov/ffpd/Fishery_Products_Presentations/Lobster_2006/lobster_2006.ppt#268,1,Trends in U.S. and World Lobster Production, Imports and Exports. Retrieved on October 25, 2007.

38. City of Huntington Beach. 2006. Welcome to Huntington Beach. Available at http://www.ci.huntington-beach.ca.us/. Retrieved on August 9, 2007.

39. DeLorme. 2005. Southern and Central California Atlas and Gazetteer. DeLorme, Yarmouth, ME.

40. Desvousges, W. H., M. F. Bingham, J. C. Kinnell, A. F. Mohamed, and K. T. Kuhns. 2005. Review and Response to the EPA's Response to Comments from the American Chemistry Council et al. and Accompanying Triangle Economic Research (TER) Report. Prepared for the Utility Water Act Group, General Electric Company, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Public Power Association, and American Petroleum Institute. April 20. Triangle Economic Research, Durham, NC.

41. Desvousges, W. H., F. R. Johnson, and H. S. Banzhaf. 1998. Environmental Policy Analysis With Limited Information: Principles and Applications to the Transfer Method. Edward Elgar, Cheltenham, UK.

42. Desvousges, W. H., M. C. Naughton, and G. R. Parsons. 1992. Benefit transfer: conceptual problems in estimating water quality benefits using existing studies. Water Resources Research 28(3):675-683.

43. DeVoretz, D. J., and K. G. Salvanes. 1993. Market structure for farmed salmon. American Journal of Agricultural Economics 75:227-233.

44. EPRI. 2005. Parameter Development for Equivalent Adult and Production Foregone Models. EPRI, Palo Alto, CA.

45. Feder, H. M., C. H. Turner, and C. Limbaugh. 1974. Observations in fishes associated with kelp beds in southern California. Available at http://content.cdlib.org/xtf/view?docId=kt9t1nb3sh&brand=default&doc.view=entire_text. Retrieved on October 23, 2007.

46. Feenberg, D., and E. S. Mills. 1980. Measuring the Benefits of Water Pollution Abatement. Academic Press, New York.

47. Finkel, A. M. 1990. A simple formula for calculating the "mass density" of a lognormally distributed characteristic: applications to risk analysis. Risk Analysis 10(2):291-301.

48. Freeman III, A. M. 1993. Nonuse values in natural resource damage assessment. In R. J. Kopp and V. K. Smith (eds.), Valuing Natural Resource Assets: The Economics of Natural Resource Damage Assessment. Resources for the Future, Inc., Washington, DC.

49. Getz, W. M., and R. G. Haight. 1989. Population Harvesting: Demographic Models of Fish, Forest, and Animal Resources. Princeton University Press, Princeton, NJ.

50. Grumbles, Benjamin. 2007. Implementation of the decision in *Riverkeeper, Inc. v. EPA*, remanding the cooling water intake structures Phase II regulation. U.S. Environmental Protection Agency, Washington, DC.

51. GSA (U.S. General Services Administration). 2006. Privately owned vehicle (POV) mileage reimbursement rates. Available at http://www.gsa.gov/Portal/gsa/ep/contentView.do?contentType=GSA_BASIC&contentId=9646. Retrieved on September 5, 2006.

52. Hackett, S. C., and M. Krachey. 2001. An Economic Overview of the California Wetfish Industry Complex. Available at http://ca-seafood.ucdavis.edu/news/wetfish/wf_econ.pdf. Retrieved on October 25, 2007.

53. Hardin, G. 1968. The tragedy of the commons. Science 162:1243-1248.

54. Hein, C. L., B. M. Roth, A. R. Ives, and M. J. V. Zanden. 2006. fish predation and trapping for rusty crayfish (orconectes rusticus) control: a whole-lake experiment. Canadian Journal of Fisheries and Aquatic Sciences 63(2):383-393.

55. Hensher, D. A. 1991. The use of discrete choice models in the determination of community choices in public issue areas impacting on business decision making. Journal of Business Research 23(4):299-309.

56. Huang, K. S., and B.-H. Lin. 2000. Estimation of food demand and nutrient elasticities from household survey data. Technical Bulletin Number 1887. U.S. Department of Agriculture, Washington, DC.

57. Huntington Beach Events.com. 2007. Huntington Beach events. Available at http://www.huntingtonbeachevents.com/2007ap14.html. Retrieved on September 20, 2007.

58. International Pacific Halibut Commission. 2007. Halibut Commission completes 2007 annual meeting. Available at http://www.iphc.washington.edu/halcom/newsrel/2007/nr20070123.htm. Retrieved on August 8, 2007.

59. Jackson, D. 2006. Albackore's Gulp! only west coast fall surf slam. Available at http://www.fishingexpeditions.com/html/surf_slam.html. Retrieved on September 20, 2007.

60. Jones, K. Undated. Dana Point Harbor fishing pier. Available at http://www.pierfishing.com/resources/index.php?id=piers:dana_point_harbor_fishing_pier. Retrieved on August 9, 2007.

61. Judd, Tim. 1998. The sequestering of secondary compounds from sponges by nudibranchs. Available at http://www.colostate.edu/Depts/Entomology/courses/en570/papers_1998/judd.html. Retrieved on October 24, 2007.

62. Kling, C. L., and J. A. Herriges. 1995. An empirical investigation of the consistency of nested logit models with utility maximization. American Journal of Agricultural Economics 77(November):875-884.

63. Kling, C., and C. Thomson. 1996. The implications of model specification for welfare estimation in nested logit models. American Journal of Agricultural Economics 78(Feb):103-114.

64. Krutilla, J. V. 1967. Conservation reconsidered. American Economic Review 57(4):777-786.

65. Lane, D. E., and C. W. Hill. 1975. The marine resources of Anaheim Bay. Available at http://content.cdlib.org/xtf/view?docId=kt6n39n885&brand=calisphere&doc.view=entire_text. Retrieved on October 23, 2007.

66. Leslie, P. H. 1945. On the use of matrices in certain population mathematics. Biometrika 33:183-212.

67. LIMPETS. Undated. The Pacific mole crab. Available at http://limpetsmonitoring.org/docs/Crab_Factsheet.pdf. Retrieved on November 15, 2007.

68. Los Angeles County Department of Beaches and Harbors. Undated. Welcome to Marina Del Rey. Available at http://beaches.co.la.ca.us/BandH/Marina/Main.htm. Retrieved on September 27, 2007.

69. Mansfield, E. 1988. Microeconomics Theory and Applications: Shorter Sixth Edition. W.W. Norton & Company, New York.

70. MBC Applied Environmental Sciences and Tenera Environmental, Inc. 2007. Draft Report Huntington Beach Generating Station Clean Water Act Section 316(b) Impingement Mortality and Entrainment Characterization Study. Prepared for AES Huntington Beach. February 26. MBC Applied Environmental Sciences, Costa Mesa, CA.

71. McConnell, K. E. 1992. Model building and judgment: implications for benefit transfers with travel cost models. Water Resources Research 28(3):695-700.

72. McFadden, D. 1997. Modelling the choice of residential location. In The Economics of Housing, Volume 1, J. M. Quigley, ed. Elgar, Northampton, MA.

73. Morey, E. R., W. D. Shaw, and R. D. Rowe. 1991. A discrete-choice model of recreational participation, site choice, and activity valuation when complete trip data are not available. Journal of Environmental Economics and Management 20(2):181-201.

74. Muncy, R. J. 1984. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (Gulf of Mexico)—pinfish. U.S. Fish and Wildlife Service FWS/OBS-82/11.26. U.S. Army Corps of Engineers, TR EL-82-7. 18 pp.

75. National Marine Fisheries Service Northwest Regional Office. 2007a. Groundfish regulations. Available at http://www.nwr.noaa.gov/Groundfish-Halibut/Groundfish-Fishery-Management/Regulations/Index.cfm. Retrieved on August 8, 2007.

76. National Marine Fisheries Service Northwest Regional Office. 2007b. Salmon fishery management. Available at http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Salmon-Fishery-Management/Index.cfm. Retrieved on August 8, 2007.

77. National Marine Fisheries Service Northwest Regional Office. 2007c. Highly migratory species program. Available at http://swr.nmfs.noaa.gov/hms/hms.htm. Retrieved on August 8, 2007.

78. National Marine Fisheries Service Southwest Regional Office. 2007a. Coastal pelagic species. Available at http://swr.nmfs.noaa.gov/fmd/cps/cps.htm. Retrieved on August 8, 2007.

79. National Marine Fisheries Service Southwest Regional Office. 2007b. Highly migratory species program. Available at http://swr.nmfs.noaa.gov/hms/hms.htm. Retrieved on August 8, 2007.

80. National Oceanic and Atmospheric Administration. 2006. 2007 Pacific halibut catch sharing plan for Area 2a. Available at http://www.nwr.noaa.gov/Groundfish-Halibut/Pacific-Halibut/loader.cfm?url=/commonspot/security/getfile.cfm&pageid=36164. Retrieved on September 27, 2007.

81. National Oceanic and Atmospheric Administration. 2007. International fisheries; Pacific tuna fisheries; restrictions for 2007 purse seine and longline fisheries in the eastern tropical Pacific Ocean. Available at http://a257.g.akamaitech.net/7/257/2422/01jan20071800/edocket.access.gpo.gov/2007/E7-10718.htm. Retrieved on September 27, 2007.

82. National Oceanic and Atmospheric Administration Shark Population Assessment Group. 2006. Population dynamics. Available at http://www.sefscpanamalab.noaa.gov/shark/researchareas.htm. Retrieved on May 10, 2007.

83. Newbold, S. C., and R. Iovanna. 2007a. Population level impacts of cooling water withdrawals on harvested fish stocks. Environ. Sci. Technol. 41(7):2108-2114.

84. Newbold, S. C., and R. Iovanna. 2007b. Supplemental information for "Population level impacts of cooling water withdrawals on harvested fish stocks." U.S. EPA, National Center for Environmental Economics, Washington, DC.

85. Neyman, J., and E. S. Pearson. 1933. On the problem of the most efficient tests of statistical hypotheses. Phil. Trans. Roy. Soc. London, Ser. A 231:289-337.

86. Office of Environmental Health Hazard Assessment. 2003. Fish: site-specific advisory information. Available at http://www.oehha.ca.gov/fish/so_cal/index.html. Retrieved on August 6, 2007.

87. Orange County Health Care Agency. 2007. Ocean water protection program: ocean and bay water closures, postings & advisories. Available at http://www.ocbeachinfo.com/. Retrieved on September 18, 2007.

88. Pacific Fishery Management Council. 2006. Council recommends pacific sardine harvest guideline for 2007. Pacific Council News 30(4):9. Available at http://www.pcouncil.org/newsletters/2006/Winter_2006.pdf. Retrieved on August 8, 2007.

89. Pauly, D., and V. Christensen. 1995. Primary production required to sustain global fisheries. *Nature* 374:255-257.

90. Pollard, J. H. 1973. Mathematical Models for the Growth of Human Populations. Cambridge University Press, Cambridge, UK.

91. Pomeroy, C., and M. Dalton. 2005. Market channels and value added to fish landed at Monterey Bay area ports. Available at http://repositories.cdlib.org/cgi/viewcontent.cgi?article=1038&context=csgc. Retrieved on October 23, 2007.

92. Public Service Electric and Gas Company (PSEG). 1999. Permit Renewal Application, NJDPES Permit No. NJ0005622, Salem Generating Station. March 4.

93. Quinlan, J. A., and L. B. Crowder. 1999. Searching for sensitivity in the life history of Atlantic menhaden: inferences from a matrix model. Fisheries Oceanography 8(s2):124-133.

94. Radtke, H. D., and S. W. Davis. 2000. Description of the U.S. West Coast Commercial Fishing Fleet and Seafood Processors. Available at http://www.psmfc.org/efin/docs/fleetreport.pdf. Retrieved on October 23, 2007.

95. *Riverkeeper, Inc., Natural Resources Defense Council, Waterkeeper Alliance, Soundkeeper, Inc., Scenic Hudson, Inc., Save the Bay-People for Narragansett Bay, Friends of Casco Bay, American Littoral Society, Delaware Riverkeeper Network, Hackensack Riverkeeper, Inc., New York/New Jersey Baykeeper, Santa Monica Baykeeper, San Diego Baykeeper, California Coastkeeper, Columbia Riverkeeper, Conservation Law Foundation, Surfrider Foundation, State of Rhode Island, State of Connecticut, State of Delaware, Commonwealth of Massachusetts, State of New Jersey, State of New York, Appalachian Power Company, Illinois Energy Association, Utility Water Act Group, PSEG Fossil LLC, PSEG Nuclear LLC, Entergy Corporation v. United States Environmental Protection Agency, Stephen L. Johnson, in his official capacity as Administrator of the United States Environmental Protection Agency*. 2007. United States Court of Appeals for the Second Circuit. Docket Nos. 04-6692-ag(L), 04-6693-ag(CON), 04-6694-ag(CON), 04-995-ag(CON), 04-6696-ag(CON), 04-6697-ag(CON), 04-6698-ag(CON), 04-6699-ag(CON). January 25, 2007.

96. Sabaton, C., L. Siegler, V. Gouraud, J. L. Baglinière, and S. Manné. 1997. Presentation and first applications of a dynamic population model for brown trout, salmo trutta l.: aid to river management. fisheries management and ecology 4(6):425–438.

97. San Diego Sportfishing Council. Undated. San Diego sportfishing online. Available at http://www.sportfishing.org/. Retrieved on September 27, 2007.

98. Schaefer, M. B. 1954. Some aspects of the dynamics of populations important to the management of commercial marine fisheries. Bull. Inter-Amer. Trop. Tuna Commission 1:27-56.

99. Schaefer, M. B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Bull. Inter-Amer. Trop. Tuna Commission 2:247-268.

100. Sheckler, D. 1999. Arch rock cove. Available at http://www.saintbrendan.com/cdnaug/anacapa8.html. Retrieved on October 24, 2007.

101. Sherman, Peter. 1998. Revised draft, derivation of 'wholly disproportionate' test re CWA Section 316. Memo to Martha Segall, U.S. Environmental Protection Agency Engineering and Analysis Division. September 14.

102. Smith, V. K. 1992. On separating defensible benefit transfers from smoke and mirrors. Water Resources Research 28(3):685-694.

103. Smith, V. K., G. L. van Houtven, and S. Pattanayak. 2002. Benefit transfer via preference calibration: "prudential algebra" for policy. Land Economics 78(1):132-152.

104. Southern California Wetlands Recovery Project. 2007. WRP regional strategy: county objectives. Available at http://www.scwrp.org/pdfs/RS-Ch4-County-Objectives.pdf. Retrieved on September 17, 2007.

105. Sportfishingreport.com. 2007. Catch. Available at http://www.sportfishingreport.com/pages/landingdetail.php?landing_id=12. Retrieved on August 6, 2007.

106. State Water Resources Control Board. 2006. Proposed 2006 CWA Section 303(d) list of water quality limited segments. Available at http://www.swrcb.ca.gov/tmdl/docs/303dlists2006/final/r8_final303dlist.pdf. Retrieved on September 7, 2007.

107. Stockteam.com. 2007. Grunion run in Huntington Beach, California. Available at http://www.stockteam.com/grunion.html. Retrieved on September 21, 2007.

108. Tietenberg, T. 2006. Environmental and Natural Resource Economics: Seventh Edition. Addison Wesley, Boston.

109. U.S. Census Bureau. 2007a. State and county quick facts: Orange County, California. Available at http://quickfacts.census.gov/qfd/states/06/06059.html. Retrieved on August 9, 2007.

110. U.S. Census Bureau. 2007b. State & county quickfacts: California. Available at http://quickfacts.census.gov/qfd/states/06000.html. Retrieved on September 13, 2007.

111. U.S. Environmental Protection Agency. 2000. Guidelines for Preparing Economic Analyses. Report Number 240-R-00-003. USEPA, Washington, DC.

112. U.S. Environmental Protection Agency. 2002. Economic and Benefits Analysis for the Proposed Section 316(b) Phase II Existing Facilities Rule. Report Number 821-R-02-001. February. U.S. EPA, Washington, DC.

113. U.S. Environmental Protection Agency. 2004a. National pollutant discharge elimination system—final regulations to establish requirements for cooling water intake structures at Phase II existing facilities; final rule. Federal Register Vol. 69, No. 131 (Friday, July 9):41,576–41,693.

114. U.S. Environmental Protection Agency. 2004b. California Regional Analysis. Available at http://www.epa.gov/waterscience/316b/phase2/casestudy/final/chb2.pdf. Retrieved on October 12, 2007.

115. U.S. Environmental Protection Agency. 2007. What you need to know about mercury in fish and shellfish. Available at http://www.epa.gov/waterscience/fishadvice/advice.html. Retrieved on August 6, 2007.

116. U.S. Fish and Wildlife Service. 2003. 2001 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation: California. Available at http://www.census.gov/prod/2002pubs/fhw01-ca.pdf. Retrieved on July 27, 2007.

117. U.S. Fish and Wildlife Service. 2007. USFWS threatened and endangered species system (TESS). Available at http://ecos.fws.gov/tess_public/SpeciesReport.do?groups=E&listingType=L. Retrieved on July 27, 2007.

118. Vitale, P. 2007. Surface Water Ambient Monitoring Program Report: Anaheim Bay and Huntington Harbour Sediment and Water Column Toxicity Study. Available at http://www.swrcb.ca.gov/swamp/regionalreports.html#rb8. Retrieved on September 7, 2007.

119. Wägele, H., and A. Klussmann-Kolb 2005. Opisthobranchia (mollusca, gastropoda)—more than just slimy slugs. Shell reduction and its implications on defence and foraging. Frontiers in Zoology 2:3.

120. Wessells, C. R., and J. L. Anderson. 1992. Innovations and progress in seafood demand and market analysis. Marine Resource Economics 7:209-288.

121. Wessells, C. R., and J. E. Wilen. 1994. Seasonal patterns and regional preferences in Japanese household demand for seafood. Canadian Journal of Agricultural Economics 42:87-103.

122. Zerbe, R. O., Jr., and D. D. Dively. 1994. Benefit-Cost Analysis in Theory and Practice. Harper Collins College Publishers, New York.

A
AN OVERVIEW OF BENEFIT-COST ANALYSIS

At the individual level, decision-making includes at least an informal comparison of benefits and costs. In the economics literature, comparing benefits and costs has been formalized in the theories of rational expectations, utility maximization, and choice (Friedman and Savage 1948; Hensher 1991; Brent 1995; Kling and Herriges 1995; Hanley, Wright, and Adamowicz 1998; Blamey et al. 2000; Blamey and Bennett 2001). With respect to private enterprise, survival in commercial activity is guided by the criterion that over time, total revenues must meet or exceed total costs. This requirement and attendant profit motivation of firms dictate that survival in the commercial arena requires explicit valuation of projects in terms of net monetized benefit to the firm. The selection of projects in the private sector based on monetized expectations leads naturally to conferring benefits on certain population segments, including employees, consumers, and (through taxes) the public. It is, in fact, this process that underlies the prices formed in markets for goods such as cars and houses. Adam Smith (1776) metaphorically identified the link between the surplus associated with private interest and socially optimal outcomes under certain conditions as an "invisible hand." Despite the appeal of Smith's "invisible hand," the set of conditions under which self-interest promotes optimal social outcomes is not observed generally.[31] For this reason, social valuation of projects and input to decision-making is often important for understanding aggregate impacts.

Benefit-cost analysis (BCA) provides a consistent method for evaluating the contribution of public policies to economic efficiency. BCA may be performed to evaluate policies before (ex ante) their implementation to help in policy selection or after (ex post) their implementation to learn of the actual consequences of the policy. BCA incorporates widely accepted principles of resource management, such as:

- In a world of limited natural, human, and financial resources, it is desirable to achieve any given goal at the least possible cost.
- When faced with multiple goals, we should allocate our scarce resources among these goals so as to achieve the greatest net benefit.[32]

BCA takes its instruction from the precepts of market exchange where the contributions to and decrements from social welfare of individuals' resource allocation decisions are estimated in dollars. Among other advantages, using dollars as the preference metric provides a measure of

[31] In the case of environmental regulation, it is the presence of externalities that makes evaluating the social cost and benefit associated with private decision-making necessary for choosing socially optimal decisions (allocation of resources).
[32] For economists, BCA is the *sine qua non*. A panel of 42 economists from academia, the private sector, and government, including three Nobel Laureates, addressed an *amicus* brief to the U.S. Supreme Court, confirming their view that benefit-cost analysis is essential for good policymaking (Arrow et al. 2000).

the intensity of individuals' preferences and provides a comparable measure of both benefits and costs. BCA can incorporate nonmarket valuation methods for nonpriced, but valued, goods when those values can be reliably measured.[33]

Markets, where buyers and sellers engage in voluntary exchange, are widely viewed as the best available institutional arrangement currently available for effectively addressing resource allocation decisions for most goods and services. Markets, which are underpinned by private property, reveal the quantities of a commodity consumers wish to purchase at a given price and thus reflect the value of the commodity to demanders. They also reveal the quantities of a commodity that producers are willing to provide and thus reflect the cost of the commodity to suppliers. The market quantities of goods and services resulting from the interaction of demanders and suppliers are efficient in the sense that it is not possible to make any person better off without making at least one other person worse off.

Markets do not perform well, however, for a class of goods termed "public goods." Pure public goods are both nonexcludable and nonrivalrous. They are nonexcludable in that, once provided, it is very costly or even impossible to prevent anyone from consuming the good. They are nonrivalrous in that their consumption by one person does not diminish the quantity of the good available to others. National defense and clean air are examples of pure public goods.

The line between private goods of the market and public goods is a fuzzy and shifting one. Many predominately private goods have some degree of publicness and visa versa. For example, a home with an attractive exterior is available for all to enjoy; a highway can be closed to those with improper vehicles or those who are unwilling to pay the toll. Both changes in public attitudes and changes in technology are responsible for the shifts.

Because of the nonexcludability of public goods, efficient markets will not develop for them. One of the roles of government is to provide public goods to society. However, governments have a problem to solve: what public goods in what quantities to provide? One way to address the question is to attempt to emulate the outcomes of a market by providing those public goods in the quantities that increase efficiency. Properly performed, BCA provides estimates of the contribution to economic efficiency (which may be negative) of putative and actual public policies.

This appendix provides a primer on BCA after first describing its legislative origins. The appendix closes with a discussion of the application of BCA for identifying Best Technology Available (BTA) and outlines regulatory requirements for a site-specific determination of BTA.

Legislative Origins of BCA

The French engineer Jules Dupuit (1844) first proposed employing BCA to evaluate a public works project. He employed aggregate measures of individual welfare to make comparisons of

[33] Section 5 provides a discussion of methodologies available for measuring certain kinds of nonmarket services. Appendix B contains a discussion of the challenges associated with reliably measuring other kinds of nonmarket services.

the benefits and costs of a bridge. The British economist Alfred Marshall further developed BCA formalizing its role in political economics and establishing the foundation for most empirical studies in welfare economics (Fuguitt and Wilcox 1999).

The *U.S. Flood Control Act of 1936* provided the first regulatory inclusion of BCA in the U.S. The Act suggested that "the Federal Government should improve or participate in the improvement of navigable waters or their tributaries including watersheds thereof, for flood-control purposes if the benefits to whomsoever they may accrue are in excess of the estimated costs." The *Flood Control Act of 1936* stated that floods were "a menace to national welfare" and asserted that "flood control on navigable waters or their tributaries is a proper activity of the Federal Government" in cooperation with other governmental entities. Thus, the *Flood Control Act of 1936* initiated the process of applying economic evaluations to public investment decisions (Shabman 1997). It bears noting that this directive provided only minimal requirements, that benefits need only exceed costs to justify a project, and that the phrase "to whomsoever they occur" precludes consideration of distributional (equity) impacts.

The Flood Control Act of 1936 vested responsibility for addressing the risks of floods across the nation to the U.S. Army Corps of Engineers. The primary methods envisioned for addressing flood risks were significant construction projects, such as dams and reservoirs that would impact the hydrology of entire river systems (Barry 1997). Executing the Act potentially has difficult requirements, such as advanced risk assessment (floods), and the Act fails to explicitly consider potential impacts, such as overbuilding in flood plains. Nevertheless, using project evaluation tools was considered the proper approach to evaluating and selecting flood-management projects.

The *U.S. Reclamation Project Act of 1939* reinforced the implementation of BCA and required that the Bureau of Reclamation weigh the benefits and cost of irrigated water (43 *U.S.C.* 485h[c]). BCA was soon required of the U.S. Army Corps of Engineers. The first applications of the Corp's federally legislated BCA were somewhat ad hoc (Fuguitt and Wilcox 1999; Watkins undated). BCA was generally considered an ancillary task and given little weight in the decision-making process.

However, in the post-war era of the late 1940s and the early 1950s, BCA began to be considered an important and useful tool for analyzing public expenditures. The so-called "*Green Book*" (for the color of its cover) was developed and revised in the 1950s to establish and disseminate a set of guidelines for water planning and management. The heart of these guidelines focused on economic efficiency, which is still the cornerstone of BCA. As government and academic economists discovered the potential contribution of this method of project evaluation, BCA quickly became the accepted standard for assessing public investment projects. Significant early examples of the application of BCA include evaluations of a London subway (Foster and Beesley 1963), disease control (Klarman 1965), and the (now called) Chunnel (Ministry of Transport 1963).[34]

In these initial applications of BCA to public investment projects, a conceptual foundation for the comparison of benefits and costs was absent. Rather, these applications supported

[34] See Mishan (1975) for a concise review of these studies.

government investment in public infrastructure with the presumptive advantage of the ability to choose optimal projects with a fixed amount of funds.[35]

By the late 1970s, regulators heeded industry's demands for a balanced consideration of social benefits associated with the costs of the regulation (Fuguitt and Wilcox 1999). Advances in economic theory and practice as well as the growth in regulatory agencies during the 1970s led to the promulgation of several increasingly detailed executive orders and Office of Management and Budget (OMB) circulars. These directives outlined the general principles and procedures for conducting BCA for the federal government. Agency-specific guidelines provided more detailed guidance and examples. Three executive orders are especially noteworthy:

- Promulgated in 1978, the Carter Administration's Executive Order 12044 provided the first requirement that BCA should be used to weigh compliance costs against derived benefits from regulations. Executive Order 12044 required Regulatory Impact Analyses, a close cousin of BCA. This order required government agencies to "prepare a regulatory analysis" weighing the costs and benefits of "regulations identified as significant" (43 *Fed. Reg*. 12663).[36]
- Issued in 1981, the Reagan Administration's Executive Order 12291 built on Executive Order 12044, effectively augmenting the scope of regulations deemed as "significant." Besides expanding the scope of which regulations would require a BCA, Executive Order 12291 stipulated that "regulatory action shall not be taken unless the potential benefits to society outweigh the potential costs" (43 *Fed. Reg*. 12663) and that "regulatory objectives shall be chosen to maximize net benefits to society" (43 *Fed. Reg*. 12663). Although Executive Order 12291 expanded the scope of BCA, like its predecessors, this Order did not establish a uniform standard for quantifying and comparing benefits and costs. Executive Order 12291 remained the basis for BCA for about 12 years.
- President Clinton's Executive Order 12866 supplanted Executive Order 12291 on September 30, 1993. It retained the fundamental tenets of Executive Order 12291 while increasing the scope of regulations requiring a BCA prior to their implementation. President Clinton recognized some of the practical and legal obstacles to President Reagan's order, but he still endorsed the view that regulations should be designed to maximize net benefits.

Under the Clean Water Act (CWA), the idea of weighing the regulatory benefits relative to costs appears in Section 304(b)(1)(B), which addresses effluent limitation guidelines. The section reads:

> Factors relating to the assessment of best practical control technology currently available shall include…consideration of the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, and shall also take into account the age of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques, process

[35] When the budget and number of projects are fixed, net benefits are maximized by selecting projects with the highest benefit-to-cost ratios first, thus simplifying the selection process.

[36] Significant regulations were ultimately defined as those that would result in "a) an annual effect on the economy of $100 million or more; or b) a major increase in costs or prices or individual industries, levels of government, or geographic regions" (43 *Fed. Reg.* 12663).

> changes, non-water quality environmental impact (including energy requirements), and such other factors as the Administrator deems appropriate.

The judicial history of this Section states that "[t]he balancing test between total cost and effluent reduction benefits is intended to limit the application of technology only where the additional degree of effluent reduction is wholly out of proportion to the costs of achieving such marginal level of reduction for any class or category of sources" (*Kennecott v. United States EPA*). Additionally, the judicial history of the CWA supports the concept of weighing the benefits and costs of the "Best Practicable Technology," which is defined as the "average of the best existing performance ... within each industrial category" (*Kennecott v. United States EPA*).

Regarding Section 316(b) of the CWA, the notion of BCA first appears *In the Matter of Public Service Company of New Hampshire* 10 ERC 1257 (May and Van Rossum 1995). This case, commonly called the Seabrook II Decision, was rendered in 1977 and held that no formal BCA was *required* under 316(b) (TetraTech Inc. 2002). However, the ruling stated that some consideration of the relationship between benefits and costs was applicable because Section 316(b) did not require implementation of technology whose cost was "wholly disproportionate" to its environmental benefits. Again, although this ruling supported consideration of regulatory benefits and costs, it gave no formal guidelines for determining "wholly disproportionate" costs, nor did it provide guidance on the measurement of benefits and costs.

Following the Seabrook II Decision, the "wholly disproportionate" cost test has been applied differently in various cases depending on the specific facts of the case. The lack of uniformity of the "wholly disproportionate" cost test has been legally enshrined through case law, where the test has been called "a relatively subsidiary" task (*BASF Wyandotte Corp. v. Costle*) that "need not be precise" (*Weyerhauser Co. v. Costle*). Thus, the EPA applies the test ad hoc and has a long history of both finding specific proposals "wholly disproportionate" as well as finding them acceptable.

In perhaps the most directly relevant statement, the EPA addressed the "wholly disproportionate" cost test in its recent revisitation of the Phase II Rule of Section 316(b) of the CWA. In the Final Rule, the EPA reaffirmed the place of the "wholly disproportionate" cost test in considering compliance costs, stating that "should facilities in these other industrial categories face compliance costs wholly disproportionate to those EPA considered and found to be economically practicable in today's economic analysis, they can seek alternative requirements" (66 *Fed. Reg.* 65311). Furthermore, the EPA provided that "should an individual new facility demonstrate that costs of regulatory compliance for a new facility would be wholly out of proportion to the costs EPA considered and determined to be economically practicable, the Director would have authority to adjust best technology available requirements accordingly" (66 *Fed. Reg.* 65322) and to create a mechanism for the practical implementation of the findings of a BCA.

In 2004, EPA finalized its Phase II 316(b) Rule, which contains a provision that potentially allows reduced compliance standards based on the results of BCA (69 *Fed. Reg.* 41576–41693). Compliance under this provision requires that the facility demonstrate that the costs of meeting the standards are "significantly greater" than the associated economic benefits. However, on January 25, 2007 the Second Circuit Court of Appeals released a ruling that disallowed many significant components of the EPA's Phase II § 316(b) rule for cooling water intake structures

(*Riverkeeper et al. v. U.S. Environmental Protection Agency*), including the benefit-cost test. In response to the Second Circuit Court ruling, EPA has suspended the Phase II Rule and directed that all permits for Phase II facilities be considered on a Best Professional Judgment basis as described at 40 *CFR* § 401.14 (Grumbles 2007; 72 *Federal Register* 37107).

Microeconomic Foundations of BCA

In a society characterized by competitive markets, prices allocate resources. In that market setting, the numbers of buyers and sellers are such that the actions of individual buyers and sellers do not significantly impact commodity prices. The primary paradigm for understanding how market-clearing prices are reached in perfect competition is the well-known model of demand and supply. This predictive model also provides normative insights, for it can be used to discover the value and cost of alternative quantities of a commodity.

In this model, the market demand for a consumer good reflects the aggregate consumption rate of a commodity that consumers will purchase for all prices. Theoretical reasoning and empirical studies both confirm that such demand curves will slope downward as illustrated in Figure A-1a. The market supply for a commodity reflects the aggregate production rate which producers will provide for all prices. Theoretical reasoning and empirical studies confirm that supply curves will slope upward as illustrated in Figure A-1.b. The tension between consumers and producers results in the establishment of a stable equilibrium where the quantity demanded and supplied are equated: P_1, Q_1 in Figure A-1.c.

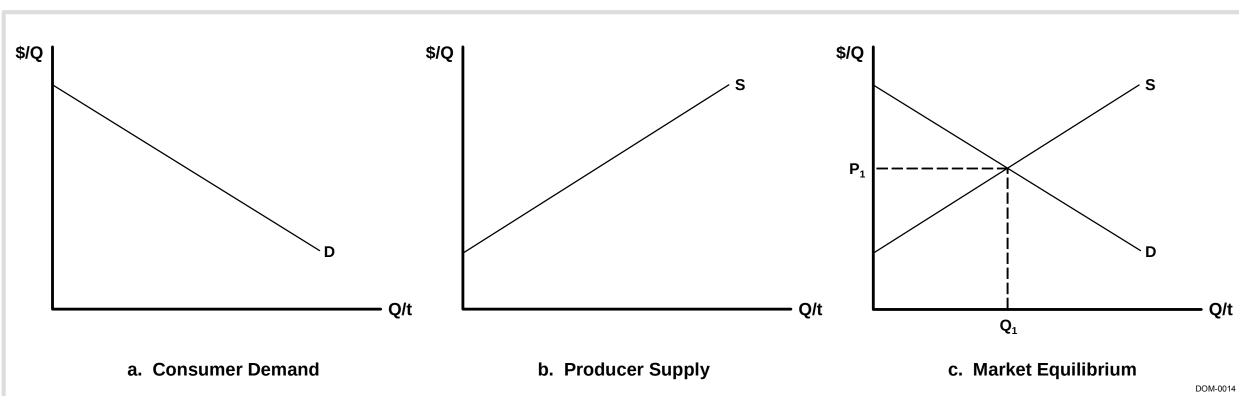

Figure A-1
Competitive Market Outcome

In competitive markets, a stable equilibrium results from the interaction of demand and supply.

The consumer's demand curve also shows the marginal valuation of each consumption rate. For example, take the step demand curve for a hypothetical consumer as shown in Figure A-2. In the figure, if the price is $10, the consumer would purchase 1 unit of the good. If the price were $8, the consumption rate would be 2, revealing that the increment in consumption is only worth $8 (or fractionally more) to the consumer.

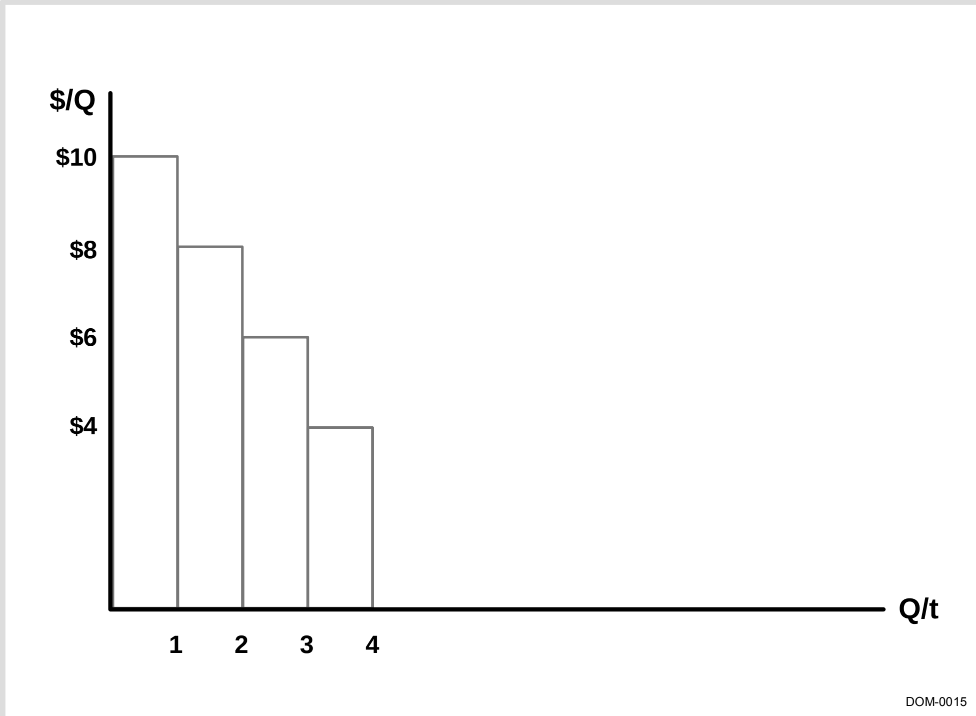

Figure A-2
Step Demand Curve

The step demand curve is useful for demonstrating how a demand curve may be interpreted.

Repeating this interpretation along the demand curve reveals the consumer's marginal valuation (MV) of additional amounts of the commodity. It can also be interpreted as the maximum the consumer would be willing to pay for an increment of the good. The area under the marginal valuation or demand curve represents the total valuation for each consumption rate. For example, 3 units of the good in Figure A-2 are worth $24 (i.e., $10 + $8 + $6) to the hypothetical consumer. It is the maximum amount of money per unit time the consumer would be willing to pay for a given amount of the good rather than to forego it entirely.

In competitive markets, a single price confronts all consumers and they select the consumption rate for the good that maximizes their economic welfare (utility). The consumer's utility-maximizing consumption rate is where her marginal cost of the good (its price) is equal to her marginal benefit (MV or demand), Q_1 in Figure A-3. Thus, as shown in the figure, there is a difference between what the consumer pays for her selected quantity of the good ($P_1 * Q_1$) and the total value of that consumption rate to the consumer (the entire area under the demand curve or value B_1 in the lower panel of Figure A-3). This difference, the shaded area of Figure A-3, is consumer surplus, the critical metric of consumer welfare because it is the difference between the value of the consumption rate to her and what she actually pays.

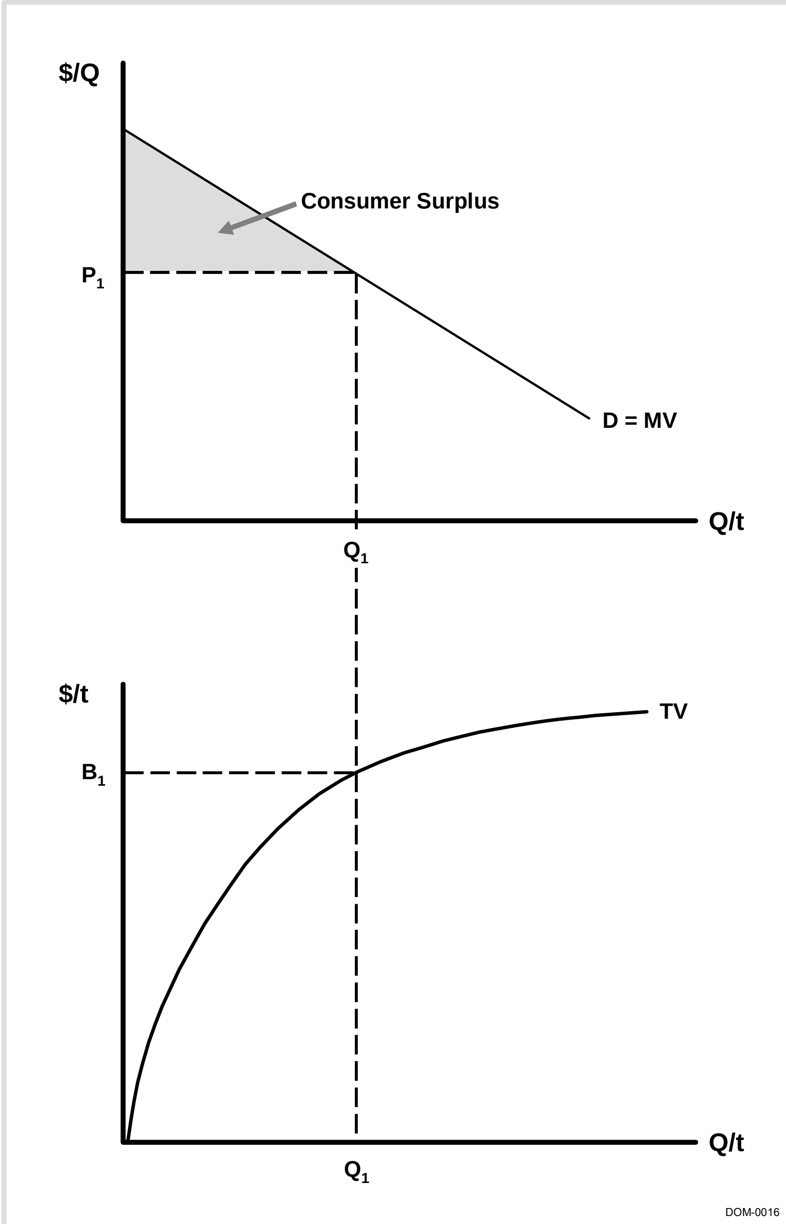

Figure A-3
Consumer Surplus

Consumer surplus is the difference between the total amount of money paid for a given quantity of a good and the maximum amount the consumer would be willing to pay for that quantity.

The producer's supply curve also shows the marginal cost of each production rate. For example, take the step supply curve for a hypothetical producer as shown in Figure A-4. In the figure, if the price is $2, the producer would produce 1 unit of the good. If the price were $4, the production rate would be 2, revealing that the increment in production costs the producer $2. This supply curve reflects the producer's marginal cost of additional amounts of the commodity. It can also be interpreted as the minimum amount of money the producer would require to provide an increment of the good. The area under the marginal cost (supply) curve represents the total cost for each production rate. For example, 3 units of the good in Figure A-4 cost $12 (i.e., $2 + $4 + $6) to the hypothetical producer. The area under the supply curve is the minimum amount of money per unit time the producer would need to provide a given amount of the good.

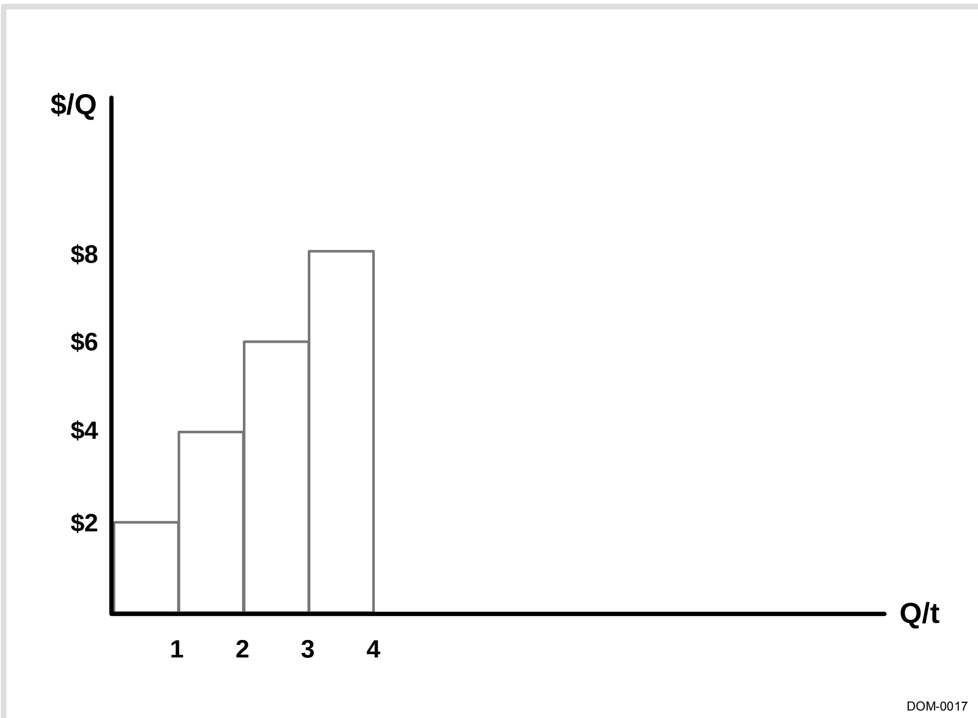

Figure A-4
Step Supply Curve

The step supply curve is useful for demonstrating how a supply curve may be interpreted.

In competitive markets, a single price confronts all producers and they select the production rate for the good that maximizes their economic welfare (profits). A producer's profit-maximizing production rate is where his marginal cost of providing the good is equal to the marginal benefit (price), Q_1 in Figure A-5. Thus, as shown in the figure, there is a difference between what the producer receives for his selected quantity of the good (P_1 * Q_1), and the total cost of that production rate (the area under the supply curve or value C_1 in the lower panel of Figure A-5. This difference, the shaded area in Figure A-5, is producer surplus, the critical metric of producer welfare. It is the difference between his cost of the production rate and what he actually receives. Producer surplus is also called economic profit.[37]

[37] Economic profit differs from the more familiar accounting profit. Accounting profit is total revenue minus expenditures. Economic profit is total revenue minus all costs, both actual expenditures made for purchased inputs plus the implicit rental of capital (resources) owned by the firm. As supply curve reflects the opportunity costs (not accounting costs) of production, producer surplus is the economic profit earned.

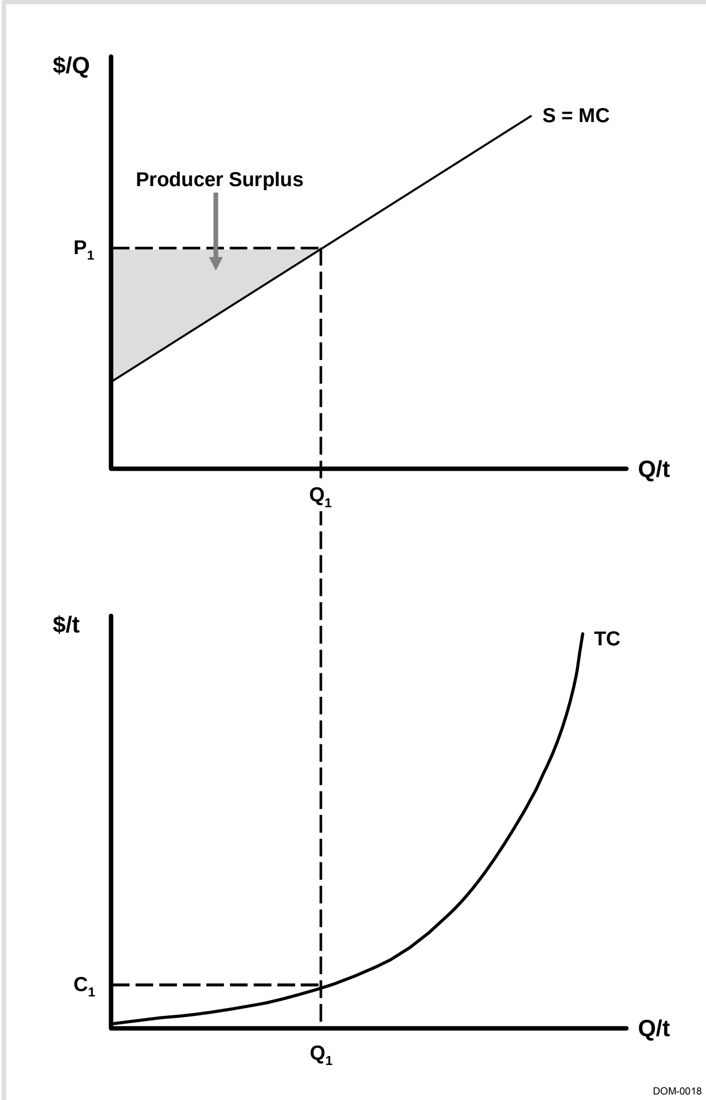

Figure A-5
Producer Surplus

Producer surplus is the difference between the total amount of money received for a given quantity of a good and the minimum amount the producer would require to provide that quantity.

Social surplus is the sum of consumer surplus and producer surplus. In competitive markets, the social surplus is maximized. In Figure A-6a, the market clearing price is P_0. Consumer surplus is represented by area P_0ab, producer surplus by area P_0bc. The social surplus is represented by area abc. In Figure A-6b, consumers' total benefit or (value) curve is shown along with the total cost curve of producers. Social surplus is measured here as TB–TC. As shown in Figure A-6c, production/consumption rates for the commodity between 0 and Q_1 all add to economic welfare, but it is rate Q_0 that maximizes social surplus.[38]

[38] Compare this outcome to the project evaluation requirements of the Flood Control Act of 1936, that benefits must be in excess of its costs to justify a project. Many "projects" in Figure A.6 would meet that requirement, including some that would only marginally improve economic welfare because they are near the points where the social surplus function meets the 0 axis (i.e., 0 and Q_1).

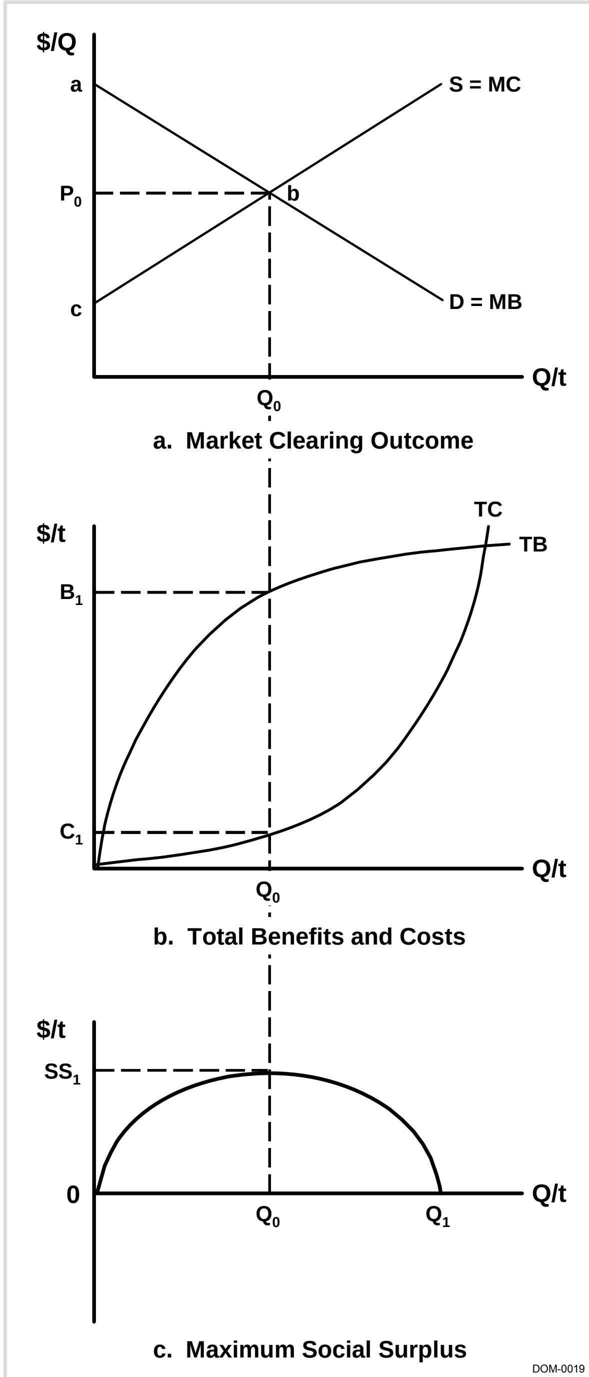

Figure A-6
Social Surplus

Social surplus, the sum of consumer and producer surplus, is maximized in competitive markets.

A Simple Example Application of BCA

To illustrate the application of the microeconomic foundations of BCA, consider the following simple example. Suppose there was a project that lowered the cost of a competitively produced good and that all the impacts of the project were registered in the market for that good. Should the project be undertaken based on BCA?

In the market where the impacts are found, the market supply curve shifts downward reflecting the lower cost of production with the project. In Figure A-7, the new market clearing outcome is P_2,Q_2. Changes in the social surplus, that is, the net benefits of the project (ignoring its costs for the moment), are the social surplus *with* the project minus the social surplus *without* it. In Figure A-7 the change is represented by area ade-abc or cbde. Thus, if the hypothetical project cost less than the amount represented by the shaded area of Figure A-7, it would add to economic welfare.

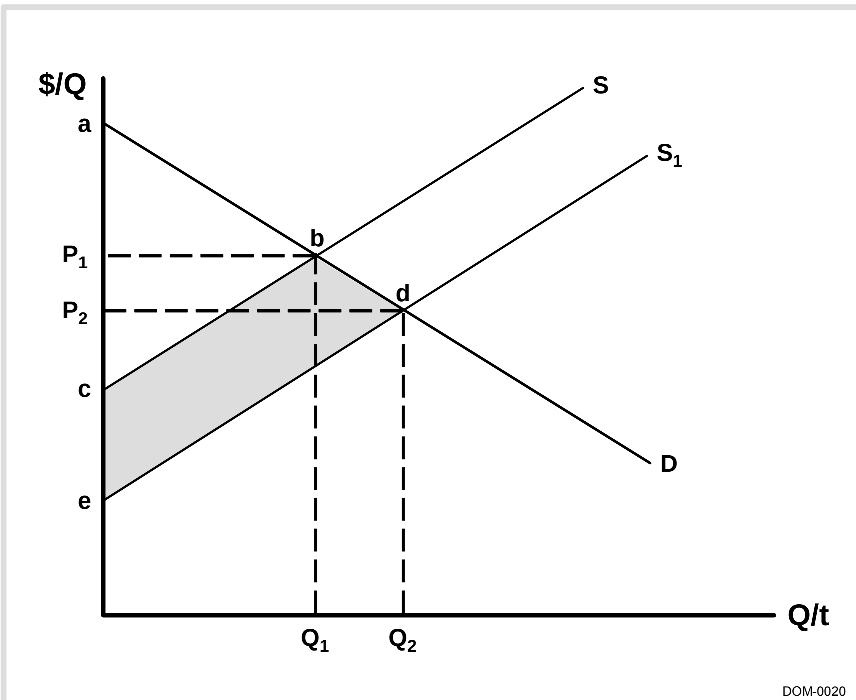

Figure A-7
Net Benefits of Hypothetical Project
Ignoring the costs of the project, the shaded area shows the contribution of the project to the social surplus.

Figure A-8a shows the change in consumer surplus for the hypothetical project. Consumer surplus increases on the original consumption rate, Q_1, due to the lower price, and also increases due to the increment in consumption from Q_1 to Q_2. Thus consumer surplus increases by the area represented by P_1bdP_2 in Figure A-8a. Consumers gain economic welfare with the project.

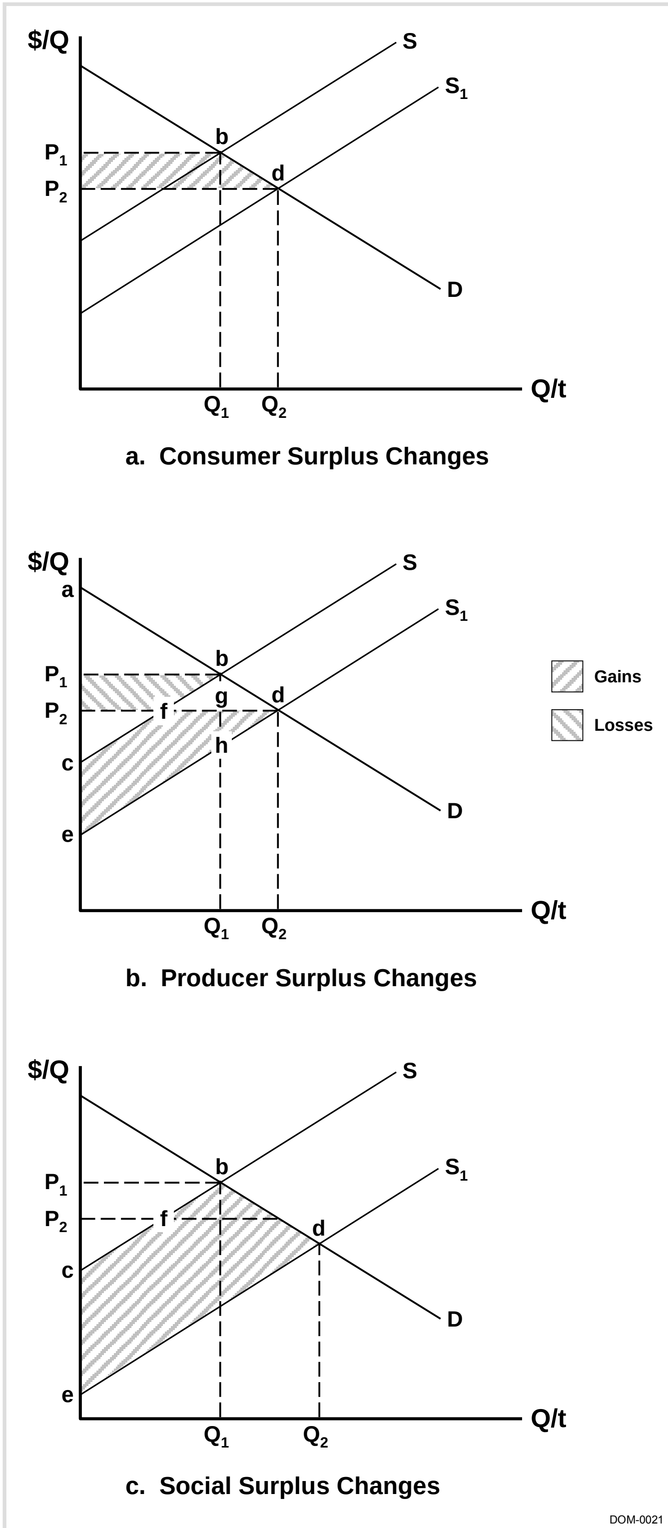

Figure A-8
Social Surplus Approach to BCA

The distribution of the change in social welfare between consumers and producers may also be estimated in this model.

The impact of the hypothetical project on producer surplus is more complex. Producer surplus declines on the original production rate, Q_1, due to the lower price shown in the area represented by P_1bfP_2 but increases by the area represented by cfghe due to the lower cost of production with the project. On the quality increment, producer surplus increases by the area represented by gdh. Thus on balance, producer surplus changes by the algebraic sum of the gains and losses or – (P_1bfP_2) + (cfde), as shown in Figure A-8b.

The net change in the social surplus provided by the hypothetical commodity is the algebraic sum of the changes in the components of the social surplus, as shown in Figure A-8c. Some of the consumer surplus gains are offset by producer surplus loss, specifically the area represented by P_1bfP_2. Thus, this is a transfer in incomes, not a net loss to society (i.e., to consumers plus producers). This result also illustrates the argument advanced by Harberger (1971), that the changes in individuals' welfare should be aggregated without regard to whom they accrue. Table A-1 summarizes the changes shown in Figure A-8.

Table A-1
Changes in Consumer and Producer Welfare in Figure A-8

Changes	Area in Figure A-8
Changes in consumer surplus	+ (P_1bdP_2)
Changes in producer surplus	– (P_1bfP_2) + (cfghe) + (gdh) = – (P_1bfP_2) + (cfde)
Changes in the social surplus: Change in consumer surplus + change in producer surplus	+ (P_1bdP_2) – (P_1bfP_2) + (cfde) = (fdb) + (chde) = cbde

An alternative perspective is to directly evaluate the changes in the benefits and costs of the commodity *with* the project. In Figure A-9, the total benefits of consumption increase by the area represented by Q_1bdQ_2 (Figure A-9a). The total costs of production decrease on the *without* project output rate, Q_1, by the amount represented by area cbhe but increase by the area represented by Q_1hdQ_2 (Figure A-9b) to supply the additional output. The change in economic welfare with the project (ignoring its costs) is the benefits minus costs or the area represented by cbde in Figure A-9c (also see Table A-2). An important insight of this analysis is that an institutional arrangement is needed to ensure that the increment in consumption goes to the highest-valued consumers and that the increment in costs comes from the lowest-cost producers. Competitive markets create such an outcome.

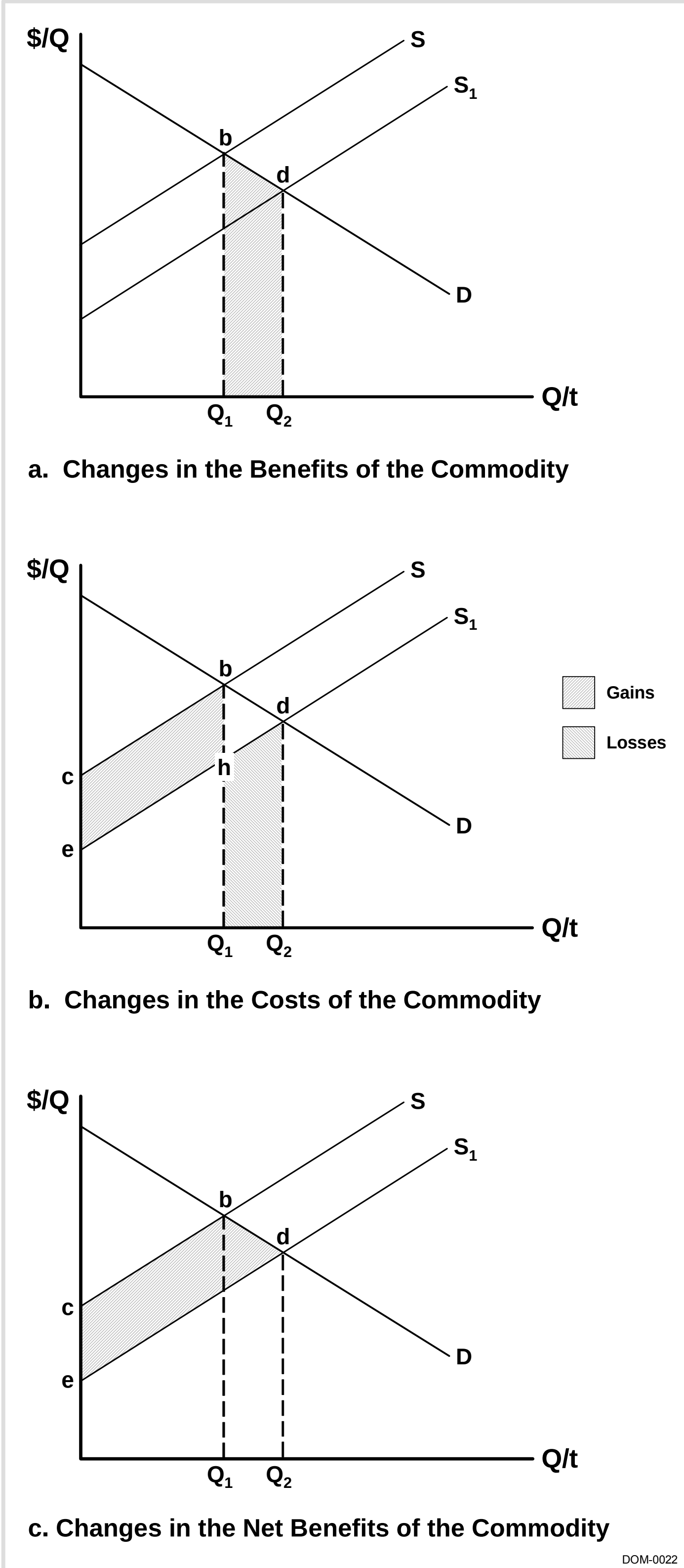

Figure A-9
Net Benefits Approach to BCA

The aggregate benefits and costs of the project may also be estimated in this model.

Table A-2
Changes in Net Benefits in Figure A-9

	Area in Figure A-9
Changes in the total benefits of the commodity	Q_1dbQ_2
Changes in total costs of the commodity	– (cbhe) + (Q_1hdQ_2)
Changes in the net benefits of the commodity: Change in total benefits – change in total costs	(Q_1dbQ_2) – [–(ecbh) + (Q_1hdQ_2)] = cbde

Welfare and Equity Considerations of BCA

As set out above, competitive markets lead to an allocation of society's resources that maximizes economic welfare (social surplus). Behind this outcome is the assumption that economic decision makers have all relevant information to make their consumption and production decisions and that they are motivated by self-interest to do the best they can with the opportunities available to them. This was the predominant view among economists since first articulated by Adam Smith (1776) in the *Wealth of Nations*: "It is not from the benevolence of the butcher, the brewer, or the baker, that we expect our dinner, but from their regard to their own interest."

Under certain highly restrictive conditions, the self-interested actions of individuals and firms lead to maximum values of aggregate social benefits. However, in general these conditions are not met. In particular, the productive or consumptive actions of firms and individuals cause unintended impacts, or externalities, to some other part of society. This concept of *externalities* and associated economic inefficiencies was originally identified by Coase (1960). Both the idea and the appropriate economic remedy have subsequently been incorporated into standard microeconomic theory.

Many of these externalities are in the form of discharges to the natural environment that are broadly termed pollution.[39] The generation of electricity can also lead to externalities in the form of fish mortality. When the producing firm does not pay for its impacts to these resources, it tends to overconsume them, leading to less than optimal allocation of society's scarce resources.

On its surface, the economic remedy for a production-based externality is straightforward—the firm causing the externality is induced to *internalize* it by being forced to pay the true cost of its impact. Internalize in this context means that the producing *firm* bears all of the costs of production internally rather than allowing some of these costs externally. This approach was originally proposed by Pigou (1932) and has since received the somewhat inaccurate moniker "Pigouvian tax." In fact, this approach is best considered a fee because its economic purpose is increasing efficiency by market correction—not raising revenue.[40] Under the Pigouvian

[39] Pollution is a primary, but not unique, type of externality. Additional significant categories of externalities include (but are not limited to) negative impacts to health, property values, and business or personal income. Additionally, externalities can also be positive (e.g., the beekeeper's bees that pollinate his neighbors' fruit trees).
[40] The primary identifying feature of an economically efficient market is that the social cost of producing the final unit (marginal cost) is equal to the social benefit of producing the final unit (marginal benefit).

approach, the sector causing an externality pays a fee by unit that equates total production cost to the true social cost (lost social benefit) of producing each unit. As with the well known result under perfect competition (Smith 1776), when faced with the true costs of production, the sector adjusts operations in an individually efficient manner that, when aggregated, leads to a socially optimal outcome.[41]

Two important features are critical to understanding the Pigouvian approach. The first is that because this approach focuses on economic efficiency, it is not expected to eliminate impacts. The idea that some positive amount of a negative externality like pollution can be socially optimal is anathema to many. However, it is a logical extension of the recognition that curtailing the externality will have costs as well as benefits and that the social surplus is maximized when these are equated at the margin. The strength of this approach implicitly causes the profit-maximizing firm to weigh the costs of reducing the externality against social costs (lost benefits). Thus in the absence of easy fixes with large benefits, we expect a certain amount of impact to continue. Because of this feature, the Pigouvian approach has sometimes been criticized as providing a "license to pollute." In fact, this is a distorted view of a common situation in which the marginal social costs of abatement rise as impacts diminish and that the marginal social benefits of abatement diminish as impacts get small.[42]

The second important feature is that unit fees are not paid to injured parties. Doing so leads to an additional inefficiency. To understand why, consider a power producer impacting a fishery. Paying anglers to fish in a reduced quality fishery induces them to use this lower valued resource at increased social cost rather than substituting a more valuable resource at reduced social cost.

When a market is impacted by an externality, there is a rationale for some form of economic intervention. As we have seen, this intervention can potentially be supported by knowledge of the social costs and social benefits at each level of production. One approach for guiding such intervention involves employing BCA. In policy-making, BCA is a customary procedure for organizing information on the advantages and disadvantages of public projects. Under the Pigouvian approach, the benefit-cost framework is valuable because money provides a consistent way to compare physically dissimilar inputs and outcomes. Monetization allows investment costs and environmental benefits and costs to be evaluated similarly in terms of their claim on scarce resources relative to social priorities.

Since Pigou, Coase (1960) has argued that government intervention may not be necessary to address the inefficiency in resource allocation associated with externalities. He has shown that private negotiation between the two parties can result in an optimal allocation of resources. However, the conditions required for this approach to be successful are quite restrictive. Further, the continued existence of an externality frequently demonstrates the ineffectiveness of such arrangements.

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[41] At lower levels of production, increased social benefit is available with increased production. At higher levels of production, increased social benefit is available at decreased levels of production.

[42] To see the folly of attempting to eliminate all impacts in this situation, consider the stated goal of the 1972 amendment to the Clean Water Act, which intended to eliminate all discharges into navigable waterways by 1985.

The usefulness of BCA in making decisions that affect groups of people is limited to the acceptance of the outcomes by potentially competing stakeholder groups. Understanding the equity implications of benefit-cost based decision-making using any criteria requires first understanding that benefits and costs accrue to people. Specifically, for any policy decision, there is not only an aggregate benefit and cost, but also individuals who are affected both positively (winners) and negatively (losers).

Although it applies the principles of the positive economic model, BCA is intrinsically a tool of normative economics. Stated simply, it is a way of determining what is, in some sense, "best" for society. Unfortunately, making this determination can be easier said than done. Mishan (1981) writes:

> In positive economics it is simpler to test the significant implications for our hypotheses than to test the set of assumptions or postulates from which they are deduced …. In normative economics, it is the other way round: … [it requires] ascertaining the validity of the conclusions from the realism of the assumptions adopted (p. 24).

In other words, even if a BCA fully and accurately measures every individual's welfare change for a specific policy change, its ability to determine whether the policy is best for society ultimately depends on the degree to which society accepts its ethical foundation.

Among the earliest contexts for BCA are the works of Hicks (1939) and Kaldor (1939), who independently proposed a policy criterion for maximizing net benefits.[43] The Kaldor-Hicks criterion established that by maximizing net benefits, winners from any decision are able to compensate losers. By comparison with "significantly greater" and "wholly disproportionate," the Kaldor-Hicks criterion can be considered a "greater than" criterion. It advises that when expected costs exceed expected benefits, by any amount, the project is not undertaken.[44] In contrast, the "significantly greater" language in the Phase II Rule of Section 316(b) of the CWA requires project implementation despite costs being greater than benefits in some instances. As a result, "significantly greater" presumably requires a higher standard for inaction. That is, the significantly greater test will result in project implementation in more instances than would a benefit-cost comparison under the Kaldor-Hicks criterion.

A difficulty with the Kaldor-Hicks or "greater than" criterion is the distributional consequence when benefits and costs accrue to different sectors. Consider the case of a power generator whose impingement and entrainment impacts cause economic losses to commercial fishing in a closed-access fishery. This power generator is able to pass along its compliance costs to consumers. The estimated costs of applying the low-cost technology are not "significantly greater" than expected benefits accruing to commercial fishing. In this situation, the 316(b) rule indicates that installation of the technology is required. When the technology is installed, benefits accrue to a limited number of commercial fisherman and costs are distributed across

[43] Other standards for decision-making identified in the economics literature include the Pareto criterion (no one is made worse off and at least one is better off) and the Little (1957) criteria, which require that the Hicks-Kaldor criteria is satisfied and the resulting change improves the distribution of income (where improvement is judgment-based).

[44] Note that this criterion does not consider uncertainty in the magnitude or outcome of benefits or costs. Moreover, it is a minimum criterion because it considers a project in isolation of other projects.

many households in the form of increased electricity rates. In this case, the remedy is a cost to a greater number of people than it is a benefit. By comparison, imagine that the power producer operates in a competitive market and has impacts to a recreational fishery. In this case, the technology financing presumably is passed through to owners of corporate stock and debt in the form of reduced dividends, growth, or increased default risk (decreased bond value). The benefits accrue to recreational anglers.

The strict application of a benefit-cost test for policy problems essentially requires that the policymaker accept efficiency as an objective. While there are clearly competing objectives and decision criteria, efficiency is widely regarded as an important consideration for decisions that affect society. One reason for this is that utilitarian efficiency sums values across all individuals in society and is, therefore, not inherently exclusive or elitist. In this way it reflects many of the underlying values in a democratic society. Another reason is that it incorporates values that are implicit in individuals' trade-offs. In other words it is based on a conceptual model (described above in "Microeconomic Foundations of BCA") that assumes that individuals' preferences are reflected in the choices they make, and it proceeds from there by assuming that they are the best judges of what is best for them. Therefore, this notion of "consumer sovereignty" is grounded in the utilitarian efficiency model, and it also reflects commonly held individualistic values and opposition to overly paternalistic government.[45] A final reason why efficiency is regarded as an important societal objective is that it imposes a similar type of discipline on government as individuals generally impose on themselves. By forcing policymakers to balance benefits and costs, it forces them to recognize unavoidable resource constraints on society, in much the same way that individuals face budget, time, and other resource constraints.

The objective of efficiency is not inherently inequitable; however, it does not consider directly the *distribution* of policy benefits and costs in society. The ethical foundation of benefit-cost analysis is open to challenge to the extent that society does care *who* gains and *who* loses (and whether they can be identified and compensated), and society cares about the original position of the gainers and losers (e.g., the underlying distribution of income).

However, while the strict application of BCA ignores the distributional implications of the policy, there is no inherent reason why it must. Indeed, BCA can identify policy winners and losers and the magnitude of their gains and losses. Distributional weights can be applied to these values to reflect the social consensus regarding the desired relationships among these stakeholders. Completely understanding the implications of any particular comparator—be it "significantly greater" or any other terminology—also requires an understanding of how benefits and costs are determined and distributed.

Using BCA to Identify the Best Technology Available

Under the requirements of the Clean Water Act, EPA must identify the "best technology available" (BTA) for addressing the threats to environmental quality arising from cooling water intake structures (CWIS) and recommend an action. In many situations there are a potentially

[45] For a critique of this point, see Railton (1990) and Sagoff (1994).

large number of CWIS technology alternatives. To apply the principles presented in "Microeconomic Foundations of BCA" involves completing the following steps.

1. *Identify technologically feasible CWIS alternatives*. Identify CWIS technology alternatives for the specific site, including technology combinations and the capital and operating costs of their implementation.
2. *Estimate the market responses to the CWIS alternatives*. Develop estimates of the impacts on all market goods affected by the CWIS alternatives.
3. *Estimate the nonmarket responses to the CWIS alternatives*. Develop estimates of the response of ecological systems to the alternatives and the services provided by those systems.
4. *Value market and nonmarket outcomes*. Develop estimates of the value to stakeholders of the market and nonmarket outcomes.
5. *Identify, quantify, and analyze sources of uncertainty*. Construct confidence intervals for each critical parameter to summarize the range of uncertainty for each estimate. Indicate which elements cannot be put into dollar terms and why.
6. *Identify the economically efficient alternative*. Compute the net benefits of each alternative and identify the gainers and losers. Identify the CWIS technology—which could include a combination of alternatives—for which net benefits are the largest.

This approach systematically incorporates considerations of parameter uncertainty in the analysis. Thus, decision makers can see both the expected net benefits of each alternative and the expected distribution of those net benefits. Depending on the nature of the benefits and costs, decision makers may choose to favor a lower net-benefit alternative with a tighter distribution of expected net benefits over one that has a higher expected net-benefit value but also has more uncertainty regarding the outcomes.

Because of a lack of information or the limits of available methodologies, it may not be possible to correctly monetize all possible benefit or cost categories. In such cases, the BCA should qualitatively describe the benefits and costs in question. For alternatives where monetized benefits fall short of costs, decision makers may decide whether or not the likely value of identified, nonmonetized net benefits is large enough to justify the investment.[46]

Using BCA to Support Site-Specific Determination

The benefits and costs of compliance alternatives are highly context-specific. A given alternative implemented in one location will have a different magnitude and distribution of benefits and cost when made in a different location. Thus, BTA cannot be identified on an industry, regional, plant-type, or water body-type basis, except when a group of sites is truly similar in all relevant aspects, including physical effects, environmental effects, and the value of the associated environmental services. For example, a pristine lake in a region with few

[46] Where substantial risks are involved, decision makers may be able to quantify the monetary value of the risks and include it as a cost associated with that alternative. This approach is the way financial markets absorb information about investments with varying risks.

recreation alternatives is not comparable for BTA evaluation purposes to a lake with low baseline water quality in a region with abundant substitute recreation alternatives.

The Phase II Rule allows for a site-specific determination of BTA if the costs of compliance using EPA's suggested approaches are estimated to be "significantly greater" than estimates of associated benefits. A facility demonstrating that the costs of complying with the rule are likely to be "significantly greater" than the benefits of compliance must submit three supporting documents. These include a Benefit Valuation Study (BVS), a Comprehensive Cost Evaluation Study, and a Site-Specific Technology Plan.

The BVS values the natural resource services associated with the recreational, commercial, and forage fish impinged and entrained at a facility. The EPA gives specific guidance on what information must be included in the BVS. Specifically, the BVS must include:

1. A description of the methodology(ies) used to value commercial, recreational, and ecological benefits (including any nonuse benefits, if applicable).
2. Documentation of the basis for any assumptions and quantitative estimates. If using an entrainment survival rate other than zero, submit a determination of entrainment survival at the facility based on a study approved by the Director.
3. An analysis of the effects of significant sources of uncertainty on the results of the study.
4. A narrative description of any nonmonetized benefits that would be realized at the site if the facility were to meet the applicable performance standards and a qualitative assessment of their magnitude and significance.
5. If requested by the Director, a peer review of the items submitted in the BVS. The facility must choose the peer reviewers in consultation with the Director, who may consult with EPA and Federal, State, and Tribal fish and wildlife management agencies with responsibility for fish and wildlife potentially affected by the facility's CWIS. Peer reviewers must have appropriate qualifications, which correspond to the materials to be reviewed.

The Comprehensive Cost Evaluation Study evaluates the costs of implementing technological, operational, and/or restoration measures to meet the performance standards for the facility. The Comprehensive Cost Evaluation Study will consist of engineering cost estimates for implementing design and construction technologies, operational measures, and/or restoration measures that would comply with 316(b) performance standards. These cost estimates are then used in conjunction with benefits estimates from the BVS to conduct benefit-cost tests and compare them with benefits presented in the BVS to determine if costs are "significantly greater" than benefits.

Specifically, the Comprehensive Cost Evaluation Study must include the following components:

1. Engineering cost estimates of technologies, operational measures, and/or restoration measures that would be needed to meet the applicable performance standards
2. Demonstration of cost-cost and benefit-cost tests
3. Engineering cost estimates to document the cost of technologies, operational measures, and/or restoration measures in the Site-Specific Technology Plan.

Cost categories should include capital costs for installation of the technologies, the net operation and maintenance (O&M) costs, the net revenue losses (lost revenues minus saved variable costs) associated with net construction downtime, and any pilot study costs associated with on-site verification and/or optimization of the technologies or measures.

The Site-Specific Technology Plan does not consider costs, but builds on the information found in the Comprehensive Cost Evaluation Study with more detailed information on how the proposed technological, operational, and/or restoration measure will be used to achieve the relevant performance standards.

References

1. Arrow, K. J., Elizabeth E. Bailey, William J. Baumol, Jagdish Bhagwati, Michael J. Boskin, David F. Bradford, Robert W. Crandall, Maureen L. Cropper, Chistopher C. Demuth, George C. Eads, Milton Friedman, John D. Graham, Wendy L. Gramm, Robert W. Hahn, Paul L. Joskow, Alfred E. Kahn, Paul R. Krugman, Lester B. Lave, Robert E. Litan, Randall W. Lutter, Paul W. Macavoy, Paul W. Mccracken, James C. Miller III, William A. Niskanen, William D. Nordhaus, Wallace E. Oates, Peter Passell, Sam Peltzman, Paul R. Portney, Alice M. Rivlin, Milton Russell, Richard L. Schmalensee, Charles L. Schultze, V. Kerry Smith, Robert M. Solow, Robert N. Stavins, Joseph E. Stiglitz, Laura D'andrea Tyson, W. Kip Viscusi, Murray L. Weidenbaum, Janet L. Yellen, and Richard J. Zeckhauser. 2000. Brief amici curiae for the Supreme Court of the United States, *American Trucking Associations, Inc., et al. v. Carol M. Browner, U.S. Environmental Protection Agency, et al.* AEI-Brookings Joint Center for Regulatory Studies, Washington DC.
2. Barry, J. M. 1997. Rising Tide: The Great Mississippi Flood of 1927 and How It Changed America. Simon and Schuster, New York.
3. *BASF Wyandotte Corp. v. Costle*. 598 F.2d 637, 656 (1st Cir. 1979).
4. Blamey, R., and J. Bennett, eds. 2001. The Choice Modelling Approach to Environmental Valuation. Edward Elgar Publishing, Inc., Northampton, MA.
5. Blamey, R. K., J. W. Bennett, J. J. Louviere, M. D. Morrison, and J. Rolfe. 2000. A test of policy labels in environmental choice modelling studies. Ecological Economics 32(2):269-286.
6. Brent, R. J. 1995. Applied Cost-Benefit Analysis. Edward Elgar Publishing Limited, Cheltenham, UK.
7. Coase, R. 1960. The problem of social cost. Journal of Law and Economics 3:1-44.
8. Dupuit, J. 1844. De la mesure de l’utilité des travaux publics. Annales de Ponts et Chaussées, Second Series, Volume 8. Translated as: Dupuit, J. (1952), On the measurement of utility of public works, International Economic Papers 2:83-110. English translation reprinted as pages 255-283 in K. J. Arrow and T. Scitovsky (1969), Readings in Welfare Economics. Richard D. Irwin, Homewood, Illinois.

9. *Flood Control Act of 1936*, 74th Congress, 2nd Sess., CHS. 651, 688 (June 20, 22, 1936). Available at http://www.ccrh.org/comm/cottage/primary/1936.htm. Retrieved on May 25, 2006.
10. Foster, C. D., and M. E. Beesley. 1963. Estimating the social benefit of constructing an underground railway in London. Journal of The Royal Statistical Society Series A (General), Vol.126, Part I.
11. Friedman, M., and L. P. Savage. 1948. The utility analysis of choices involving risk. Journal of Political Economy 56:279-304.
12. Fuguitt, D., and S. Wilcox. 1999. Cost-Benefit Analysis for Public Sector Decision Makers. Quorum Books, Westport, CT.
13. Grumbles, Benjamin. 2007. Implementation of the decision in *Riverkeeper, Inc. v. EPA*, remanding the cooling water intake structures Phase II regulation. Washington, DC: U.S. Environmental Protection Agency.
14. Hanley, N., R. E. Wright, and V. Adamowicz. 1998. Using choice experiments to value the environment. Environmental and Resource Economics 11(3-4):413-428.
15. Harberger, A. C. 1971. Three basic postulates for applied welfare economics: an interpretive essay. Journal of Economic Literature 9(3):785-797.
16. Hensher, D. A. 1991. The use of discrete choice models in the determination of community choices in public issue areas impacting on business decision making. Journal of Business Research 23(4):299-309.
17. Hicks, J. R. 1939. The foundations of welfare economics. Economic Journal 49 (December):696-712.
18. Kaldor, N. 1939. Welfare propositions in economics and interpersonal comparisons of utility. Economic Journal 49(145):549-552.
19. *Kennecott v. United States EPA*. 780 F.2d 445, 448 (4th Cir. 1985).
20. Klarman, H. E. 1965. Syphilis control problems. In Measuring Benefits of Government Investments, ed. R. Dorfman. Brookings Institution, Washington, DC.
21. Kling, C. L., and J. A. Herriges. 1995. An empirical investigation of the consistency of nested logit models with utility maximization. American Journal of Agricultural Economics 77(November):875-884.
22. Little, I. 1957. A Critique of Welfare Economics 2nd Edition. Oxford University Press.
23. May, J. R., and M. K. Van Rossum. 1995. The quick and the dead: fish entrainment, entrapment, and application of Section 316(b) of the Clean Water Act. Vermont Law Review 20(2)Winter:402.
24. Ministry of Transport, U.K. 1963. Proposals for a Fixed Channel Link. Cmnd. 6137.
25. Mishan, E. J. 1975. Cost Benefit Analysis: An Informal Introduction. Allen and Unwin Limited, London.
26. Mishan, E. J. 1981. Introduction to Normative Economics. Oxford University Press, New York, NY.

27. Pigou, A. C. 1932. The Economics of Welfare, Fourth Edition. Macmillan and Co., London.

28. Railton, P. 1990. Benefit-cost analysis as a source of information about welfare. In Valuing Health Risks, Costs and Benefits for Environmental Decision Making: Report of a Conference. National Academy Press, Washington, D.C.

29. Sagoff, M. 1994. Should preferences count? Land Economics 70(2):127-144.

30. Shabman, L. 1997. Making benefit estimation useful: lessons from flood control experience. Water Resources Update Autumn(109):19-23.

31. Smith, A. 1776. An Inquiry into the Nature and Causes of the Wealth of Nations. Methuen and Co., Ltd., London. Edwin Cannan, ed. 1904. Fifth edition.

32. TetraTech Inc. 2002. Evaluation of cooling system alternatives proposed Morro Bay Power Plant. Available at http://www.swrcb.ca.gov/rwqcb3/MorroBayDNA/Reports/TetraTechMBPP.pdf. Retrieved on August 11, 2006.

33. Watkins, T. Undated. An introduction to cost benefit analysis. Available at http://www2.sjsu.edu/faculty/watkins/cba.htm. Retrieved on May 25, 2006.

34. *Weyerhaueser Co. v. Costle*. 590 F.2d 1011, 1048 (D.C. Cir. 1978).

B
NONUSE VALUATION

Nonuse values are the values that people hold for natural resource services that they do not use. These services may include ecological services, such as habitat for fish and wildlife. Or, some people may gain benefit simply from knowing the resource exists—either because they want it to be available for people to use in the future or because they believe the resource has some inherent right to exist. As the rule points out, the economic literature commonly refers to two components of nonuse values as bequest (or altruistic) values and existence values, respectively (EPA 2004b, p. A9-3).

Currently, the only methods available for estimating nonuse values are survey-based techniques that ask respondents to value, choose, rate, or rank natural resource services in a hypothetical context. The reliability of this approach for evaluating nonuse impacts is questionable. The relevant literature has long noted and thoroughly documented the difference between people's stated intentions and actual behaviors (Kemp and Maxwell 1993**.** This difference between intentions and behavior is called hypothetical bias. Researchers in the natural resource arena recognized hypothetical bias more than 25 years ago, defining it as the potential error due to not confronting an individual with a real situation (Rowe, d'Arge, and Brookshire 1980).

The two sections of this appendix describe the two primary techniques available for nonuse valuation: contingent valuation (CV) and stated preference (SP) surveys. These sections provide overviews of the techniques, summarize the data and analysis requirements of each approach, discuss each method's advantages and disadvantages, and provide examples. The third section of this appendix describes the progression of nonuse valuation in 316(b) applications. The final section of this appendix describes strategies for instances where the EPA will require a quantitative estimate of nonuse values.

Contingent Valuation (CV) Methodology

The contingent valuation (CV) method for estimating the value of natural resource services involves a direct survey of individuals to elicit their willingness to pay (WTP) for different levels of services.[47] For example, the survey may ask respondents a question such as, "What is the maximum amount you would pay to restore wild salmon runs in the Columbia River Basin?"[48] The responses are analyzed to determine the average WTP for preserving wild salmon runs. This

[47] See Hausman (1993) and Arrow et al. (1993) for a more detailed critique of CV.
[48] Natural resource economists have used a variety of question formats. This question is an open-ended format. Alternatives include bidding games, payment cards, and referendum or dichotomous-choice. In the dichotomous choice format, respondents are offered a particular payment amount and allowed to accept or reject that amount. See Mitchell and Carson (1989) for a detailed discussion.

method requires that individuals be able to express their value for marginal changes in the fishery and, furthermore, that their responses to hypothetical questions indicate their actual valuations of the changes described in the questions.

The CV method attempts to establish, through the course of a survey, a hypothetical market where environmental changes can be sold like commodities. Thus, the main task of the CV survey is to neutrally, accurately, and credibly present the commodity to be traded and the mechanism through which the trading will occur. In most cases, the commodity is some alternative level of environmental quality and the mechanism is some specified policy or investment. In the case of a fishery, the commodity might be a program for removing several dams, which would result in the restoration of wild salmon runs. The survey would describe the current status of the fishery, the degree of improvement, and a way for financing the dam removal. Ultimately, the goal of the CV survey is to establish circumstances that represent the way a market would operate for the resource services. Oral or written descriptions, supplemented by visual aids, are used to make the survey informative and realistic. Careful control is required over the information given to respondents so answers are based on the same information in each interview and all respondents receive sufficient information to perform the valuation task.

In addition to designing the survey, researchers must determine the relevant population for the survey and draw a representative sample. The relevant market is important because average individual WTP estimates must be aggregated over the affected population to determine total WTP. For any study, the analyst must determine whether the relevant market is limited to neighboring counties or includes the entire state or country. Depending on the relevant population, survey administration costs can vary considerably. Identifying the relevant market in a CV study is an important decision, for which data often are limited (Desvousges et al. 1994).

CV studies require expertise in survey development and administration. CV surveys must be thoroughly tested to ensure that the survey instrument collects unbiased information from the respondents, and this process can be very costly. Survey administration costs will vary with the mode selected, with in-person interviews being the most costly.

The level of analytical complexity varies as well, from simple regression analysis to sophisticated modeling, although CV models tend to be less complex than other methods. The value estimate from CV data is typically the average WTP from the survey question. Researchers may model these responses to determine what characteristics of respondents influence their WTP, and some analysis is required to calculate the variance of the responses. Some question formats require models to determine the mean value, such as the dichotomous-choice format where respondents answer Yes or No to a proposed cost rather than provide a value. Nevertheless, these models are well-established in the literature and relatively straightforward to estimate.

Many economists believe that a carefully designed and implemented CV study can reliably measure such use values as the value that anglers place on an increase in fish catch at a site. Using CV to estimate use values is less controversial, and more likely to be reliable, because the respondents' actual behavior and experience with the resource serves as a reference for the hypothetical payment estimates. However, where use values are concrete and have a basis in actual behavior, nonuse values are inherently subjective and difficult to measure. The validity and reliability of CV is questionable in such circumstances because respondents' hypothetical payment for a nonuse service has no behavioral experience to support or test the expressed value. This lack of a linkage between actual behavior and the hypothetical payment makes CV estimates particularly sensitive to variations in survey design, implementation, and analysis.

The main advantage of the CV method is the control it gives the researcher. Researchers can define the commodity to suit their specific needs, as long as the market remains credible. Thus, the researcher is not constrained by the existence of actual sites with the characteristics needed to determine the value for a given environmental improvement.

The main shortcoming of the CV method is its reliance on responses to hypothetical questions, rather than observances of actual behavior. When people are asked for an amount that they would hypothetically be willing to pay for some described commodity, they have little incentive to consider the response carefully. In contrast, when making actual decisions about how to spend their own scarce resources of time and money, people make careful choices. Therefore, economists have long felt that observations of actual behavior more accurately reflect preferences than responses to hypothetical questions do.

Olsen, Richards, and Scott (1991) conducted a CV study in the Pacific Northwest to estimate the existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. The study focused on estimating resource values to both resource users and resource nonusers. Resource nonusers were defined as individuals who had not been involved in the commercial fishing industry and who had not participated in the sport fishery for the last five years. The population consisted of all the Pacific Northwestern households (Washington, Oregon, Idaho, and western Montana) with telephones because the survey was implemented through telephone interviews.

The Social and Economic Sciences Research Center at Washington State University administered the survey. The sample consisted of 695 responses from resource nonusers and 482 from resource users. As part of the valuation procedure, the survey asks two key questions:

- Respondents were asked about their last electric power bill payment (monthly bill) and their estimated average monthly power bill for the year. This question served to introduce the payment vehicle.
- Respondents were then asked to identify the maximum amount they would pay above their average monthly power bill to double the size of the salmon and steelhead runs.

The results show that households are willing to pay $171 million (1989 dollars) annually for a doubling of the salmon steelhead runs, or $68.49 per additional fish added to the river system. These estimates include both use and nonuse values because values for both users and nonusers are contained in the average. Estimated for just anglers in the Columbia River Basin, the average value for doubling the salmon runs is $132.47 per fish, and a marginal value of $54.84 per fish for doubling the catch rate.

This study is typical of CV fish-valuation studies in its inclusion of both use and nonuse values, its focus on highly valued game fish, and its use of a policy that results in a large increase in the fish population. Cooling water intake structure (CWIS) applications, in contrast, will typically involve only use values, common sport fish species, and relatively small changes in fish populations. Therefore, using estimates from CV fishing studies for use in a CWIS-related benefit-cost analysis may require careful interpretation.

Stated Preference (SP) Methodology

Stated-preference (SP) methods are based on the principle that commodities have value because of their attributes. For example, a car has value because of such specific characteristics as size, color, comfort, body style, handling, gas mileage, and price. People generally have preferences among these attributes and are willing to accept trade-offs among them, so a car buyer may be willing to accept less comfort for better handling.[49] An SP survey asks respondents to rank, rate, or choose among a series of different alternatives with different levels of attributes. By analyzing the choices made by respondents, researchers can uncover the underlying preferences for these attributes.

SP methods have been used extensively in marketing research and product development (Cattin and Wittink 1982, Wittink and Cattin 1989). Specific marketing applications have been aimed at new-product identification, market segmentation, advertising, distribution, competitive analysis, and price optimization. In recent years, the SP methods have been applied in the fields of environmental and health economics as an alternative to the CV method. For example, the SP technique has been used to value hunting trips and fishing (Gan and Luzar 1993, MacKenzie 1993, and Roe, Boyle, and Teisl 1996), to explain recreation site choice selection (Adamowicz, Louviere, and Williams 1994), to determine public preferences for siting a noxious facility (Opaluch, et al. 1993), and to estimate customers' WTP for green electricity (Johnson et al. 1995). SP has also been applied to measure changes in fishery services (Banzhaf, Johnson, and Mathews 2001).

Two features are common among all types of SP surveys. First, respondents are asked about commodities with multiple characteristics or attributes. Second, respondents are asked to perform a series of judgment or rating tasks to express their preferences among those attributes.

SP questions can take many forms, each involving a somewhat different cognitive task and a somewhat different perspective on consumer preferences. While each approach has advantages and disadvantages, there is no empirical evidence that one particular elicitation format is clearly superior to others (Huber 1997). Regardless of the question format, an SP study requires sophisticated modeling to uncover the underlying preferences implied by the responses to the SP questions. Furthermore, designing the survey requires high-level expertise to ensure that the information required for the analysis is collected in an unbiased way.

[49]Defining the properties of such preferences has been explored by multi-attribute utility theory (Keeney and Raiffa 1978).

Like CV, SP has the advantage of giving the researcher control to manipulate the content of the survey to suit the needs of the study. However, SP has several advantages over conventional CV approaches. Primarily, SP encourages respondents to explore their preferences for various attribute combinations through a series of choices. The process of explicitly trading off attributes encourages greater respondent introspection than is likely to occur in a traditional CV format. The absence of such introspection has been a major criticism of the validity and reliability of CV estimates (Schkade and Payne 1994).

In addition, SP provides values for individual components of commodities as well as for commodities as a whole in a single survey. The SP method also allows analysts to devise internal consistency checks because respondents provide answers to multiple questions. These internal consistency checks are a significant improvement over the rudimentary technique of using general follow-up questions to assess respondents' motives for answers to single CV questions. Having more information from respondents on their relative preferences for the scenarios allows analysts to systematically evaluate whether a respondent's pattern of answers is plausible and consistent with economic theory used to construct social values.

The SP technique has several potential problems that require careful survey design. First, the SP technique can pose a cognitively challenging task to respondents, particularly if they are unfamiliar with some of the attributes of the commodity to be valued. Furthermore, SP data pose analytical challenges for the researcher because of the dynamic learning process involving both preferences and a particular judgment task. To the extent that respondents become engaged in the learning process, later responses may be better indicators of preferences than earlier responses. It also is possible that fatigue could affect the quality of later responses. Sophisticated modeling of SP data may make it possible to detect such intertemporal effects.

Finally the SP technique, like CV, elicits expressed preferences under hypothetical conditions. As a result, the responses are likewise hypothetical, which implies that respondents do not have to make a real-dollar commitment as they would in a real-market situation. Thus, in that respect, SP does not offer any advantage over CV.

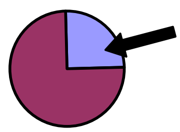
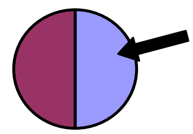
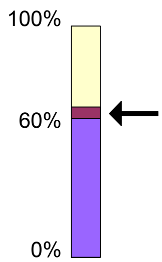
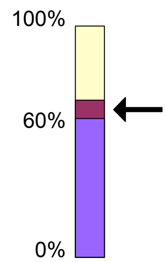
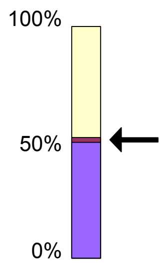
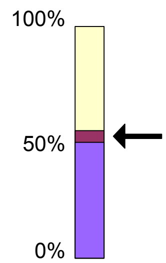
In 2005, EPA issued a draft SP study specifically designed to elicit nonuse values for use in 316(b) applications (EPA 2005).[50] Although the EPA has since abandoned its plans to field this survey throughout the United States, the SP questionnaire is the most informative example of an SP study for 316(b) analysis.[51]

Figure B-1 below contains a sample SP question from the EPA 2005 SP study. In this design, respondents are presented with two different (but not described) technologies for achieving I&E reductions at a facility, Option A and Option B. These two options differ in the number of fish saved per year through I&E reductions, the percentage increase in fish populations over 3–5 years, the percentage increase in recreational and commercial catches, and the increased cost per household. Survey respondents could select either option, or could select neither.

[50] *Supporting Statement For Information Collection Request For Willingness To Pay Survey For §316(B) Phase III Cooling Water Intake Structures: Instrument, Pre-Test, And Implementation (OW-2005-0006-0002)* (hereafter, EPA 2005).

[51] See Desvousges et al. (2005) for a critique of this proposed SP study.

Question 1. Assume Options A and B would require <u>different technology</u> to prevent fish losses in facilities that use cooling water, and that all types of fish would be affected. How would you vote?

	OPTION A	OPTION B
Fish Saved per Year (Out of total lost in cooling water intakes)	 **456 million fish saved per year** **Annual Losses Reduced by ¼**	 **912 million fish saved per year** **Annual Losses Reduced by ½**
Effect on Long-Term Fish Populations (After 3-5 Years)	 **Total Fish Populations Increase to 65%**	 **Total Fish Populations Increase to 68%**
Effect on Annual Recreational and Commercial Catch (After 3-5 Years)	 **Catch Increases to 52%**	 **Catch Increases to 55%**
Increase in Cost of Living for Your Household	**$2 per month** ($24 per year) Cost of new regulations passed on to consumers	**$3 per month** ($36 per year) Cost of new regulations passed on to consumers

Scientists expect that other effects on the environment and economy will be negligible.

Please check <u>one</u>:

❑ I would vote for Option A.

❑ I would vote for Option B.

❑ I would not vote for either option.

Figure B-1
Sample SP Question from the EPA 2005 SP Study

Because the EPA never fielded this study, we cannot provide a discussion of the valuation results. However, Desvousges et al. (2005) conducted a pilot test of this study to learn whether the SP survey designed by the EPA could produce reliable estimates of nonuse benefits. They concluded that the study could not and identified the following problems:

- Respondents are not valuing marginal changes in forage fish populations. Respondents' answers range from use values for specific fish in specific waterbodies to more generalized concerns for the environment. The fact that EPA's survey elicits values other than the nonuse value of forage fish is a fatal flaw.
- The survey responses reveal a consistent pattern of hypothetical bias. The respondents' answers clearly show that they viewed their responses as hypothetical, non-binding answers to a survey, not a genuine commitment of personal resources.
- Respondents' answers are entirely dependent upon the information provided in the survey questionnaire and the accompanying PowerPoint slide show. Barnthouse (2005) shows that the information contained in the EPA survey materials is inaccurate and inconsistent with the scientific literature on the effects of CWIS on the environment.
- EPA also has failed to include information concerning the inherent uncertainty of the effects of CWIS on the environment, which further limits the usefulness of the survey responses.
- Many respondents indicated that they found the survey process to be long, difficult and confusing. Such a finding increases the chances of significant nonresponse bias in the survey. The evident confusion in respondents' answers is yet another source of statistical noise that further lowers the likelihood that this survey would yield useful information.
- Because the survey design does not address whether valuation responses are solely for this specific program or are simply reflections of some larger mental account for protecting fish, it is not possible to fully evaluate the nature of respondents' preferences. That is, the EPA survey design does not try to determine whether people value protecting all fish from all forms of predation and whether the value of reducing the impacts of CWIS on forage fish is a subset of that broader valuation. At a minimum, this survey presents a classic illustration of the conundrum as to whether respondents have preferences for reducing the effects of CWIS on forage fish or whether such preferences are merely an artifact of the survey process.

Role of Nonuse Values in the Phase II 316(b) Rule Development

As discussed in Section 5 of this report, the EPA currently requires that nonuse values be considered in a benefits assessment. In many instances, nonuse values can be treated qualitatively. This section of the appendix describes the various methods that EPA evaluated in its assessment of nonuse values during the period of the proposed rule and the Notice of Data Availability (NODA). The section then presents EPA's guidelines in the Final Phase II Rule for addressing nonuse values.

EPA Approach: Proposed Rule

In the proposed rule, EPA presented three potential approaches for quantifying nonuse values. These include the Habitat Replacement Cost (HRC) method, the Societal Revealed Preference (SRP) approach, and the Fisher-Raucher approximation. After public comment and further review EPA repudiated these methods. The following sub-sections describe each approach.

Habitat Replacement Cost Method

For the HRC method, the costs estimated by EPA are the total costs of restoring habitats so that they produce ecological services equivalent to those expected from technological alternatives. Numerous reviewers commented that these costs are not benefits. Rather, they are alternative costs for achieving the objectives of the proposed regulation. Mitigation approaches such as stocking and habitat restoration may be acceptable alternatives to technology installation. However, the cost of such alternatives bears no implicit relationship to the benefits of reducing I&E. Therefore, it is important not to confuse this method of mitigation scaling with measuring the benefits of the mitigation.

Appropriate economic measures of benefits require that they be based on the willingness-to-pay principle, and HRC is not based on this principle. In many cases, the cost of developing a resource can substantially exceed the resource's value. Although EPA extensively evaluated HRC during its development of the Phase II Rule, EPA ultimately decided that the HRC method should not be used as a means of estimating benefits due to limitations and uncertainties regarding the application of this methodology (*Fed. Reg.*, Volume 69, No. 131, p. 41,625).

Societal Revealed Preference Method

The second cost-based methodology employed by EPA in the Proposed Rule is called Societal Revealed Preference (SRP). Rather than using the cost of a hypothetical alternative, SRP uses historical costs under prior government mandates to measure benefits. Like the HRC method, this cost-based approach has no foundation in economic theory and is not accepted by economists as a legitimate method of empirical valuation. In fact, the SRP method is a corrupted application of the legitimate revealed preference method. An essential characteristic of revealed preference analysis and not SRP is that willingness to pay is revealed by those who are doing the paying. The SRP methodology takes the fact that a program exists as evidence that its benefits exceed its costs. EPA removed the disputed results of the SRP analyses from its benefits estimates for the final rule.

Fisher-Raucher Approximation

For the Proposed Rule analysis, EPA also presented the Fisher-Raucher or ''50 percent'' rule. This approach approximates nonuse values at 50 percent of recreational use values. The approximation is derived from a comparison of use and nonuse values for water quality improvements (Fisher and Raucher 1984). The 50-percent rule is inappropriate in this context because there is no reason to believe that the ratio of nonuse to use benefits from water quality improvements could be applied to the environmental improvement from reductions in I&E. Moreover, because use values for fish often arise from their *consumption*, there is no conceptual reason to believe that there is a positive association between use and nonuse values in this context. EPA does not employ the 50-percent rule in its final analysis and this approach is not employed in this assessment.

EPA Approach: Notice of Data Availability (NODA)

EPA used two approaches to evaluate nonuse values in the NODA. These include a revised form of the HRC method and the Production Forgone method. After public comment and further review EPA repudiated the revised HRC method. The Production Forgone method is included in EPA's final benefits analysis. The following sub-sections describe each approach.

Revised Habitat Replacement Cost

In the NODA, EPA presented a revised HRC methodology that evaluated nonuse benefits based on estimated willingness-to-pay values for the resource improvements that would be achieved by equivalent restoration. It was based on an approach that combines an estimate of the amount of habitat required to offset I&E losses by means of wild fish production with a benefits estimate of willingness to pay for aquatic habitat preservation/restoration from existing studies.

This approach is fundamentally flawed for a number of reasons (Bingham, Desvousges, and Mohamed 2003). A theoretical shortcoming of this approach is that there is no good reason to presume that willingness-to-pay values for habitat restoration are an appropriate proxy for either the total value or the nonuse value of the fishery resources that would be preserved due to reduced I&E. EPA does not employ this revised HRC approach in its final analysis.

Production Forgone

When calculating benefits for the NODA, EPA valued forage fish based upon their value as inputs to recreational and commercial stocks. The Production Forgone methodology recognizes that the value of forage species is through indirect use rather than nonuse. This methodology passes the biological effects of increased biomass availability through trophic levels until it reaches commercially and recreationally valuable species. At this point, catch changes and recreational and commercial values are calculated. Although commenters disagreed on certain assumptions, the approach was generally accepted.[52] Valuing forage benefits in this manner accounted for nearly all biomass but led to only marginally higher estimates of economic impacts to recreational and commercial fishing.[53]

[52] For example, Barnthouse (2002) indicates that the transfer efficiency is not correct.

[53] The recreational and commercial fishing mortality rates specified by EPA indicate that very few of these fish are expected to die naturally. Valuing forage fish in terms of production forgone added less than 20 percent to total benefits.

EPA Approach: Final Rule—Qualitative Discussion of Nonuse Values

Although it evaluated a variety of methods for quantifying benefits associated with reductions in I&E losses, EPA ultimately determined that none of the methods it considered for assessing nonuse benefits provided results that were appropriate to include in this final rule, and has thus decided to rely on a qualitative discussion of nonuse benefits (EPA 2004a, p. 41,624) in the absence of impacts to sustainable populations or threatened and endangered species. In the final Phase II Rule, EPA provides the following guidance on how to assess the nonuse benefits associated with reductions in I&E (EPA 2004a, p. 41,647–41,648):

- Nonuse benefits may arise from reduced impacts to ecological resources that the public considers important, such as threatened and endangered species. Nonuse benefits can generally only be monetized through the use of stated preference (SP) methods. When determining whether to monetize nonuse benefits, permittees and permit writers should consider the magnitude and character of the ecological impacts implied by the results of the impingement and entrainment mortality study and any other relevant information.
- In cases where an impingement mortality and entrainment characterization study identifies substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function in a facility’s waterbody or watershed, nonuse benefits should be monetized.
- In cases where an impingement mortality and entrainment characterization study does not identify substantial harm to a threatened or endangered species, to the sustainability of populations of important species of fish, shellfish, or wildlife, or to the maintenance of community structure and function in a facility’s waterbody or watershed, monetization is not necessary.

Strategies for Nonuse Value Assessments

In a few rare instances, it may be necessary to evaluate nonuse values in a more rigorous way. For example, if a plant’s CWIS were located near habitat for an endangered species, such as a manatee or a sturgeon or a salmon, there may be a need to measure the nonuse value associated with that species. In some instances, rather than quantifying those impacts, it may be possible to reach agreement with the regulatory agency over a restoration program that would offset the impacts on the potentially affected species.

If that alternative is not feasible or acceptable within a jurisdiction, then the last alternative would be to conduct a CV or SP survey. As described earlier, these surveys would involve asking respondents in one form or another how much they would be willing to pay to protect the endangered species in the particular location. Clearly, the most serious limitation of the method is that the responses are based on what people say they would do, not what they would actually pay.

Given these limitations, it is not possible to conduct a survey that would meet most generally accepted reliability criteria. Nonetheless, it could still be in a utility’s interest to conduct such a study. For example, even with substantial hypothetical bias, the estimated benefits could be less than the cost of a closed cycled cooling tower, which would enable a less expensive technology to be selected. Alternatively, some restoration programs might be envisioned that would involve substantial life cycle costs for the utility that would not be desirable. Thus, it is important to fully evaluate the potential options before rejecting the notion of quantifying nonuse benefits outright.

Additionally, some factors can lead to better studies. Accordingly, we recommend that a utility:

- Conduct extensive pretesting of the survey questionnaire to ensure that people understand the questions (Mathews, Freeman, and Desvousges 2006).
- Develop a rigorous sampling plan to ensure that the sample is representative of the target population.
- Use the SP form of the valuation question rather than the CV form.
- Include extensive tests for reliability within the survey design to test whether or not the answers conform to established economic principles (Johnson and Mathews 2001).

Even with these steps, hypothetical bias is likely to be present. However, the reliability tests will enable such bias to be evaluated and demonstrated, so that some type of adjustment can be made in the final responses. Such adjustments could be negotiated with the regulators and could even be considered in the determination of the meaning of “significantly greater than.” For example, suppose that the SP survey revealed that costs were three times greater than the benefits of a closed cycle cooling system with no adjustment made for hypothetical or other biases. However, suppose that making the adjustments for bias were to result in costs being five times greater than benefits of a closed cycle cooling system. Calculating such a range would provide the regulator with a greater sense of confidence that even with all possible benefits explicitly included, the costs of closed cycle cooling would be significantly greater than the benefits.

References

1. Adamowicz, W., J. Louviere, and M. Williams. 1994. Combining revealed and stated preference methods for valuing environmental amenities. Journal of Environmental Economics and Management 26:271-292.
2. Arrow, K., R. Solow, P. R. Portnoy, E. E. Leamer, R. Radner, and H. Schuman. 1993. Report of the NOAA Panel on Contingent Valuation. 58 *Fed. Reg.* 4601 *et. seq*. January 15.
3. Banzhaf, M. R., F. R. Johnson, and K. E. Mathews. 2001. Opt-out alternatives and anglers’ stated preferences. In The Choice Modelling Approach to Environmental Evaluation, J. Bennett and R. Blamey, eds. Edward Elgar Publishing, Northampton, MA.
4. Barnthouse, L. 2002. Review of Methodology Used by EPA to Evaluate Impacts of Entrainment and Impingement Losses and Comments on the PISCES (August 2002) Report. Prepared for the Riverkeeper Inc. Prepared for EPRI. LWB Environmental Services, Oak Ridge, TN.
5. Barnthouse, L. W. 2005. Comments on EPA 316(b) “Willingness to Pay” Survey Materials. July. LWB Environmental Services, Inc., Hamilton, OH.

6. Bingham, M. F., W. H. Desvousges, and A. F. Mohamed. 2003. Comments on Benefit Estimation of EPA's Proposed Phase II 316(b) Rule as Summarized in the Notice of Data Availability: Final Report. Prepared for The Utility Water Act Group. June. Triangle Economic Research, Durham, NC.
7. Cattin, P., and D. Wittink. 1982. Commercial use of conjoint analysis: a survey. Journal of Marketing 46(Summer):44-53.
8. Desvousges, W. H., M. F. Bingham, J. C. Kinnell, A. F. Mohamed, and K. T. Kuhns. 2005. Review and Response to the EPA's Response to Comments from the American Chemistry Council et al. and Accompanying Triangle Economic Research (TER) Report. Prepared for the Utility Water Act Group, General Electric Company, American Chemistry Council, American Forest and Paper Association, American Iron and Steel Institute, American Public Power Association, and American Petroleum Institute. April 20. Durham, NC: Triangle Economic Research.
9. Desvousges, W.H., S.P. Hudson, S.K. Snow, R.W. Dunford, A.R. Gable, M.C. Ruby, and R.A. Sandefur. 1994. Comments on the National Oceanic and Atmospheric Administration's Natural Resource Damage Assessment Proposed Rule. Prepared for NOAA. Durham, NC: Triangle Economic Research.
10. Fisher, A., and R. Raucher. 1984. Intrinsic benefits of improved water quality. Conceptual and empirical perspectives. Advances in Applied Micro-Economics 3:37-66.
11. Gan, C., and E. J. Luzar. 1993. A conjoint analysis of waterfowl hunting in Louisiana. Journal of Agricultural and Applied Economics 25:36-45.
12. Hausman, J. A., ed. 1993. Contingent Valuation: A Critical Assessment. Elsevier Science Publishers, Amsterdam.
13. Huber, J. 1997. What we have learned from 20 years of conjoint research: when to use self-explicated, graded pairs, full profiles or choice experiments. Paper prepared for the Sawtooth Software Conference:1-16. August.
14. Johnson, F. R., W. H. Desvousges, E. E. Fries, and L. L. Wood. 1995. Conjoint analysis of individual and aggregate environmental preferences. TER Technical Working Paper T-9502. Triangle Economic Research, Durham, NC.
15. Johnson, F. R., and K. E. Mathews. 2001. Sources and effects of utility-theoretic inconsistency in stated-preference surveys. American Journal of Agricultural Economics 83(5):1328-1333.
16. Keeney, R. L., and H. Raiffa. 1978. Decisions with Multiple Objectives: Preferences and Tradeoffs. John Wiley and Sons, New York.
17. Kemp, M., and C. Maxwell. 1993. Exploring a budget context for contingent valuation estimates. In Contingent Valuation: A Critical Assessment. J. A. Hausman, ed. Elsevier Science Publishers B.V., Amsterdam.
18. Mackenzie, J. 1993. A comparison of contingent preference models. American Journal of Agricultural Economics 75(3):593-603.
19. Mathews, K. E., M. L. Freeman, and W. H. Desvousges. 2006. How and how much? The role of information in stated choice questionnaires. In Valuing Environmental Amenities

Using Choice Experiments: A Common Sense Guide to Theory and Practice, ed. B. Kanninen. Springer, Dordecht, The Netherlands.

20. Mitchell, R. C., and R. T. Carson. 1989. Using Surveys to Value Public Goods: The Contingent Valuation Method. Resources for the Future, Inc., Washington DC.
21. Olsen, D., J. Richards, and R. D. Scott. 1991. Existence and sport values for doubling the size of Columbia River Basin salmon and steelhead runs. Rivers 2(1):44-56.
22. Opaluch, J. J., S. K. Swallow, T. Weaver, C. W. Wessells, and D. Wichelns. 1993. Evaluating impacts from noxious facilities: including public preferences in current siting mechanisms. Journal of Environmental Economics and Management 24:41-59.
23. Roe, B., K. J. Boyle, and M. F. Teisl. 1996. Using conjoint analysis to derive estimates of compensating variation. Journal of Environmental Economics and Management 31:145-159.
24. Rowe, R. D., R. d'Arge, and D. S. Brookshire. 1980. An experiment on the economic value of visibility. Journal of Environmental Economics and Management 7:1-19.
25. Schkade, D. A., and J. W. Payne. 1994. How people respond to contingent valuation questions: a verbal protocol analysis of willingness to pay for an environmental regulation. Journal of Environmental Economics and Management 26:88-109.
26. U.S. Environmental Protection Agency. 2004. National pollutant discharge elimination system—final regulations to establish requirements for cooling water intake structures at Phase II existing facilities, final rule. Federal Register Vol. 69, No. 131 (Friday, July 9):41,576-41,693.
27. U.S. Environmental Protection Agency. 2005. Supporting Statement For Information Collection Request For Willingness To Pay Survey For §316(B) Phase III Cooling Water Intake Structures: Instrument, Pre-Test, and Implementation (OW-2005-0006-0002).
28. Wittink, D. R., and P. Cattin. 1989. Commercial use of conjoint analysis: an update. Journal of Marketing 53(July):91-96.

C

ADDITIONAL INFORMATION ON RECREATIONAL SALTWATER FISHING

Table C-1 summarizes the recreational groundfish regulations for 2007 in the Southern Management Area (California Department of Fish and Game, Marine Region 2007a).

Table C-1
Groundfish Regulations in the Southern Management Area

Species	Time Period[a, b, c, d, e]	Depth Limit[a, b, c, d, e]	Daily Bag Limit[b]	Minimum Size Limit[b, f, g]
RCG Complex[a] (including all species of rockfish, cabezon, and greenlings	Boat-based anglers:[c] Open: March–Dec. Closed: Jan.–Feb. Divers, shore-based anglers:[c] Open year-round	May only be taken or possessed in waters *less than* 360 ft (60 fm) deep[a] See exception[h]	10 fish in combination per person See sub-limits for cabezon, greenling, and bocaccio	See individual species and groups
Canary and yelloweye rockfish, cowcod	Closed all year NO RETENTION		NO RETENTION	
Bocaccio	Same as RCG Complex	Same as RCG Complex	1 fish per person Also included in the 10-fish aggregate RCG Complex bag limit	10" total length
Cabezon	Same as RCG Complex	Same as RCG Complex	1 fish per person Also included in the 10-fish aggregate RCG Complex bag limit	15" total length
Kelp or rock greenling	Same as RCG Complex	Same as RCG Complex	2 fish per person Also included in the 10-fish aggregate RCG Complex bag limit	12" total length
Ocean whitefish	Same as RCG Complex	Same as RCG Complex	10 fish per person	None
California sheephead	Same as RCG Complex	Same as RCG Complex	5 fish per person	12" total length
California scorpionfish	Open all year	Jan.–Feb.: may only be taken or possessed in waters *less than* 240 ft (40 fm) deep[a] March–Dec.: may only be taken or possessed in waters *less than* 360 ft (60 fm) deep[a]	5 fish per person	10" total length
Lingcod	All anglers and divers:[c] Open: April–Nov. Closed: Jan.–March, Dec.	Same as RCG Complex	2 fish per person	24" total length

Table C-1, continued

Species	Time Period[a, b, c, d, e]	Depth Limit[a, b, c, d, e]	Daily Bag Limit[b]	Minimum Size Limit[b, f, g]
Leopard shark [d]	Divers, shore-based anglers:[c] open all year Boat-based anglers[c] within Newport Bay, Alamitos Bay, San Diego Bay, Mission Bay: open all year *Outside the bays listed above: same as RCG Complex*	Boat-based anglers[c] within Newport Bay, Alamitos Bay, San Diego Bay, Mission Bay: no depth restrictions *Outside the bays listed above: same as RCG Complex*	3 fish per person	36" total length
Pacific sanddabs and "other flatfish" [e] (see Section 28.48, p. 39 of the regulations)	Open all year with certain gear restrictions during Jan. and Feb.[e]	None, although certain gear restrictions apply in depths greater than 360 ft (60 fm)[e]	See Section 28.48 of the regulations	See Section 28.48 of the regulations
Other federal groundfish (see Sections 28.49, 28.51, 28.52, 28.53, 28.57 of the regulations)	Same as RCG Complex	Same as RCG Complex	See Sections 28.49, 28.51, 28.52, 28.53, 28.57 of the regulations	See Sections 28.49, 28.51, 28.52, 28.53, 28.57 of the regulations

[a] In the Cowcod Conservation Areas, fishing is prohibited in waters greater than 120 feet (20 fathoms) deep. Fishing also is subject to the Time Period closures for the Southern Management Area. See Section 27.50 of the regulations for further information on species restrictions.

[b] Subject to in-season change. Call the Recreational Groundfish Fishing Regulations Hotline at (831) 649-2801, visit the Marine Region Web site at www.dfg.ca.gov/mrd, send an e-mail to AskMarine@dfg.ca.gov, or call your nearest DFG office for the latest information.

[c] Divers and shore-based anglers are exempt from season and depth restrictions affecting the RCG complex, ocean whitefish, California sheephead, and other federally managed groundfish (except for lingcod). However, when spear fishing during a boat-based closure, only spear fishing gear is allowed aboard any vessel or watercraft. Also, when angling from shore during a boat-based closure, no vessel or watercraft may be used to assist in taking or possessing species included in this table. The following definitions describe boat-based and shore-based anglers, and divers:

- Boat-based anglers are those who fish from boats or vessels of any size or any other type of floating object, including kayaks and float tubes.
- Shore-based anglers are those who fish from beaches, banks, piers, jetties, breakwaters, docks, and other manmade structures connected to the shore.
- Divers are spear fishermen entering the water either from the shore or from a boat or other floating object.

[d] The sport fishery for leopard shark inside Newport Bay, Alamitos Bay, Mission Bay, and San Diego Bay is exempt from season and depth restrictions that affect other federally managed groundfish.

[e] In closed areas or during closed periods, Pacific sanddab, butter sole, curlfin sole, flathead sole, rex sole, rock sole, and sand sole (defined as "Other Flatfish" in Section 1.91(a)(10)) may ONLY be taken using the following gear: up to 12 No. 2 (or smaller) hooks and up to 2 lb. of weight.

[f] See regulations for information on gear restrictions and fillet lengths.

[g] Total length is the longest straight-line measurement from the tip of the head with the mouth closed to the end of the longest lobe of the tail. A measurement illustration is available on page 71 of the *2007 Ocean Sport Fishing Regulations* booklet.

[h] EXCEPTION: During the open season, groundfish may be possessed in closed areas and in water depths closed to fishing only aboard vessels in transit with no fishing gear in the water. See sub-section 27.20(b) of the regulations.

Source: California Department of Fish and Game, Marine Region (2007a)

An angler may take or possess no more than 20 finfish of all species combined and not more than 10 of any species, except as provided in the *2007 Ocean Sport Fishing Regulations*. Within the overall daily bag limit of 20 finfish, special limits apply as follows:

- Prohibited—garibaldi; broomtail and gulf grouper; white shark, except with a permit issued for scientific or educational purposes; green sturgeon, which must be released and reported on a Sturgeon Fishing Report Card; and giant (black) sea bass, except that an angler may keep two giant sea bass per day when fishing south of the U.S.-Mexico border with a valid Mexican license or permit
- One fish—white sturgeon, which must be reported on a Sturgeon Fishing Report Card; Pacific halibut, only from May 1–October 31; marlin; sevengill and sixgill shark
- Two fish—salmon; striped bass; broadbill swordfish; and blue, thresher, or shortfin mako shark
- Three fish—Trout, except that taking steelhead rainbow trout from ocean waters is prohibited; and white seabass, except that only one white seabass may be taken in waters south of Pt. Conception between March 15 and June 15
- Five fish—California halibut.

As of May 1, 2007, the California Department of Fish and Game Ocean Salmon Project—Marine Region (2007) prohibited the retention of coho salmon or steelhead trout in any ocean fishery.

Table C-2 lists the site characteristics of Huntington Beach waters and also lists substitute saltwater fishing sites and their characteristics.

Table C-2
Site Characteristics of Huntington Beach and Substitute Saltwater Fishing Sites

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Agua Hedionda Lagoon		Fishing, boating, boat ramp	California halibut, spotfin croaker	1
Anaheim Bay		Fishing, wildlife watching, boating, marina, boat ramp, picnicking. Adjoins Seal Beach National Wildlife Refuge.	California halibut, diamond turbot, sculpin, surfperch	1
Batiquitos Lagoon		Fishing, birdwatching, no boating	California halibut, diamond turbot	
Belmont Pier		Fishing, fishing pier	Barracuda, bonito, mackerel, jacksmelt, queenfish, shark, topsmelt, walleye surfperch, white croaker	
Bolsa Bay		Fishing, fishing pier, wildlife watching. Adjoins Bolsa Chica Ecological Reserve.	Barracuda, halibut, mackerel, sand bass, sculpin	1
Cabrillo Pier		Fishing, fishing pier	Croaker, halibut, mackerel, queenfish, surfperch	
Catalina Island		Fishing, boating	Barracuda, calico bass, lingcod, rockfish, white seabass, yellowtail	
Dana Point Harbor		Fishing, fishing pier, boating, boat ramp, charters	Barracuda; black seaperch; bonito; California halibut; corbina; diamond turbot; jacksmelt; opaleye; Pacific mackerel; pileperch; queenfish; rays; rubberlip and white seaperch; sargo; sharks; shinerperch; small kelp bass; spotfin, white, and yellowfin croaker; spotted sand bass. Anglers caught state-record corbina and yellowfin croaker at Dana Point Harbor.	1
Fiesta Bay		Adjoins Northern Wildlife Reserve and Kendall-Frost marsh. Fishing, boating, boat ramps, jet skiing, water skiing.		2
Gulf of Santa Catalina		Fishing, boating, fishing pier, boating tours, excursions, whale watching	Blackperch, blacksmith, calico bass, California scorpionfish, California sheephead, grass rockfish, halfmoon, jacksmelt, kelp rockfish, kelp seaperch, ocean whitefish, opaleye, rainbow seaperch, rock wrasse, rubberlip seaperch, shinerperch, topsmelt, white sea bass, yellowtail	

Table C-2 (Continued)

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Horseshoe Kelp		Fishing	Albacore, bluefin and yellowfin tuna, calico bass, rockfish, sculpin, white croaker, white seabass, yellowtail	
Huntington Beach	3.5 miles of shoreline	Adjoins Huntington Beach State Park and Bolsa Chica Ecological Reserve. Fishing, fishing pier, fishing derbies, boating, boat ramps, boat tours, marinas, swimming, surfing, camping, volleyball, AVP Pro Beach Volleyball Tour events, marathons and other athletic events, concerts, festivals, other special events.	Bass, bat ray, bonito, cabezon, California grunion, California halibut, corbina, halfmoon, jacksmelt, mackerel, opaleye, perch, queenfish, ray, sand bass, sanddab, sardine, sculpin, shark, shovelnose guitarfish, sole, surfperch, tuna, turbot, yellowfin croaker. Anglers caught state-record jack mackerel (5 lbs., 8 oz.) and bat ray (181 lbs.) at Huntington Beach.	2
King Harbor		Fishing, boating, boat ramp, boat rentals, charters		1
Long Beach		Fishing, boating, boat ramps, marina, charters, whale watching, harbor tours, Belmont Pier	Barracuda, bocaccio, bonito, calico bass, California sheephead, corbina, croaker, halfmoon, halibut, mackerel, perch, queenfish, rockfish, sand bass, sanddab, sargo, sculpin, surfperch, white seabass, whitefish, yellowtail. Angler caught state-record pile perch on February 26, 2007.	2
Malibu Pier		Fishing, fishing pier, boating, kayaking, charters, boat tours, surfing	Halibut, rockfish, queenfish, sea bass	
Marina del Rey		Fishing; fishing dock; fishing derbies; boating; boat ramps; boat rental; charters; cruises; whale watching; largest marina on the West Coast; WaterBus during the summer; near Aubrey Austin, Chace, and Admiralty Parks and North Jetty Walkway; picnicking; concerts; parades; fireworks; swimming; biking; windsurfing; kayaking; special events; 19 anchorages	Barracuda, calico bass, dorado, halibut, marlin, rock cod, sand bass, tuna, wahoo, white sea bass, yellowtail	2

Table C-2 (Continued)

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Mission Bay	2,000 acres	Fishing, boating, boat ramps, sailing, jet skiing, water skiing, marinas, sea kayaking, camping, playgrounds, beaches, swimming, wind surfing, picnicking, volleyball, softball, horseshoes, bicycling, jogging, wildlife reserves, visitor center, San Diego Aquatic Center	Barracuda; bonito; calico, sand, and spotted sea bass; corvine; mackerel; white seabass; yellowfin croaker	5
Newport Bay		Adjoins Newport Municipal Beach, Newport Beach Jetties, and West Oceanfront and Grant Street beaches. Fishing, fishing pier, boating, boat ramp, boat rentals, charters, swimming, RV camping.	Bonito, corbina, croakers, halibut, marlin, sand bass, spotted bay bass. Anglers caught state-record corbina and spotted sand bass from Newport Bay and blue marlin from the Balboa portion of the bay.	1
Pacific Ocean		Fishing, at least 23 fishing piers, boating, boat ramps, beaches, swimming, whale watching, volleyball, hiking. Adjoins many parks, including Pacific Ocean Park, Crystal Cove State Park, Corona del Mar State Beach, Inspiration Point, Little Corona del Mar beach, Lookout Point Park, and Rocky Point in Corona del Mar.	Albacore tuna; barred sand bass; barred seaperch; bigeye tuna; black, spotfin, white, and yellowfin croaker; black and walleye surfperch; blacksmith; blue, brown, grass, and olive rockfish; bocaccio; cabezon; California barracuda; California corbina; California halibut; California lizardfish; California scorpionfish; California sheephead; chub mackerel; giant sea bass; halfmoon; horn shark; jack mackerel; jacksmelt; kelp bass; kelp greenling; leopard shark; ocean whitefish; opaleye; queenfish; rubberlip seaperch; sanddab; sargo; shortfin mako shark; spotted sand bass; striped bass; treefish rockfish; turbot; white seabass. Anglers caught state-record barred sand bass, barred seaperch, bigeye tuna, cabezon, California barracuda, California sheephead, giant sea bass, kelp bass, leopard shark, ocean whitefish, opaleye, scorpionfish, shortfin mako shark, spotfin croaker, and treefish rockfish from the Pacific Ocean.	16

Table C-2 (Continued)

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Point Dume		Part of Point Dume State Preserve. Fishing, fishing pier (Paradise Cove), swimming, diving, surfing, nature trails, wildlife watching.	Barracuda, bass, bonito, croaker, yellowtail	
Point Vicente Palos Verdes		Fishing, diving, picnicking, hiking, whale watching	Barracuda, bluefin tuna, bonito, calico bass, croaker, halibut, sand bass, sea bass, sheephead, yellowtail	
Redondo Pier		Fishing, fishing pier, boating, excursions, arcade, boardwalk, whale watching	Corbina, halibut, mackerel, sardine	
San Diego Bay		Fishing, at least 4 fishing piers, boating, boat ramps, marinas, fishing charters, sea kayaking, adjacent parks, "Day at the Docks"	Abalone, albacore and bluefin tuna, barracuda, barred sand bass, bass, bat ray, big-eyed tuna, bonito, calico bass, covina, croaker, dorado, flounder, halibut, mackerel, Pacific bonefish, shark, skipjack tuna, spotted bay bass, white sea bass, yellowfin, yellowtail. Anglers caught state-record thresher shark and skipjack tuna from San Diego Bay.	5
San Pedro Bay		Fishing	Croaker, sardine, queenfish	
San Pedro Channel		Fishing, boating, charters	Sardine	
Santa Barbara Channel		Fishing, fishing pier, boating, boat ramps, swimming, whale watching, island excursions	Albacore, barracuda, blue and mako shark, bluefin tuna, bonito, calico bass, dorado, halibut, ling cod, mackerel, rockfish, sheephead, striped marlin, wahoo, white sea bass, whitefish, yellowfin tuna, yellowtail	2
Santa Monica Bay		Fishing, fishing pier	Barracuda, barred bonito, calico bass, bonito, California halibut, guitarfish, mackerel, queenfish, salema, sand bass, sculpin, seaperch, surfperch, thornback, yellowfin croaker, yellowtail. Angler caught state-record yellowfin croaker from Santa Monica beach.	
Short Bank		Fishing	Croaker	
White's Point		Fishing, wildlife watching	Kelp bass, rockfish, sculpin, white croaker	

Sources: DeLorme (2005); Jackson (2006); Jones (undated); California DFG, Marine Region (2007a, 2007b, 2007c, 2007d); Los Angeles County Department of Beaches and Harbors (undated); San Diego Sportfishing Council (undated)

References

1. California Department of Fish and Game, Marine Region. 2007a. 2007 Ocean Sport Fishing Regulations. Available at http://www.dfg.ca.gov/marine/oceanfish2007.pdf. Retrieved on July 31, 2007.
2. California Department of Fish and Game, Marine Region. 2007b. Record ocean sportfish. Available at http://www.dfg.ca.gov/marine/faqtrph3.asp. Retrieved on September 27, 2007.
3. California Department of Fish and Game, Marine Region. 2007c. State managed commercial fisheries: cabezon, greenlings and sheephead (CGS). Available at http://www.dfg.ca.gov/Mrd/cgs.html. Retrieved on August 8, 2007.
4. California Department of Fish and Game, Marine Region. 2007d. Popular features. Available at http://www.dfg.ca.gov/MRD/index_regs.html. Retrieved on August 9, 2007.
5. California Department of Fish and Game, Ocean Salmon Project—Marine Region. 2007. "2007 Ocean Salmon Sport Regulations." Available at http://www.dfg.ca.gov/mrd/salmonsport07.pdf. Retrieved on August 7, 2007.
6. DeLorme. 2005. Southern and Central California Atlas and Gazetteer. DeLorme, Yarmouth, ME.
7. Jackson, D. 2006. Albackore's Gulp! only west coast fall surf slam. Available at http://www.fishingexpeditions.com/html/surf_slam.html. Retrieved on September 20, 2007.
8. Jones, K. Undated. Dana Point Harbor fishing pier. Available at http://www.pierfishing.com/resources/index.php?id=piers:dana_point_harbor_fishing_pier. Retrieved on August 9, 2007.
9. Los Angeles County Department of Beaches and Harbors. Undated. Welcome to Marina Del Rey. Available at http://beaches.co.la.ca.us/BandH/Marina/Main.htm. Retrieved on September 27, 2007.
10. San Diego Sportfishing Council. Undated. San Diego sportfishing online. Available at http://www.sportfishing.org/. Retrieved on September 27, 2007.

D
ADDITIONAL INFORMATION ON RECREATIONAL FRESHWATER FISHING

California offers several angler recognition programs for inland fishing, as described below.

- Inland Water Fishing Record Program—An angler catching a state-record fish must land the fish unaided. The fish must be weighed on a scale certified by a government agency and in the presence of two witnesses unknown to the angler or diver. A biologist must identify the catch (California DFG 2007a).
- California Fishing Passport Program—The passport lists 150 different species of freshwater and saltwater finfish and shellfish that inhabit waters throughout California. Participating anglers catch and document all of the different species listed, receiving a stamp for each one (California DFG 2007b).
- Trophy Black Bass Program—An angler lands a trophy-size bass and submits an application form for recognition. To qualify, a largemouth bass must weigh at least 10 pounds; smallmouth and spotted bass must weigh at least 6 pounds. Once the catch is verified, the angler receives a certificate. Of the 25 biggest largemouth bass caught in the U.S., 21 were landed from California waters (California DFG 2007c; California DFG, Fisheries Programs Branch 2003).
- California Heritage Trout Challenge—To earn a certificate, an angler catches and photographs six different types of native trout from their historic drainages in California. The angler submits an application along with the photos. There is no time restriction on completing the challenge, but an angler can earn only one certificate per calendar year (California DFG 2007e).

The South Coast Region of the California DFG regulates the fisheries of freshwater bodies near Huntington Beach. Tables D-1 and D-2 summarize the regulations at freshwater substitute sites in the South Coast Region (District) of California (California Department of Fish and Game 2007f). Within the district, substitute sites are located throughout Los Angeles and Orange Counties, as well as in parts of Riverside, San Bernardino, San Diego, and Ventura Counties.

Table D-1
Freshwater Fishing Regulations in the South Coast Region of California

Fish	County	Body of Water	Open Season	Size (Total Length)	Bag Limit
Black bass	Los Angeles	Castaic Lake	All year	18-inch minimum	2
	Riverside	Diamond Valley Lake	All year	15-inch minimum largemouth No smallmouth may be kept	5
		Skinner Lake	All year	15-inch minimum	2
	San Bernardino	Silverwood Lake	All year	15-inch minimum	2
	San Diego	Barrett Lake	All year	No fish may be kept	0
		El Capitan Reservoir	All year	15-inch minimum	5
		Lake Cuyamaca	All year	No size limit No smallmouth may be kept	5
		Lake Hodges	All year	15-inch minimum	5
		Upper Otay Lake	All year	Only artificial lures with barbless hooks may be used for any kind of fish No fish may be kept	0
	Ventura	Lake Casitas	All year	12 inches No more than 1 longer than 22 inches	5
	District counties	All other lakes/reservoirs in the district	All year	12-inch minimum	5
		All other rivers/streams and private ponds in the district	All year	No size limit	5
Bullhead	District counties	All district waters	All year	No size limit	No limit
Candlefish	District counties	All district waters, fish taken by dip net	All year	No size limit	25 lb.
Catfish	Los Angeles	Alondra County Park Lake	All year	No size limit	5
		Belvedere Park Lake	All year	No size limit	5
		Cerritos Park Lake	All year	No size limit	5
		Earvin "Magic" Johnson Park Lake	All year	No size limit	5
		Kenneth Hahn Park Lake	All year	No size limit	5
		La Mirada Park Lake	All year	No size limit	5
	San Bernardino	Cucamonga-Guasti Park Lakes	All year	No size limit	5
		Glen Helen Park Lake	All year	No size limit	5
		Mojave Narrows Lake	All year	No size limit	5
		Prado Lake	All year	No size limit	5
		Yucaipa Regional Park Lakes	All year	No size limit	5
	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
		All other waters in the county	All year	No size limit	5
	District counties	All other district waters	All year	No size limit	10
Clams, freshwater	District counties	All district waters, taken by hand or by appliance operated by hand	All year	No size limit	50 lb. in the shell

Table D-1, continued

Fish	County	Body of Water	Open Season	Size (Total Length)	Bag Limit
Coho (silver) salmon	District counties	All district waters	None	No fish may be kept Return to water unharmed	0
Crappie	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
		El Capitan Lake, Lake Hodges	All year	10-inch minimum	25
	District counties	All other district waters	All year	No size limit	25
Crayfish	District counties	All district waters, taken by hand, hook and line, dip net, or trap not larger than 3 ft.	All year	No size limit	No limit
Grass carp	District counties	All district waters	None	No fish may be kept Return to water unharmed	0
Green sturgeon	Statewide	All waters	None	No fish may be kept Report on a Sturgeon Fishing Report Card	0
Lamprey	District counties	All district waters, taken by hand, hook, spear, bow and arrow fishing tackle, dip net, or trap not larger than 3 ft.	All year	No size limit	No limit
Mountain whitefish	District counties	All district waters	Only when trout may be taken in the water body	No size limit	5
Shad, American	District counties	All district waters, fish taken by angling only	All year	No size limit	25
Striped bass	Riverside	Lake Elsinore	All year	18-inch minimum	2
	District counties	All other district waters	All year	No size limit	10
Sunfish	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
	District counties	All other district waters	All year	No size limit	No limit
Tilapia	San Diego	Barrett Lake, Upper Otay Lake	All year	No fish may be kept	0
	District counties	All other district waters	All year	No size limit	No limit
Trout, salmon, steelhead	San Diego	All streams, except anadromous waters Only artificial lures with barbless hooks may be used	All year	No size limit	2
	District counties	All anadromous waters	Closed	No trout, salmon, or steelhead may be caught	0
		All district streams, except anadromous waters in Los Angeles, Ventura, Santa Barbara, Orange, San Bernardino, and Riverside Counties Above Rindge Dam on Malibu Creek	All year	No size limit	5
		All district lakes and reservoirs	All year	No size limit	5
White bass	District counties	All district waters	All year	No size limit White bass may not be transported alive	No limit
White sturgeon	Statewide	All district waters Must take bait or lure in its mouth	All year	46–66 inches May possess 3 per year Report on a Sturgeon Fishing Report Card	1

Source: California Department of Fish and Game (2007)

Table D-2
Alphabetical List of Waters with Special Fishing Regulations in the South Coast Region of California

County	Body of Water	Open Season	Restriction	Size (Total Length)	Bag Limit
San Bernardino	Bear Creek	All year	Only artificial lures with barbless hooks may be used	No size limit	2
	Big Bear Lake tributaries	Saturday preceding Memorial Day through Feb. 28	5 fish per day 10 in possession	No size limit	5
	Deep Creek from headwaters at Little Green Valley to confluence of Willow Creek	All year	Only artificial lures with barbless hooks may be used	No size limit	2
Los Angeles and Ventura	Piru Creek and tributaries upstream of Pyramid Lake	All year	Only artificial lures with barbless hooks may be used	No size limit	2
	From Pyramid Dam downstream to the bridge about 300 yards below Pyramid Lake	None	Closed to fishing all year	Not allowed	0
	From the bridge approximately 300 yards below Pyramid Lake to the falls about ½ mile above the old Highway 99 bridge	All year	Only artificial lures with barbless hooks may be used	Not applicable	0
Los Angeles	San Gabriel River, west fork and tributaries, upstream of Cogswell Dam, Cogswell Reservoir	All year	Only artificial lures with barbless hooks may be used	No size limit	2
	From Cogswell Dam downstream to the second bridge upstream of the Highway 39 bridge	All year	Only artificial lures with barbless hooks may be used	Not applicable	0
Los Angeles and Orange	San Gabriel River upstream of the Highway 22 bridge to the start of concrete-lined portion of the river channel	Saturday preceding Memorial Day through Nov. 30	Only artificial lures with barbless hooks may be used	No size limit	0 trout or steelhead
Ventura	Santa Paula Creek and tributaries above the falls located 3 miles upstream from the Highway 150 bridge	All year	Bag limit	No size limit	5
	Sespe Creek and tributaries above Alder Creek confluence	All year	Only artificial lures with barbless hooks may be used	Not applicable	0

Source: California Department of Fish and Game (2007)

Anglers also can choose to fish at many freshwater sites located near Huntington Beach. Among the most attractive are those offering both freshwater fishing and other recreation:

- Big Bear Lake, within San Bernardino National Forest, where anglers can catch bluegill, trout, catfish, crappie, largemouth bass, and silver salmon (Bigbear.us 2005).

- Diamond Valley Lake, where anglers can catch catfish, bluegill, crappie, bass, sunfish, and trout. Bass and other fishing tournaments are held at Diamond Valley Lake (Metropolitan Water District of Southern California undated).
- Lake Piru, within the Los Padres National Forest and near Sespe Condor Sanctuary, where anglers can catch bass, bluegill, catfish, crappie, trout, perch, and sunfish (Lake Piru Recreation Area 1998).
- Pyramid Lake, within Pyramid Lake Recreation Area and part of the Angeles National Forest, where anglers can catch bluegill; catfish; crappie; largemouth, smallmouth, and striped bass; and trout (FishingNetwork.net 2004).
- Silverwood Lake, adjoining Silverwood Lake State Recreation Area, San Bernardino National Forest, and the Pacific Crest Trail, where anglers can catch bass, bluegill, catfish, perch, silver salmon, and trout (FishingNetwork.net 2007).

Anglers may purchase a Second-Rod Stamp that is valid only in lakes, reservoirs, and the Colorado River District (California DFG 2007f).

Table D-3 compares several attractive substitute freshwater fishing sites. Table D-4 lists the site characteristics of additional substitute freshwater fishing sites and their characteristics.

Table D-3
Comparison of Substitute Freshwater Fishing Sites

Water Bodies	Freshwater Bass	Bluegill	Catfish	Crappie	Salmon	Trout	Boat Ramp(s)	Noteworthy Facts
Freshwater								
Big Bear Lake	•	•	•		•	•	•	Within San Bernardino National Forest. Marinas adjoin lake. Eight boat ramps are available.
Diamond Valley Lake	•	•	•	•		•	•	Fishing tournaments are held at this lake.
Lake Piru	•	•	•	•		•	•	Within the Los Padres National Forest and near Sespe Condor Sanctuary.
Pyramid Lake	•	•	•	•		•	•	Within Pyramid Lake Recreation Area and part of Angeles National Forest.
Silverwood Lake	•	•	•		•	•	•	Adjoins Silverwood Lake State Recreation Area, San Bernardino National Forest, and Pacific Crest Trail.

Sources: DeLorme (2005); Jones (undated); Sportfishingreport.com (2007); San Diego Sportfishing Council (undated); Bigbear.us (2005); Metropolitan Water District of Southern California (undated); Lake Piru Recreation Area (1998); FishingNetwork.net (2004); FishingNetwork.net (2007)

Table D-4
Site Characteristics of Substitute Freshwater Fishing Sites

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Alondra Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Amargosa Creek		Fishing	Trout	
Anaheim Lake	75 acres	Fishing	Bluegill, carp, catfish, largemouth bass, rainbow trout	
Angler's Lake	7 acres	Fishing	Bass, bluegill, catfish, trout	
Appollo Park Lakes	26 acres	Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Ballona Creek		Fishing, boating, wildlife watching		
Barrett Lake	811 acres	Restricted entry. Catch-and-release largemouths. Fishing, boating, canoeing, kayaking, tubing.	Black and white crappie, bluegill, bullhead, catfish, Florida-strain and largemouth bass	
Bear Creek	9 miles	Fishing	Trout	
Belvedere Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Big Bear Lake	3,000 acres	Within San Bernardino National Forest. Fishing, boating, boat ramps, boat rentals, marinas, sailing, water skiing, jet skiing, camping, swimming.	Bluegill, brown and rainbow trout, catfish, crappie, largemouth bass, silver salmon	8
Big Rock Creek		Adjoins Big Rock Creek Wildlife Sanctuary. Fishing, camping.	Trout	
Bouquet Canyon Creek		Fishing	Trout	
Bouquet Reservoir		Fishing	Trout	
California Aqueduct		Fishing	Bass, bluegill, catfish, crappie, green sunfish, striped bass	
Cachuma Lake	3,000 acres	Part of Cachuma Lake Recreation Area. Fishing, fishing derbies, boating, boat ramp, regattas, hiking, lake cruises, camping, nature programs, cabins, marina, playgrounds, family fun center, nature center.	Bluegill, channel catfish, crappie, largemouth and smallmouth bass, rainbow trout, redear sunfish	1
Carr Park Lake	11 acres	Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Castaic Lake (Upper and Lower)	2,235 acres	Part of Castaic Lake State Recreation Area and Angeles National Forest. Fishing, boating, boat ramp, boat rental, marina, sailing, jet skiing, water skiing, boat rental in upper lake, hiking, biking, picnicking, playgrounds, swimming in lower lake.	Black, white crappie; bluegill; carp; channel catfish, largemouth, smallmouth, and striped bass; rainbow trout	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Centennial Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Cerritos Park Lake		Fishing, picnicking, playground, ball diamonds	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Cogswell Reservoir		Part of Angeles National Forest. Fishing.		
Corona Lake		Fishing, boating, boat ramp, boat rentals, tubing.	Bass, catfish, tilapia, trout	1
Cottonwood Lake		Fishing	Bass, bluegill, catfish, trout	
Cucamonga-Guasti Park Lakes		Fishing, swimming, picnicking, playground, volleyball, horseshoe pits, picnicking	Bass, catfish, trout	
Deep Creek	36 miles	Fishing, swimming	Trout	
Diamond Valley Lake	4,500 acres	Fishing, boating, boat ramp, boat rentals, fishing tournaments	Blue and channel catfish, bluegill, crappie, Florida and smallmouth bass, green and redear sunfish, rainbow trout	1
Dixon Lake	70 acres	Fishing, camping, picnicking	Black crappie, bluegill, channel catfish, Florida bass, rainbow trout	
Doane Pond	3 acres	Within Palomar Mountain State Park. Fishing, camping, hiking, picnicking.	Bluegill, bullhead, catfish, rainbow trout	
Downy Wilderness Park Ponds		Fishing, picnicking, playground, ball diamonds	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Echo Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
El Capitan Reservoir	1,562 acres	Fishing, boating, boat ramp, boat rentals, tubing, picnicking	Blue and channel catfish, bluegill, bullhead, carp, crappie, Florida bass, green sunfish	1
El Dorado Park Lakes		Fishing, picnicking, playground, ball diamonds, hiking, nature center	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Elizabeth Lake	35 acres	Part of Angeles National Forest. Fishing, boating, boat ramp, picnicking.	Bass, bluegill, catfish, crappie, trout	1
Glen Helen Park Lake		Fishing, swimming, water slides, hiking, camping, hiking, volleyball, picnicking	Channel catfish, largemouth bass, trout	
Green Valley Lake	9 acres	Fishing, non-motorized boating, boat rental, hiking	Bass, catfish, crappie, rainbow trout	
Hansen Dam Lake	9 acres	Fishing, boating, boat ramp	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Harbor Park Lake[a]		Fishing, boating, boat ramp, picnicking	Carp	1
Hesperia Lake	7 acres	Fishing, camping, picnicking	Bluegill, carp, catfish, largemouth bass, sturgeon, trout	
Hollenbeck Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Huntington Park Lake		Fishing, playground, picnicking, ballfields	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Irvine Lake	750 acres	Fishing, boating, boat ramp, boat rentals, marina, camping, picnicking	Blue and channel catfish; bluegill; brook, brown, California golden, and rainbow trout; crappie; largemouth bass; redear sunfish; sturgeon; wiper	1
Jackson Lake	7 acres	Part of Angeles National Forest. Fishing, boating for non-motorized craft, picnicking.	Bluegill, rainbow trout Trout were stocked during the week of 9/17/2007.	
Jenks Lake	10 acres	Fishing, fishing pier, non-motorized boating, swimming, hiking, camping, picnicking	Bluegill, catfish, largemouth bass, rainbow trout, redear sunfish	
Jess Ranch Lakes		Fishing, tubing (bass lake) (privately owned)	Bluegill, bass, catfish, trout	
John Ford Park Lake		Fishing	Catfish, rainbow trout	
Kenneth Hahn Park Lake		Fishing, picnicking, trails, playgrounds, athletic fields	Bluegill, catfish, largemouth bass, rainbow trout	
Laguna Niguel Lake	44 acres	Fishing, boating, boat rental, tubing	Black and white crappie, bluegill, channel catfish, Florida and largemouth bass, rainbow trout	
Lake Casitas	2,700 acres	Adjoins Los Padres National Forest. Fishing, boating, boat ramps, picnicking.	Bluegill, catfish, crappie, Florida and largemouth bass, perch, redear sunfish, trout	2
Lake Cahuilla		Within Lake Cahuilla County Park. Fishing, non-motorized boating, camping, picnicking, horseback riding, hiking.	Bluegill, channel and flathead catfish, largemouth and striped bass, rainbow trout	
Lake Cuyamaca	110 acres	Fishing, boating, boat ramps, boat rental, camping, picnicking, wildlife viewing	Bluegill, channel catfish, crappie, Florida and smallmouth bass, perch, sturgeon, trout	2
Lake Elsinore	3,300 acres	Adjoins Lake Elsinore State Park. Fishing, boating, boat ramps, water skiing, jet skiing, swimming, camping.	Bluegill, carp, catfish, crappie, striped bass	4

[a]A fish consumption advisory attributable to DDT and chlordane has been issued for Harbor Park Lake.

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Lake Evans	86 acres	Part of Buena Vista Aquatic Recreational Area. Fishing, sailing, boating, camping, bicycling, fishing derbies.	Bass, bluegill, carp, catfish, rainbow trout	
Lake Fulmer	3 acres	Fishing, tubing, swimming, picnicking	Bluegill, catfish, largemouth bass, rainbow trout	
Lake Gregory	120 acres	Within Lake Gregory Regional Park. Fishing, non-motorized boating, boat rental, tubing, sail boarding, picnicking, swimming, basketball, volleyball, hiking	Bass, brown and rainbow trout, bullhead, catfish, crappie	
Lake Hemet	420 acres	Within San Bernardino National Forest. Fishing, boating, boat ramp, boat rental, camping.	Bass, bluegill, catfish, rainbow trout	1
Lake Henshaw		Within Cleveland National Forest. Fishing, boating, boat ramps, boat rental, camping, cabins.	Bass, bluegill, channel catfish, crappie, rainbow trout	2
Lake Hodges	1,234 acres	Fishing, boating, boat ramp, sailing, tubing, biking, horseback riding, picnicking	Bluegill, bullhead, carp, channel catfish, crappie, Florida-strain largemouth bass	1
Lake Jennings	85 acres	Within Lake Jennings County Park. Near three other county parks. Fishing, boating, boat ramp, boat rentals, camping, hiking, picnicking, playground, horseshoe pits, nature trail.	Blue and channel catfish, bluegill, crappie, largemouth bass, rainbow trout	1
La Mirada Park Lake		Fishing, playgrounds, tennis and handball courts, fishing derbies	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Lake Morena	220 acres	Within Lake Morena County Park. Fishing, boating, boat ramp, boat rental, camping.	Bluegill, crappie, catfish, German brown and rainbow trout, largemouth bass	1
Lake Perris	1,800 acres	Within Lake Perris State Recreation Area. Fishing, boating, boat ramps, boat rental, horseback riding, stables, camping, picnicking, hunting, museum.	Alabama spotted and largemouth bass, bluegill, bullhead, carp, channel catfish, crappie, crayfish, green and redear sunfish, rainbow trout	3
Lake Piru	1,200 acres	Within the Los Padres National Forest and near Sespe Condor Sanctuary. Fishing, boating, boat ramp, boat rentals, marina, water skiing, camping, swimming, hiking, wildlife watching.	Bass, blue and channel catfish, bluegill, brown and rainbow trout, crappie, perch, redear sunfish	1
Lake Poway	60 acres	Fishing, boating, boat rental, sailing, hiking, camping, picnicking, volleyball, softball, horseshoe pits, horseback riding	Bluegill, channel catfish, Florida bass, rainbow trout	

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Lake Sherwood		Adjoins Santa Monica Mountains Recreation Area		
Lake Webb	873 acres	Part of Buena Vista Aquatic Recreational Area. Fishing, boating, boat ramps, jet skiing, camping, bicycling.	Trout	3
Lake Wohlford	146 acres	Fishing, boating, boat ramp, boat rental, camping	Black crappie, bluegill, channel catfish, Florida bass, rainbow trout	1
Legg Lake		Fishing, picnicking, softball fields, bicycling	Bass, bluegill, catfish, crappie, rainbow trout	
Little Rock Creek		Fishing	Trout	
Little Rock Reservoir	150 acres	Part of Angeles National Forest. Fishing, boating, boat ramp, picnicking.	Catfish; German brown, Kamloops, and rainbow trout	1
Lincoln Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Los Angeles River		Fishing	Yellowfin croaker	
Loveland Reservoir		Fishing	Bluegill, catfish, largemouth bass, redear sunfish	
Lytle Creek		Fishing	Trout	
Earvin "Magic" Johnson Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Malibu Creek		Within Malibu Creek State Park. Fishing, swimming, hiking, wildlife watching, horseback riding, camping, picnicking, visitor center.	Trout	
Mile Square Regional Park Lakes		Fishing, picnicking, community park, wilderness area, golfing, ball diamonds, archery, paddle boats	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Mill Creek		Fishing, beach	Rockfish, surfperch	
Miramar Reservoir	162 acres	Fishing, boating, boat ramp, boat rental, marina, tubing, bicycling, jogging, walking, roller blading, picnicking	Bluegill, channel catfish, Florida bass, redear sunfish, trout Trophy-size bass have been caught at Miramar	1
Mojave Narrows Lake		Part of Mojave Narrows Regional Park. Fishing, camping, hunting, horseback riding.	Bass, channel catfish, trout	
Murray Reservoir	171 acres	Fishing, boating, boat ramp, bicycling, jogging, walking, picnicking	Black crappie, bluegill, channel catfish, Florida bass, trout	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Oso Reservoir	175 acres	Adjoins O'Neill Regional Park. Fishing, boating, canoeing, rowing, boat rentals, tubing, marina, camping.	Bass	
Otay Lake (Upper and Lower)	1,100 acres (Lower) 20 acres (Upper)	Fishing, boating, boat ramp, boat rental, tubing, picnicking. Tubing and wading allowed in Upper Otay.	Lower: black and white crappie; bluegill; bullhead; blue, channel, white catfish; Florida bass. Angler caught state-record bluegill (3 lbs., 8 oz.) at Lower Otay Lake.	1
Peck Road Water Conservation Park	80 acres	Fishing, picnicking	Bluegill, bullhead, channel catfish, crappie, largemouth bass, rainbow trout	
Perris Reservoir	2,250 acres	Fishing, boating, boat ramps, water skiing, jet skiing, tubing, swimming, camping	Alabama spotted and largemouth bass, bluegill, channel catfish, crappie, rainbow trout	3
Piru Creek		Fishing	Rainbow trout	
Prado Lake	56 acres	Fishing, non-motorized boating, boat ramp, boat rental, camping	Bluegill, bullhead, carp, catfish, largemouth bass, trout	1
Puddingstone Lake	250 acres	Fishing, boating, boat ramp, boat rental, sailing, water skiing, jet skiing, camping	Bluegill, channel catfish, crappie, largemouth bass, perch, rainbow trout	1
Pyramid Lake	1,297 acres	Within Pyramid Lake Recreation Area and part of Angeles National Forest. Fishing, boating, boat ramp, jet skiing, picnicking.	Bluegill; catfish; crappie; largemouth, smallmouth, and striped bass; trout	1
Quail Lake		Fishing.	Catfish, largemouth and striped bass	
Ralph Clark Park Lake		Part of Ralph B. Clark Regional Park. Fishing, picnicking, playgrounds, ballfields.	Bluegill, catfish, largemouth bass, rainbow trout	
Rancho Simi Park Lake	2.5 acres	Fishing, tennis courts, picnicking	Bluegill, carp, catfish, largemouth bass, rainbow trout	
Reflection Lake	17 acres	Fishing, boating, camping, playground, recreation area (privately owned)	Bass, bluegill, catfish, trout	
San Dieguito River	55 miles	Adjoins San Dieguito River Park. Fishing, hiking.		

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
San Felipe Creek		Part of San Felipe Creek Ecological Reserve. Fishing, hiking, hunting, wildlife viewing.	Green sunfish, tilapia	
San Gabriel Reservoir		Part of Angeles National Forest. Fishing, picnicking.	Rainbow trout	
San Gabriel River		Western portion is part of Angeles National Forest. Fishing, fishing platforms, canoeing, kayaking, hiking, biking, wildlife watching.	Rainbow trout, steelhead	
San Jacinto River		Fishing, hiking, hunting, camping, picnicking, wildlife watching	Trout	
San Luis Rey River		Fishing, biking	Trout	
San Vicente Reservoir	1,069 acres	Fishing, boating, boat ramp, boat rental, marina, water skiing, tubing, picnicking	Blue, channel, and white catfish; bluegill; bullhead; crappie; Florida bass; green sunfish; trout. Angler caught state-record blue catfish (101 lbs.) at San Vicente Reservoir.	1
Santa Ana River Lakes		Fishing, boating, boat ramp, boat rental (privately owned)	Bass, bluegill, catfish, crappie, sturgeon, trout, wiper. Angler caught state-record channel catfish (52 lbs., 10 oz.) at Santa Ana River Lakes.	1
Santa Ana River, South Fork		Fishing	Green sunfish, trout	
Santa Fe Dam Lake	70 acres	Fishing, electric-powered boating, boat ramp, marina	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	1
Santa Paula Creek		Fishing		
Santee Lakes (four)	7–11 acres	Fishing, non-powered boat rental, camping, picnicking, playgrounds, volleyball, horseshoe pits	Bass, bluegill, channel catfish, trout	
Santiago Creek		Within Santiago Oaks Regional Park and Irvine Regional Park. Fishing, hiking.		
Sespe Creek		Fishing, hiking, camping	Rainbow trout, steelhead	
Silverwood Lake	980 acres	Adjoins Silverwood Lake State Recreation Area, San Bernardino National Forest, and Pacific Crest Trail. Fishing, boating, boat ramp, boat rental, marina, wind surfing, camping, picnicking, swimming, wildlife viewing, biking, hiking, nature trails, visitor center.	Bluegill, brown and rainbow trout, channel catfish, largemouth and striped bass, perch, silver salmon	1

Table D-4, continued

Water Body	Miles/Acres	Site Characteristics	Sport Fish	# Boat Ramps
Skinner Lake	1,200 acres	Fishing, boating, boat ramps, boat rental, marina, sailing, horseback riding, camping	Bluegill, carp, catfish, crappie, largemouth and striped bass, perch, trout	2
Sutherland Reservoir	557 acres	Fishing, boating, boat ramp, tubing, picnicking, waterfowl and turkey hunting	Blue and channel catfish, bluegill, bullhead, carp, crappie, Florida bass, redear sunfish	1
Sweetwater Reservoir		Fishing (limited)	Bass, bluegill, bullhead, carp, catfish, perch, rock bass	
Tri-City Park Lake		Fishing	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Vail Lake		Fishing, boating, boat ramp, boat rental, marina, camping	Bass, bluegill, catfish, crappie, trout	1
Yorba Regional Park Lakes		Fishing, picnicking, playgrounds, ballfields	Bluegill, carp, catfish, crappie, largemouth bass, rainbow trout	
Yucaipa Regional Park Lakes		Within Yucaipa Regional Park. Fishing, boating, swimming, picnicking, camping, playground, volleyball, horseshoe pits.	Bass, catfish, rainbow trout	

Sources: DeLorme (2005); Sportfishingreport.com (2007); California Department of Fish and Game (DFG) 2007a, 2007b, 2007c, 2007d, 2007e, 2007f; San Diego Sportfishing Council (undated); Bigbear.us (2005); Metropolitan Water District of Southern California (undated); Lake Piru Recreation Area (1998); FishingNetwork.net (2004, 2007)

References

1. Bigbear.us. 2005. Big Bear Lake, California. Available at http://www.bigbear.us/fishreport.html. Retrieved on September 27, 2007.
2. California Department of Fish and Game, Fisheries Programs Branch. 2003. California trophy black bass program. Available at http://www.dfg.ca.gov/fish/documents/TBB_App.pdf. Retrieved on September 20, 2007.
3. California Department of Fish and Game. 2007a. State inland water record fish policy. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/SIWR/SIWR_Policy.asp. Retrieved on September 27, 2007.
4. California Department of Fish and Game. 2007b. Welcome to the California fishing passport web site. Available at http://www.dfg.ca.gov/fishingpassport/. Retrieved on September 27, 2007.
5. California Department of Fish and Game. 2007c. Trophy black bass certificate program. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/TBB/index.asp. Retrieved on September 27, 2007.

6. California Department of Fish and Game. 2007d. Public health advisories on fish consumption. Available at http://www.dfg.ca.gov/marine/fishcon1.asp. Retrieved on September 14, 2007.
7. California Department of Fish and Game. 2007e. California heritage trout challenge. Available at http://www.dfg.ca.gov/fish/Fishing/Recognition/HTC/HTC_Policy.asp. Retrieved on September 27, 2007.
8. California Department of Fish and Game. 2007f. 2007–2008 California Freshwater Sport Fishing Regulations. Available at http://www.dfg.ca.gov/regulations/07-08-inland-fish-regs.pdf. Retrieved on July 31, 2007.
9. DeLorme. 2005. Southern and Central California Atlas and Gazetteer. DeLorme, Yarmouth, ME.
10. FishingNetwork.net. 2004. Pyramid Lake. Available at http://fishingnetwork.net/socal/pmid.htm. Retrieved on September 27, 2007.
11. FishingNetwork.net. 2007. Silverwood Lake. Available at http://fishingnetwork.net/socal/silver.htm. Retrieved on September 27, 2007.
12. Lake Piru Recreation Area. 1998. You'll love the Lake Piru recreation area. Available at http://www.lake-piru.org/. Retrieved on September 27, 2007.
13. Metropolitan Water District of Southern California. Undated. Diamond Valley Lake. Available at http://www.dvlake.com/. Retrieved on September 27, 2007.
14. San Diego Sportfishing Council. Undated. San Diego sportfishing online. Available at http://www.sportfishing.org/. Retrieved on September 27, 2007.
15. Sportfishingreport.com. 2007. Catch. Available at http://www.sportfishingreport.com/pages/landingdetail.php?landing_id=12. Retrieved on August 6, 2007.

E
SUPPLEMENTAL INFORMATION FOR RECREATION MODEL

Table E-1
Ocean Fishing Sites: Beaches, Boat Ramps, and Piers

County	Place Name	Type	Latitude	Longitude
Santa Barbara	Carpinteria State Beach	Beach	34°25'00"	119°30'00"
Ventura	Emma Wood State Beach	Beach	34°16'51"	119°20'00"
	San Buenaventura State Beach	Pier	34°15'00"	119°15'00"
	San Buenaventura State Beach	Beach	34°15'00"	119°15'00"
	Peninsula Beach	Beach	34°15'00"	119°15'00"
	Peninsula Beach	Boat ramp	34°15'00"	119°15'00"
	McGrath State Beach	Beach	34°15'00"	119°15'00"
	McGrath State Beach	Boat ramp	34°15'00"	119°15'00"
	Mandalay Beach	Beach	34°10'00"	119°15'00"
	Hollywood Beach	Beach	34°10'00"	119°15'00"
	Oxnard Beach	Beach	34°10'00"	119°15'00"
	Oxnard Beach	Boat ramp	34°10'00"	119°15'00"
	Oxnard Beach	Boat ramp	34°10'00"	119°15'00"
	Port Hueneme Beach Park	Beach	34°10'00"	119°10'00"
	Port Hueneme Beach Park	Pier	34°10'00"	119°10'00"
Los Angeles	Leo Carillo State Beach	Beach	34°05'00"	118°55'00"
	Robert H. Meyer Memorial State Beach	Beach	34°00'00"	118°55'00"
	Point Dume State Beach	Beach	34°00'00"	118°50'00"
	Paradise Cove	Pier	34°00'00"	118°45'00"
	Paradise Cove	Beach	34°00'00"	118°45'00"
	Escondido Beach	Beach	34°00'00"	118°45'00"
	Corral Beach	Beach	34°00'00"	118°45'00"
	Surfrider Beach (Malibu Lagoon Beach)	Beach	34°00'00"	118°40'00"
	Malibu Pier	Pier	34°00'00"	118°40'00"
	Malibu Pier	Boat ramp	34°00'00"	118°40'00"
	Las Tunas Beach	Beach	34°00'00"	118°35'00"
	Topanga Beach	Beach	34°00'00"	118°35'00"
	Will Rogers State Beach	Beach	34°00'00"	118°35'00"

Table E-1, continued

County	Place Name	Type	Latitude	Longitude
Los Angeles	Santa Monica Beach	Beach	34°00'00"	118°30'00"
	Santa Monica Municipal Pier	Pier	34°00'00"	118°30'00"
	Santa Monica Municipal Pier	Boat ramp	34°00'00"	118°30'00"
	Ocean Park	Beach	34°00'00"	118°30'00"
	Santa Monica Mountains National Recreation Area	Beach	34°00'00"	118°30'00"
	Venice Beach	Beach	34°00'00"	118°30'00"
	Venice Fishing Pier	Pier	34°00'00"	118°30'00"
	Marina Del Ray Harbor	Pier	34°00'00"	118°25'00"
	Marina Del Ray Harbor	Boat ramp	34°00'00"	118°25'00"
	Marina Del Ray Harbor	Boat ramp	34°00'00"	118°25'00"
	Playa Del Ray	Beach	33°55'00"	118°30'00"
	Playa Del Ray	Boat ramp	33°55'00"	118°30'00"
	Dockweiler State Beach	Beach	33°55'00"	118°25'00"
	Manhattan Beach	Beach	33°55'00"	118°25'00"
	Manhattan Beach Municipal Pier	Pier	33°55'00"	118°25'00"
	Manhattan Beach Municipal Pier	Boat ramp	33°55'00"	118°25'00"
	Hermosa Beach	Beach	33°50'00"	118°25'00"
	Hermosa Beach Municipal Pier	Pier	33°50'00"	118°25'00"
	Redondo Beach Municipal Pier	Pier	33°50'00"	118°25'00"
	Redondo Beach Municipal Pier	Boat ramp	33°50'00"	118°25'00"
	Redondo Sportfishing Pier	Pier	33°50'00"	118°25'00"
	Redondo Beach	Beach	33°50'00"	118°25'00"
	Palo Verdes Shoreline Park	Park	33°45'00"	118°20'00"
	Royal Palms State Beach	Beach	33°45'00"	118°20'00"
	Cabrillo Beach Park	Beach	33°40'00"	118°15'00"
	Cabrillo Beach Park	Boat ramp	33°40'00"	118°15'00"
	Cabrillo Beach Park	Boat ramp	33°40'00"	118°15'00"
	Cabrillo Fishing Pier	Pier	33°40'00"	118°15'00"
	Queensway Bay	Boat ramp	33°45'00"	118°10'00"
	Queensway Bay	Boat ramp	33°45'00"	118°10'00"
	Belmont Pier	Pier	33°45'00"	118°10'00"
	Belmont Shore	Beach	33°45'00"	118°10'00"
	Belmont Shore	Boat ramp	33°45'00"	118°10'00"
	Alamitos Bay	Boat ramp	33°45'00"	118°05'00"
	Alamitos Bay	Boat ramp	33°45'00"	118°05'00"
	Alamitos Bay	Boat ramp	33°45'00"	118°05'00"
Orange	Seal Beach	Beach	33°45'00"	118°05'00"
	Seal Beach Fishing Pier	Pier	33°45'00"	118°05'00"

Table E-1, continued

County	Place Name	Type	Latitude	Longitude
Orange	Sunset Beach	Pier	33°45'00"	118°05'00"
	Sunset Beach	Beach	33°45'00"	118°05'00"
	Sunset Beach	Boat ramp	33°45'00"	118°05'00"
	Sunset Beach	Boat ramp	33°45'00"	118°05'00"
	Trinidad Island	Pier	33°45'00"	118°05'00"
	Bolsa Chica State Beach	Beach	33°40'00"	118°05'00"
	Huntington Beach	Beach	33°40'00"	118°00'00"
	Huntington Beach	Boat ramp	33°40'00"	118°00'00"
	Huntington Harbor	Pier	33°40'00"	118°00'00"
	Huntington State Beach	Beach	33°40'00"	118°00'00"
	Newport Beach	Beach	33°35'00"	117°55'00"
	Newport Beach Pier	Pier	33°35'00"	117°55'00"
	Newport Harbor	Boat ramp	33°35'00"	117°55'00"
	Newport Harbor	Boat ramp	33°35'00"	117°55'00"
	Balboa Beach	Beach	33°35'00"	117°55'00"
	Balboa Beach	Pier	33°35'00"	117°55'00"
	Corona Del Mar State Beach	Beach	33°35'00"	117°52'30"
	Crystal Cove State Park	Beach	33°35'00"	117°50'00"
	Laguna Beach	Beach	33°30'00"	117°50'00"
	Aliso Point County Park	Pier	33°30'00"	117°45'00"
	Doheny State Beach	Beach	33°30'00"	117°40'00"
	Doheny State Beach	Boat ramp	33°30'00"	117°40'00"
	Capistrano Beach	Beach	33°25'00"	117°40'00"
	San Clemente Municipal Pier	Pier	33°25'00"	117°40'00"
	San Clemente State Beach	Beach	33°25'00"	117°35'00"
San Diego	San Onofre State Beach	Beach	33°25'00"	117°35'00"
	Avalon Bay Fishing Pier	Pier	33°20'00"	117°20'00"
	Oceanside Harbor	Boat ramp	33°13'00"	117°25'00"
	Oceanside Harbor	Pier	33°13'00"	117°25'00"
	Oceanside Pier	Pier	33°13'00"	117°20'00"
	Carlsbad State Beach	Beach	33°10'00"	117°20'00"
	South Carlsbad State Beach	Beach	33°05'00"	117°20'00"
	Leucadia State Beach	Beach	33°05'00"	117°20'00"
	Moonlight State Beach	Beach	33°05'00"	117°20'00"
	San Elijo State Beach	Beach	33°00'00"	117°15'00"
	Cardiff State Beach	Beach	33°00'00"	117°15'00"
	Solana Beach	Beach	33°00'00"	117°15'00"
	Torrey Pines State Beach	Beach	32°55'00"	117°15'00"
	Torrey Pines State Reserve	Beach	32°55'00"	117°15'00"
	Crystal Pier	Pier	32°50'00"	117°15'00"
	Fiesta Bay	Boat ramp	32°50'00"	117°15'00"
	Fiesta Bay	Boat ramp	32°50'00"	117°15'00"

Table E-1, continued

County	Place Name	Type	Latitude	Longitude
San Diego	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Mission Bay	Boat ramp	32°45'00"	117°15'00"
	Ocean Beach Fishing Pier	Pier	32°45'00"	117°15'00"
	Embarcadero Marina Park	Pier	32°40'00"	117°15'00"
	Embarcadero Marina Park	Boat ramp	32°40'00"	117°15'00"
	G Street Pier	Pier	32°40'00"	117°10'00"
	Shelter Island Fishing Pier	Pier	32°40'00"	117°10'00"
	Silver Strand	Boat ramp	32°40'00"	117°10'00"
	National City Launching Ramp	Boat ramp	32°40'00"	117°05'00"
	National City Launching Pier	Pier	32°40'00"	117°05'00"
	Silver Strand State Beach	Beach	32°35'00"	117°10'00"
	Chula Vista Boat Ramp	Boat ramp	32°35'00"	117°05'00"
	Imperial Beach	Pier	32°35'00"	117°10'00"
	Imperial Beach	Beach	32°35'00"	117°10'00"
	Border Field State Park	Beach	32°30'00"	117°10'00"

ATTACHMENT 6

Site-Specific Technology Plan and Verification Monitoring Plan

ALDEN

Solving flow problems since 1894

ATTACHMENT 6

SITE-SPECIFIC TECHNOLOGY PLAN AND VERIFICATION MONITORING PLAN FOR HUNTINGTON BEACH GENERATING STATION

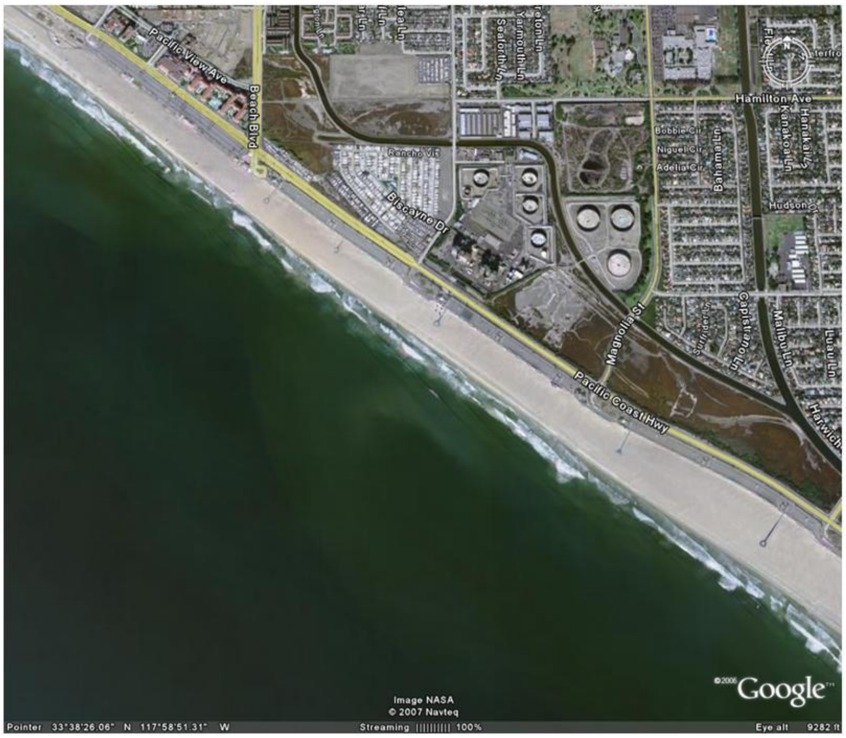


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TABLE OF CONTENTS

1.0 Introduction

AES Huntington Beach (AES) has selected Compliance Alternative 5 from the Rule and Special Provision VI.C.2(a)(5) of the NPDES permit for compliance with the 95% impingement mortality reduction standard and 90% entrainment reduction standard for Huntington Beach Generating Station (HBGS) Units 1 & 2. Units 3 & 4 are using restoration measures for compliance as discussed in Attachment 3. As discussed in the Impingement Mortality and Entrainment Characterization Study (Attachment 2), HBGS is estimating an 82% reduction in impingement mortality through use of the offshore velocity cap. However, the permit requires that HBGS achieve a 95% reduction. Due to the need to consider alternatives to provide for the 13% shortfall for impingement mortality reduction and to reduce entrainment for Units 1 & 2, AES is proposing to use site-specific standards.

The decision to use site-specific standards was based on an evaluation of the costs of alternative technologies and operational measures. Use of this alternative requires submittal of a Comprehensive Cost Evaluation Study (Attachment 4) and a Benefit Valuation Study (Attachment 5) in addition to the Site-specific Technology Plan and Verification Monitoring Plan provided in this document. The results of the comprehensive cost evaluation demonstrated that all of the feasible alternative technologies and operational measures evaluated had costs that were significantly greater than the economic benefit. The result is that the existing cooling water intake structure (CWIS) was determined to be Best Technology Available (BTA).

The regulatory requirements for this Comprehensive Demonstration Study (CDS) document are specified in the Federal Phase II Rule at §125.95(b)(6)(iii) as follows:

> (A) A narrative description of the design and operation of all existing and proposed design and construction technologies, operational measures, and/or restoration measures that have been selected in accordance with § 125.94(a)(5);
>
> (B) An engineering estimate of the efficacy of the proposed and/or implemented design and construction technologies or operational measures, and/or restoration measures. This estimate must include a site-specific evaluation of the suitability of the technologies or operational measures for reducing impingement mortality and/or entrainment (as applicable) of all life stages of fish and shellfish based on representative studies *(e.g.,* studies that have been conducted at cooling water intake structures located in the same waterbody type with similar biological characteristics) and, if applicable, site specific technology prototype or pilot studies. If restoration measures will be used, a Restoration Plan must be provided that includes the elements described in paragraph (b)(5) of this section.
>
> (C) A demonstration that the proposed and/or implemented design and construction technologies, operational measures, and/or restoration measures achieve an efficacy that is as close as practicable to the applicable performance standards of § 125.94(b) without resulting in costs significantly greater than either the costs considered by the Administrator for a like facility in establishing the applicable performance standards, or

as appropriate, the benefits of complying with the applicable performance standards at the facility; and,

(D) Design and engineering calculations, drawings, and estimates prepared by a qualified professional to support the elements of the Plan.

Section 2.0 provides the information required by sections (A) and (D) while Section 3.0 provides an assessment of the biological efficacy of the existing design and operations to meet EPA's impingement mortality and entrainment reduction performance standards responsive to sections (B) and (C).

For verification monitoring, the Rule requires that a plan for a minimum of two years of monitoring be submitted. The specific requirements for the plan are provided in §125.95(b)(7) of the Phase II Rule and include:

(i) Description of the frequency and duration of monitoring, the parameters to be monitored, the basis for determining the parameters, and the frequency and duration for monitoring. The parameters selected and duration and frequency of monitoring must be consistent with any methodology for assessing success in meeting applicable performance standards in the Technology Installation and Operation Plan as required by paragraph (b)(4)(ii) of this section.

(ii) A proposal on how naturally moribund fish and shellfish that enter the CWIS would be identified and taken into account in assessing success in meeting the performance standards in § 125.94(b).

(iii) A description of the information to be included in a bi-annual status report to the Director.

Section 4.0 provides the proposed Verification Monitoring Plan.

2.0 Existing Technology and Operations

2.1 Intake Technology Description

The existing intake at HBGS is located about 1,500 ft offshore in 30 ft of water, as shown on Figure 1. The intake is fitted with a velocity cap that is 33 ft by 28 ft with a 5 ft high opening, as shown on Figure 2. For a detailed description of the source waterbody description, CWIS, and cooling water system (CWS) see the §122.21(r) (2), (3), and (5) information (Attachment 1) and the previously submitted Proposal for Information Collection (PIC). This type of intake is common at facilities with offshore intakes. A detailed discussion of the velocity cap performance is provided in the Impingement Mortality and Entrainment Characterization Study (Attachment 2). The velocity cap redirects the intake flow from a vertical direction to a horizontal direction. Current science indicates that fish are able to sense horizontal changes in velocity better than they can sense vertical gradients. In addition, fish are better able to detect and avoid rapid increases or decreases in flow velocity than more gradual changes. The velocity at the face of the velocity cap is about 1.3 ft/sec which is substantially higher than the surrounding ambient currents of approximately 0.3 to 0.7 ft/sec. This difference in velocity magnitude should elicit an avoidance response among many of the impingeable organisms.

2.2 Operational Procedures

Heat treatment is used to control biofouling. The heat treatment raises the water temperature to 105º F to control biofouling in the intake structure and condenser. This treatment is conducted approximately every six to eight weeks.

2.3 Operation and Maintenance

The traveling water screens are inspected each shift. Heat treatment is conducted as needed for plant operations. All operations are recorded on daily status sheets. All equipment is serviced and maintained based on the equipment manufacturer's recommendation.

2.4 Discussion

An assessment of alternative intake technologies and operational options was conducted (Attachment 4, Appendix A). The biological efficacy of the feasible options and their costs were also determined (Attachment 4, Appendix E). Based on the results of the Comprehensive Cost Evaluation Study, the existing cooling water intake structure was determined to be BTA.

3.0 Biological Efficacy of Existing Technology and Operations

The level of performance that is currently achieved at HBGS is presented in the Impingement Mortality and Entrainment Characterization Study (Attachment 2). Early studies of velocity caps have indicated that they can reduce impingement by about 90% (Weight 1958). The results of the Huntington Beach Generating Station Velocity Cap Effectiveness Study carried out by a team of researchers from the University of Washington, College of Fisheries, estimated an 82% reduction in impingement mortality associated with the design and operation of the velocity cap at HBGS (Thomas, et. al. 1980). The effectiveness estimated from this study was verified by more recent studies at another southern California facility. The estimated 82% reduction in impingement mortality provided by the velocity cap is within the performance standard range proposed in the Federal Phase II Rule. However, no entrainment reduction credit is assumed for Units 1&2.

As discussed in the Comprehensive Cost Evaluation Study, feasible alternative impingement mortality and entrainment reduction technologies and operational measures were evaluated and none were determined to have a cost that was not significantly greater than the economic benefits that would be provided. Therefore, it was determined that the existing cooling water intake structure is as close as practicable to meeting the applicable performance standards in the NPDES permit at this time and is BTA.

4.0 Verification Monitoring Program

Estimates of velocity cap efficacy for HBGS are based on site-specific studies using reverse flow. This is the best method currently available for evaluating the efficacy of this technology in estimating the impingement mortality reduction benefit. However, verification testing is not recommended due to the numbers of fish that would be sacrificed while conducting this type of study. In addition, verification tests would not be able to provide the same level of accuracy provided in the previous studies because chlorine injections were used to clear the tunnels of fishes between trials in the previous study that would not be permitted under the current NPDES permit. Similarly, since no additional fish protection technologies and operational measures have been identified at this time for entrainment, no biologically-based verification monitoring has been proposed.

HBGS will continue to operate as it currently does during the CDS submittal process. If the California Regional Water Quality Control Board – Santa Ana Region (the Board) approves this portion of the CDS, AES will continue to operate in this manner for the remainder of this permit cycle. No additional construction or change in operations will be needed with this option.

To demonstrate that the HBGS CWIS is in compliance, AES commits to the following practices:

- Divers will make annual inspections of the velocity cap and remove any debris that could impact its effectiveness.
- The current heat treatment for biofouling control will be continued.
- Manufacturers' recommended maintenance schedules will be followed for all CWIS components.
- The traveling water screens will be inspected daily to ensure their proper operation, clean condition and all maintenance will be completed according to the manufacturer's recommendations. Records will be maintained on the daily status sheets.
- All pump flows will be monitored to ensure that intake structures are operating within design parameters. Daily records of pump operation with flow rates will be maintained.
- A logbook will be maintained to record scheduled observations of system components to monitor proper operation.

Compliance with the above commitments will be documented in bi-annual status reports to the Director as required in §125.95(b)(7)(iii).

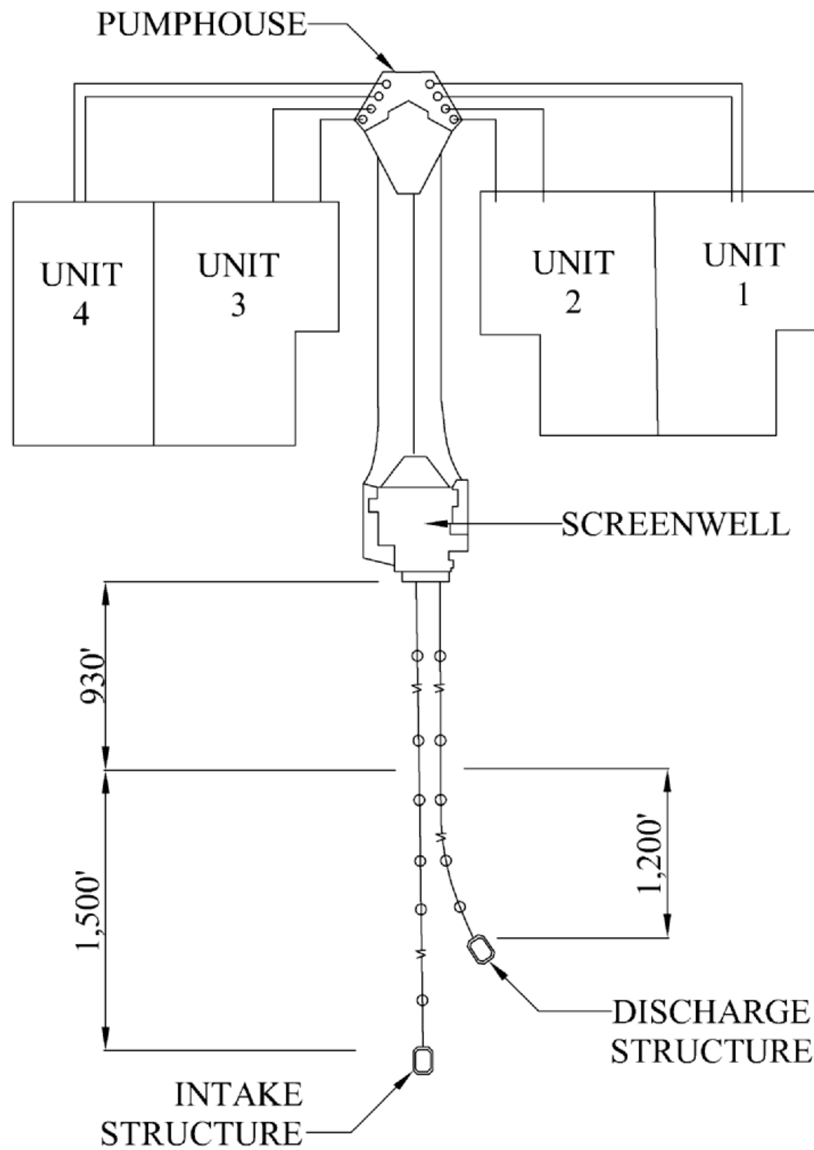

Figure 1 HBGS CWIS

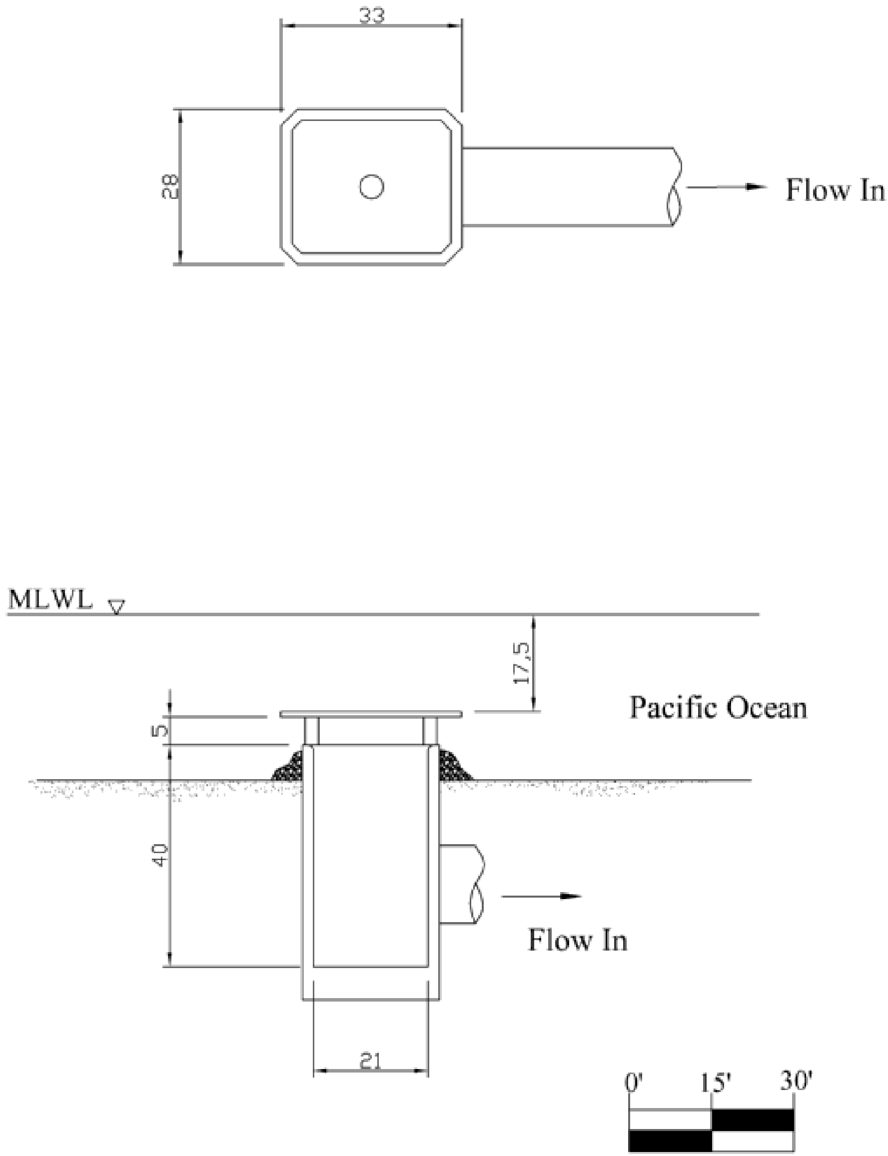

Figure 2 Velocity Cap Plan and Section

5.0 References

AES Comprehensive Demonstration Study (2007). Attachment 1 - 122.21 (r) (2), (3), (5) Report for the Huntington Beach Generating Station.

AES Comprehensive Demonstration Study (2007). Attachment 2 – Impingement Mortality and Entrainment Characterization Report for the Huntington Beach Generating Station.

AES Comprehensive Demonstration Study (2007). Attachment 3 – Restoration Plan for the Huntington Beach Generating Station.

AES Comprehensive Demonstration Study (2007). Attachment 4 – Comprehensive Cost Evaluation Report for the Huntington Beach Generating Station.

AES Comprehensive Demonstration Study (2007). Attachment 5 – Huntington Beach Generating Station Benefits Valuation Study.

Thomas, G.L., R.E. Thorne, W.C. Acker, T.B. Stables, and A.S. Kolok. 1980. The effectiveness of a velocity cap and reduced flow in reducing fish entrapment. Final report to So.Calif. Edison Co. FRI-UW-8027. 31 Dec. 1980. 22 p. plus appendices.

Weight, R.H. 1958. Ocean Cooling Water System for 800 MW Power Station. Journal of the Power Division of the American Society of Civil Engineers. Paper 1888.