Public Workshop (10/1-2/12)
Bay-Delta Workshop 2
Deadline: 9/14/12 by 12 noon

STATE OF CALIFORNIA – CALIFORNIA NATURAL RESOURCES AGENCY
EDMUND G. BROWN JR., *Governor*

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 653-5791

RECEIVED
9-14-12
SWRCB Clerk

State Water Resources Control Board
1001 I Street
Sacramento, California 95814

Via email: commentletters@waterboards.ca.gov

Subject: Bay-Delta Workshop 2 – Bay-Delta Fishery Resources

Dear Chairman Hoppin and Members of the Board:

The Department of Water Resources (DWR) appreciates, once again, the opportunity to participate in the upcoming workshop process for Phase 2 of the Bay-Delta Water Quality Control Plan (WQCP) update. To reiterate a theme voiced by DWR in the Workshop 1 proceeding, there is a significant amount of new understanding regarding the physics, chemistry and biology of the San Francisco Bay / Sacramento-San Joaquin Delta Estuary (Bay-Delta) since the Board's 2009 Staff Report. DWR will present what it believes is the most current scientific understanding on the Bay-Delta pelagic and salmonid fish species, and the benefits that will accrue from a successful implementation of the Bay Delta Conservation Plan (BDCP), should it be approved. Furthermore, DWR believes that much of what DWR discusses in this letter and attached report supplants the understanding expressed in the 2009 Staff Report.[1]

Pelagic Fish Science

To summarize the major points previously submitted by DWR with regard to pelagic fish species, the historic notion that river flows and the location of the low salinity zone are the master variables to restoration of the Bay-Delta is less than certain. Rather, DWR and other presenters demonstrated that the whole range of ecosystem stressors must be considered when pursuing solutions to restore pelagic fish species, and not focus on only flow-first regimes. For this workshop, DWR reiterates the information on pelagic fish species that it submitted for Workshop 1.

[1] DWR also directs the State Water Board's attention to its submission during the WQCP update Phase 1 NOP public comment period. DWR's May 23, 2011 submission contains relevant information on pelagic and salmonid fish science, and DWR requests that this submission be incorporated into the record for the Phase 2 process. Comments on the Revised Notice of Preparation and Notice of Additional Scoping for Potential Amendments of 2006 Water Quality Control Plan, May 23, 2011, DWR Staff Counsel Erick Soderlund. A copy of this submission can be provided to the State Water Board upon request.

Salmonid Fish Science
New information contained in the attached report on salmonid fish species includes data showing there is an overemphasis on direct losses and hypothesized indirect impacts due to SWP / CVP export operations. The science shows that exports appear to have no significant effect or only a modest contribution on salmonid survival. Also, Delta hydrology is affected by many factors. The "footprint" of exports is only one of many factors. The data shows that this "footprint" that potentially affects downstream migrating salmonids is less substantial than has been hypothesized. At the same time, there is an underemphasis on life history diversity, habitat for rearing and migrating salmonids, and the marine portion of the salmonid lifecycle.

DWR would also like to draw attention to the fact that since 1986 it has offset fish losses through the Delta Fish Agreement, also known as the "Four Pumps Agreement." This Agreement between the DWR and the Department of Fish and Game (DFG) provides for offsetting adverse fishery impacts caused by the diversion of water at the Harvey O. Banks Delta Pumping Plant. Through the Four Pumps Agreement, direct losses of Chinook salmon, steelhead, and striped bass are offset or mitigated through the funding and implementation of fish mitigation projects. DWR and DFG work closely with the Fish Advisory Committee, made up of representatives of the State Water Contractors, sport and commercial fishing groups, and environmental groups, to implement the agreement and projects funded under the agreement.

In addition to the Delta Fish Agreement, DWR entered into a subsequent agreement with DFG in 2010 known as the Fish Restoration Program Agreement (FRPA), which addresses specific habitat restoration requirements of the US Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) biological opinions (Biological Opinions) for State Water Project (SWP) and Central Valley Project (CVP) operations. FRPA is also intended to address the habitat requirements of the DFG Longfin Smelt Incidental Take Permit (ITP) for SWP Delta operations.

Also, when considering the competing requirements of the different fish species, it should be noted that Lake Oroville has a limited cold water pool. Under the existing regulatory framework, it can be difficult to meet downstream temperature requirements in the Lower Feather River. If flow requirements are changed to include a Fall X2 requirement, it would require the release of additional flows from Oroville during the time when the cold water pool is at its lowest. This will be discussed in more detail in Workshop 3. However, this issue is of sufficient importance that DWR is reiterating here that the release of these flows will, at best, make it difficult to meet both the fall X2 requirement and the downstream temperature requirements for salmonids.

BDCP

In addition to salmonid science, DWR submits comments on the benefits of the BDCP. Although BDCP is in the process of being developed, and a public review draft is not yet available, much preliminary information has been released and can be viewed on the BDCP website. The BDCP is a comprehensive approach designed to address a suite of stressors, and takes into account the occasional competing requirements of Delta resources. Flexibility in management actions to improve the Delta ecosystem is essential to adapt to future Delta conditions, especially given uncertainty in some of the science and a changing climate. BDCP relies extensively on the best available science for the development of restoration and water operations plans. It also recognizes the limitations of the current system, and responds to the needs of a changing Delta including expanding the "tool box" for creating solutions.

The State Water Board voiced some criticism to the interested parties participating in Workshop 1 regarding a lack of specific solutions offered to them. DWR understands this frustration and intends to offer in the future more specific solutions. However, at this time DWR is unsure of how to present solutions that may improve the Bay-Delta ecosystem because the workshops are designed to address discrete portions of the science. DWR believes it would be more helpful to the Board to have Delta solutions that are considered in a broader, holistic context so the Board can then balance effects and address public interest issues. Furthermore, DWR reiterates that new information will be available in the near future. Therefore, such solutions may be identified after the workshop process is complete, when new information is fully analyzed.

Thank you for consideration of these comments and the attached report and Phase 1 submission. If you have any questions, feel free to contact me at (916) 653-8045.

Sincerely,

Katherine Kelly for

Russ Stein
Acting Deputy Director

Attachment

SWRCB Workshop 2—Delta Fishery Resources

DWR Contributions

September 12, 2012

Revised December 12, 2012

1.0 Bay-Delta Fishery Resources – Salmonid Habitat, Diversity, and Management

Take Home Points:

- *Despite extensive management actions to protect and enhance Central Valley salmon, none of the populations are considered robust.*
- *We propose that Delta salmon management has not succeeded for several reasons:*
  - ***An overemphasis on direct losses and hypothesized indirect impacts due to SWP and CVP exports operations.***
    - *Although salmon losses at water diversions remain a concern, data suggests that Bay-Delta Accord and D-1641 management practices have resulted in a major reduction in juvenile salvage.*
    - *While there is evidence that inflow affects survival, exports appear to have no detectable effect or only a modest contribution. Exports is one of the many factors influencing the hydrodynamics of the Bay-Delta, and the hydrodynamic "footprint" of exports that potentially affect downstream migrating salmonids is less substantial than has been hypothesized.*
  - ***Too little emphasis on life history diversity.***
    - *There has been a major loss of life history diversity in Central Valley salmon, leading to reduced viability of the different runs.*
  - ***Too little emphasis on habitat for rearing and migrating juvenile salmonids.***
    - *Habitat limitation is likely the major problem for downstream migrating salmon. There is insufficient rearing habitat, leaving fish exposed to predators and without adequate food resources.*
    - *Due to the trapezoidal geometry of the Sacramento River and other Delta channels, increasing flows have little effect on habitat availability.*
    - *A growing body of evidence supports the importance of seasonal floodplain and tidal habitat for salmonid rearing and migration.*
  - ***An overemphasis on hatchery production to support salmon populations.***
    - *There is substantial new evidence that hatchery management practices can have adverse effects on wild salmonid populations. Recommended*

improvements to hatchery management practices have the potential to minimize these adverse effects.

   - ***Too little emphasis on the San Francisco Bay and marine portion of the life cycle.***
     - *Recent studies suggest that few migrating juvenile salmon use San Francisco Bay as rearing habitat prior to ocean entry.*
     - *Ocean survival is one of the major factors driving population trends.*
- *New tools should help to improve salmon management:*
   - *Important new developments in the use of genetics and telemetry and tagging to assist in management of Central Valley salmonids.*
   - *There is substantial uncertainty about the potential benefits of different management actions, but several new life history models represent important tools.*

Suggested near- to long-term actions:

- *Better leadership is needed for both salmonid science and management to improve integration of actions and research.*
- *Experimentally evaluate management actions which might improve survival and growth of juvenile salmonids in the Delta. Potential management actions include experimental habitat enhancements, predator removals and a trap and barge program for juvenile salmonids emigrating from the San Joaquin Basin. These and other actions should be implemented as part of an experimental design (with controls and treatments) which allows any benefits to be quantified.*
- *Continued research to investigate the importance of habitat and its link to life history diversity for salmon. Support research on the role of habitat in regulating salmon survival in the Delta, including food availability and predation.*
- *Continued studies examining how salmonids rear and migrate in the Delta*
- *Support efforts to improve hatchery management (e.g. mark 100% of hatchery fish, eliminate releases outside of natal tributaries, monitor and develop thresholds for the proportion of hatchery fish spawning on natural spawning grounds, reduce or discontinued production of some stocks)*
- *Support habitat restoration projects including the development of detailed management and monitoring plans.*
- *Support new studies on the fate of salmon in San Francisco Bay and the Pacific Ocean and potential management options.*
- *Support for alternative conveyance as called for in the BDCP*

Summary of New Information on Salmon:

Salmon remain the highest profile fish along the California coast, both because of its commercial and recreational value, as well as its cultural importance. It is therefore a major concern that adult salmon populations plummeted in recent years. Although there is evidence that adult populations are starting to rebound somewhat, there is concern about the long-term viability of several of the major salmon populations (NMFS 2009). As described in Lindley et al. (2009), the salmon collapse is attributable to both short-term and long-term issues. Consistent with many of the findings of the Lindley et al. (2009) study, we are concerned that salmon management activities have overemphasized some approaches, while substantially underestimating the importance of others. Specifically, we propose that Central Valley salmon management has not succeeded for several reasons:

- *An overemphasis on export effects:* While salmon losses remain a concern at water diversions, direct losses and concerns about indirect losses due to the SWP and CVP operations have unfortunately overshadowed other critical management issues such as habitat. Moreover, new information suggests that Bay-Delta Accord and-1641 management practices have been successful in achieving a major reduction in juvenile entrainment losses.
- *Too little emphasis on life history diversity:* As discussed in several new reports, there has been a major loss of life history diversity in Central Valley salmon, leading to reduced viability of the different runs.
- *Too little emphasis on habitat for rearing and migrating juvenile salmonids:* Habitat limitation is likely the major problem for downstream migrating salmon. There is insufficient rearing habitat in the Delta, leaving fish exposed to predators and without adequate food resources.
- *An overemphasis on hatchery production to support salmon populations:* There is substantial new evidence that hatchery management practices have had a significant role in reducing genetic and life history diversity of salmonids. Improvements to hatchery management practices have the potential to diminish these adverse effects in the future.
- *Too little emphasis on the marine portion of the life cycle:* Although ocean survival is one of the major factors driving population trends, there has been insufficient research on the relative importance of Bay and Ocean conditions and how these habitats should be included in the overall management on Central Valley salmon stocks. In addition, there has been insufficient research on the importance of estuary use to subsequent ocean survival.

In the following sections, we provide a review of some of the major new research that led to these conclusions.

1.1 The effects of flow and exports in the Delta

Since the 1970s, the effects of water project operations have been the focus of Delta salmon studies (Kjelson et al. 1981, 1982; Kjelson and Brandes 1989). Though not explicitly stated at the time these studies began, these nearly 40 years of study were conducted to test the hypothesis that South Delta exports are an important driver of juvenile salmonid survival in the Delta. Here, we examine the historical and recent evidence of the roles of exports and inflow (as influenced by reservoir operations) as drivers of salmon migration and survival.

Recent studies have provided good evidence that inflow affects migration pathway and survival of downstream migrating juvenile salmon through the Delta. In these studies, survival and migration pathways are linked because migration routes leading to the interior Delta are associated with lower survival rates (Newman and Brandes, 2010). In contrast to inflow, there is much less evidence for the effects of exports on migration pathway and survival. Part of the reason may be that at a key channel junction where fish enter the interior Delta (Georgiana Slough), the division of flows is less sensitive to exports than commonly assumed (Cavallo, In Prep). Although it remains difficult to quantify indirect effects of exports on salmonids, there is sufficient data to provide at least basic estimates of direct effects (i.e. salmon entrainment). The best available data suggest that young salmon entrainment rates since 1994 are generally lower than over the prior 14 year period. We propose that recent entrainment rates have been reduced following the Bay-Delta Accord (1994) and the subsequent Water Rights Decision D-1641 (1999).

Note that this does not mean that entrainment is never an issue. As will be discussed below, episodic events are still a concern. In addition, the threshold examined in this report is population level effects, which is different than that which may be required under the State and Federal Endangered Species Acts (CESA and FESA), where the focus is frequently on “take” at levels well below losses capable of driving population trends. In other words, CESA and FESA may require changes in operations to avoid exceeding specific take levels even if the expected losses represent a relatively small percentage of the population.

1.1.1 For San Joaquin Basin salmon, inflow but not exports seems to be a primary driver of survival

The effect of exports and SJR flows on the survival of juvenile salmonids has been the subject of intense study and more than 25 years of focused experiments (VAMP and pre-VAMP studies). Quantitative analyses from mark-recapture experiments have found no evidence for statistically significant adverse effects on the survival of juvenile salmonids related to south Delta export rates (CDFG 2005; Newman 2008). In contrast, these same studies, as well as others which did not quantitatively evaluate export effects (e.g., Kjelson et al. 1982; Kjelson and Brandes 1989; Baker and Morhardt 2001; SJRGA 2007), have found evidence for a positive effect of SJR flows on survival of juvenile salmonids.

In a new study, Zeug and Cavallo (In review) analyzed a larger dataset of CWT releases for both the Sacramento and San Joaquin River basins and also did not observe a negative relationship between exports and survival to ocean recovery.

1.1.2 For Sacramento Basin salmon, the evidence for inflow and export effects is mixed

Several studies have evaluated patterns of survival among Sacramento River basin Chinook. Similar to their findings in the San Joaquin basin, Kjelson and Brandes (1989) used a regression approach found a positive relationship between flow and recovery rate of CWT-ed fall-run smolts at Chipps Island and as adults in the ocean. Survival rates were substantially lower among fish that were exposed to diversion at the Delta Cross Channel gates, a major entry point to the Central Delta. Newman and Rice (2002) fit a quasi-likelihood model to investigate effects of Delta Cross Channel gate position, flow, and the fraction of inflow exported (E:I ratio) on survival of various North Delta release groups of CWTed fall-run and also found positive effects of flow, and lower survival for fish released above the Delta Cross channel gates. Their analysis suggested that increasing the E:I ratio resulted in decreased survival, but the effect was not statistically significant. Newman (2003) compared estuarine and ocean survival among paired releases using two different modeling approaches (pseudo-likelihood and Bayesian nonlinear hierarchical) and found significant effects of both flow and export levels using both analysis approaches, although there was substantial variability on effect sizes.

The above analyses evaluated effects of flow and exports from single models. More recent analyses have adopted a model comparison approach in which a series of models are constructed that include different predictors, and their relative fit to the data is compared using information-theoretic criteria (e.g., AIC, Burnham and Anderson 2002). This approach is valuable because it allows an evaluation of how much different potential predictors (e.g., flow, exports) help to explain variability in survival. Recent analyses that have adopted this approach have shown no evidence for a statistically significant effect of exports (Zeug and Cavallo, In review). Newman and Brandes (2010) also adopted this model comparison approach and analyzed recovery data from a focused experiment, wherein paired releases of juvenile late-fall run Chinook were released simultaneously in Georgiana Slough (leading to the interior Delta) and into the Sacramento River at Ryde. Over 15 different paired releases from 1993 – 2005, they found that the Georgiana Slough groups had consistently lower survival relative to the Ryde release groups when they examined the fractions recovered at Chipps Island, the ocean fishery, and at inland sites. However, due to large environmental variation, models that did and did not include exports had equivalent predictive abilities. Given the difficulty of detecting an effect of exports even with over ten years of paired release data, Newman and Brandes (2010) recommended that future work use telemetry to provide insight into reach-specific survival rates for migrating fish. Along these lines, recent acoustic telemetry studies have shown that river inflows can positively influence juvenile Chinook survival (Perry 2010; Perry et al. 2012; Cavallo et al. 2012), similar to conclusions from Newman and Rice (2002) and Newman (2003). In contrast, Michel (2010) did not find an influence of flow on survival on yearling Chinook salmon.

1.1.3 The risk of Sacramento Basin salmon entry into the Central Delta (a high mortality region) appears to be strongly influenced by inflow changes, but not exports

As noted above, there is only weak evidence for export effects on survival, but stronger evidence for flow effects. Emerging information on Delta hydrodynamics and fish telemetry may help to explain these patterns. An understanding of hydrodynamics within the Delta is critical to evaluating how altered river inflows and South Delta exports may influence juvenile salmonids. Among the many assessments of Delta environmental conditions which are available, altered hydrodynamics resulting from South Delta exports have almost universally been identified as a significant adverse effect for juvenile salmonids. For example, the National Research Council of the National Academies (NRC 2012) concluded "losses [of juvenile salmonids] are substantive and are at least in part attributable to pump operations that alter current patterns into and through the channel complex, drawing smolts into the interior waterways and toward the pumps."

Despite the perceived importance of the issue, there have been few detailed quantitative assessments of how exports influence Delta hydrodynamics. Kimmerer and Nobriga (2008) used a Particle Tracking Model (PTM) to characterize Delta flow patterns and to evaluate entrainment risks for larval fishes. The PTM is typically applied by injecting particles at locations within a simulated Delta; the fate of particles after one or more months is then reported (e.g., Kimmerer and Nobriga 2008). However, with PTM the fate of particles is a gradual process, such that reliance upon PTM as an indicator of generalized hydrodynamic conditions has left sub-daily variations in hydrodynamic conditions largely un-described. Whereas PTM may be applicable to larvae with more passive drifting behavior (Kimmerer and Nobriga 2008), sub-daily flow conditions are more likely to be important for fishes with directed swimming behavior. Salmon smolts are known to be strong swimmers and to move through the Delta more quickly than tracer particles, with larger smolts migrating more quickly than smaller ones (Baker and Morhardt 2001). In addition, salmon are known to show complex diel behaviors (Perry 2010; Chapman et al., 2012).

Kimmerer and Nobriga (2008) demonstrated that particle fate, both in terms of destination and arrival timing, was very sensitive to river inflows and, to a somewhat lesser extent, exports. They observed that tides acted only to “spread out and delay the passage of particles” and thus, the fate of particles largely reflects net, non-tidal flow, and does not describe sub-daily hydrodynamics resulting from the interaction of tides with river inflows and exports. Yet, sub-daily tidal flow in the Delta is much larger than tidally-averaged net flow (Baker and Morhardt 2001). In addition, tidal flow and stage have been observed to strongly influence discharge and water velocities within Delta channels and junctions (Burau et al. 2007). These tidally-driven variations are known to influence salmon migration, and recent studies have pointed out that the interaction of complex fish behaviors and sub-daily changes in flow is the key to understanding migration and entrainment, particularly at junctions (Blake and Horn 2003; Vogel 2004; Burau et al. 2007; Perry and Skalski 2008; Perry 2010).

It is well known that the majority of juvenile salmon production from the Central Valley originates in the Sacramento Basin. As discussed in the previous section, a major concern for these juveniles is that their survival is significantly lower if they enter the central Delta as opposed to remaining in the mainstem Sacramento River (Newman and Brandes 2010). The greatest risk is entry into the central Delta via Georgiana Slough and Delta Cross Channel. The latter of these two channels has operable gates, which commonly remain closed during key outmigration periods to protect juvenile winter run (NMFS 2008). Georgiana Slough has no such gates and is therefore a primary entry point to the Central Delta for Sacramento Basin juvenile salmon. Moreover, telemetry studies show that entry into Georgiana Slough is strongly dependent on the proportion of flow from Sacramento River that enters this reach (Perry 2010).

Based on this logic, it is instructive to look at the proportion of flow that enters Georgiana Slough under a range of hydrologic conditions. Cavallo et al. (In prep) recently examined this issue using the extensive DSM2 hydrodynamic modeling studies performed by Kimmerer and Nobriga (2008), described above. In this case, Cavallo et al. (In prep) relied on the original hydrodynamic information because it contained the detailed output for flow splits at key channels and was thought to be more appropriate than PTM to examine how different conditions affect salmon movements.

Figure 1 summarizes the hydrodynamic output for a series of DSM2 model runs under low, medium, and high inflow conditions. For each of the three flow levels, simulations were performed for low (2000 cfs), medium (6000 cfs), and high exports (10000 cfs). The model outputs show that inflow influences how much water moves into Georgiana Slough. Under most inflow and export conditions, around half of the water entering these junctions was diverted from the mainstem river to the interior Delta. However, Cavallo et al (In prep) found virtually no effect of exports on the amount of flow that enters Georgiana Slough. Based on the work showing the response of Sacramento Basin fish to flow entering Georgiana Slough (Perry 2010), these results suggest that the risk of entry into the Central Delta (a high mortality region) is sensitive to inflow, but not exports. These hydrodynamic results may help explain why there is only weak evidence for export effects on survival of Sacramento basin fish.

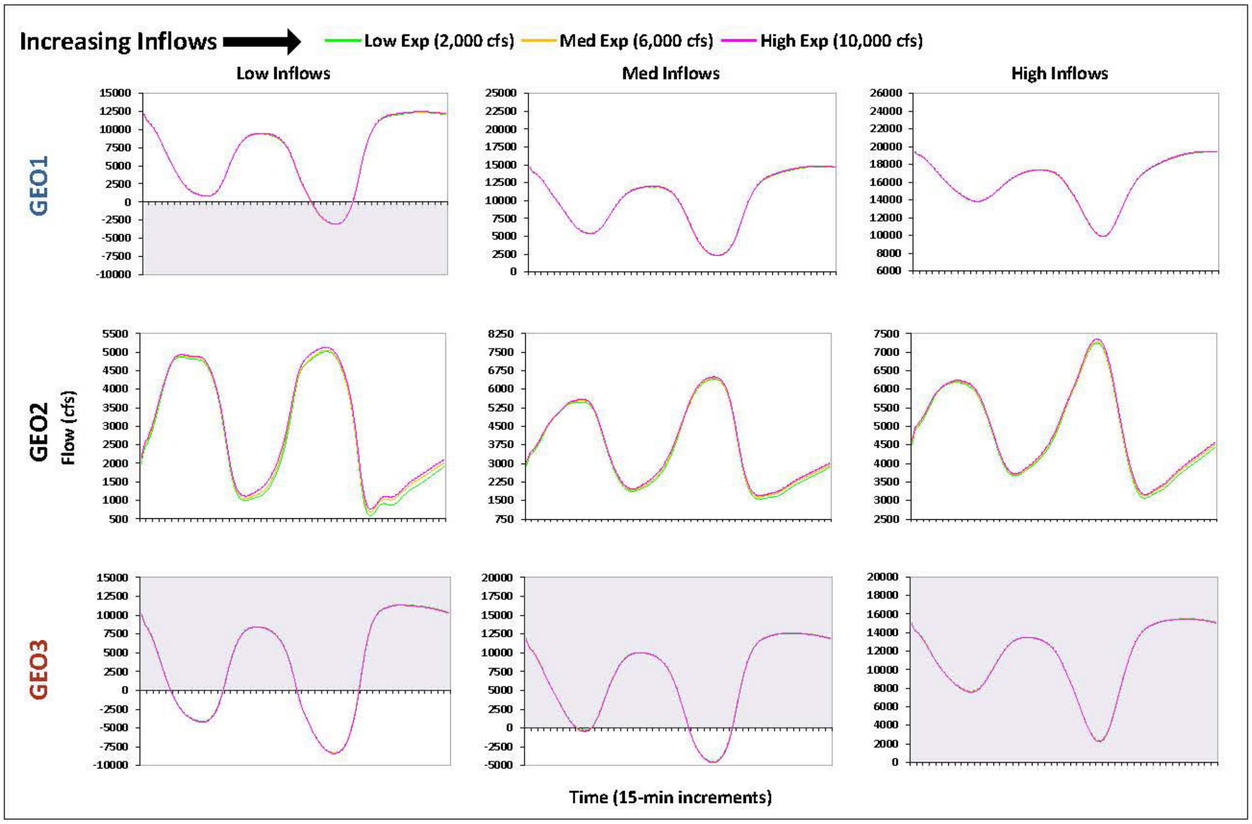

Figure 1. Flow in Georgiana Slough Junction Channels over 24 Hours. Time of day in 24-hr format is on the x-axis, starting at 0000 hours and ending at 2345 hours. Magnitude of flow is on the y-axis. Curve color indicates export level. Channel designations are: GEO1 = Sacramento River Above Georgiana Slough; GEO2= Georgiana Slough; GEO3 = Sacramento River below Georgiana Slough. For channel GEO2, all flow is toward the interior Delta. For the other channels, flow displayed in the shaded area is away from the center of the junction.

1.1.4 A recent analysis of tagged salmon suggests that entrainment rates may be occasionally elevated

Millions of coded-wire-tagged (CWT) juvenile Chinook salmon have been released upstream of the Delta (Brandes and McLain 2001) and these data provide an abundance-scaled metric of entrainment loss (Kimmerer 2008). Kimmerer (2008) estimated the salvage of 64 CWT release groups from the Sacramento River (1997-2005) as a proportion of total juveniles leaving the Delta. Total juveniles leaving the Delta was taken as the sum of salvaged juveniles and juveniles leaving at Chipps Island, estimated from Chipps Island Trawl data. Nearly half of the release groups had 3% or more of juveniles leaving the Delta as salvaged fish, and a fifth of release groups had 10% or more of juveniles leaving the Delta as salvaged fish. These results support the possibility of occasionally elevated entrainment rates for migrating Chinook salmon smolts; however, effects of these potentially elevated entrainment rates on the overall population remain unclear.

1.1.5 Management actions have reduced juvenile salmon losses

While salmon entrainment rates may be occasionally high, there is evidence based on naturally produced fish that Bay-Delta Accord and D-1641 management actions have resulted in a major reduction in fish losses. Fish salvage at the Delta pumps is the longest-term and most consistent data set available on fish in or passing through the Delta (Grimaldo et al. 2009). The shortcomings of these data are well-recognized (Kimmerer 2008; Grimaldo et al. 2009); however, salvage at the SWP and CVP fish facilities currently represents the best available tool to examine trends in entrainment of Delta fishes. By salvage we refer to expanded salvage: the number of Chinook salmon juveniles collected at the salvage facilities (as estimated from salvage sample counts) without accounting for entrained fish not captured by the fish screens or for prescreen losses. Based on this logic, the number of fish salvaged at the Delta pumps is used as a trigger for Endangered Species Act take restrictions. Moreover, the salvage data are often cited as an index of both direct and indirect mortality rates associated with pumping.

While factors affecting salvage of several Delta fishes have been examined in detail (Grimaldo et al. 2009), patterns of Chinook salmon salvage have not been well-studied except in an operational context. One important point, however, is that the salvage data suggest that there has been a substantial decrease in juvenile salmon entrainment since the Bay-Delta Accord was passed in 1994 by the SWRCB followed by D-1641 in 1999. Figure 2 shows the long-term patterns of annual salvage of juvenile Chinook salmon (all races) at the SWP and CVP. While there appears to be no consistent trend in annual salvage, the numbers for the past decade have been relatively low, especially in relation to the number of adult fish observed returning to rivers (an indicator of juvenile production). Compared to the previous 14 years, average annual salvage since 1995 has dropped at the SWP from 34,996 to 12,437, with maximum annual salvage dropping from 93,789 to 42,196 between these two periods. No concomitant drop occurred at the CVP, with pre and post 1995 average annual salvage of 33,963 and 42,196 (maximum 277,754 and 160,750). Decreasing salvage at SWP since 1995 coincides with reduced February-June exports mandated by the Bay Delta Accord and D-1641 (Figure 3) to keep take levels low.

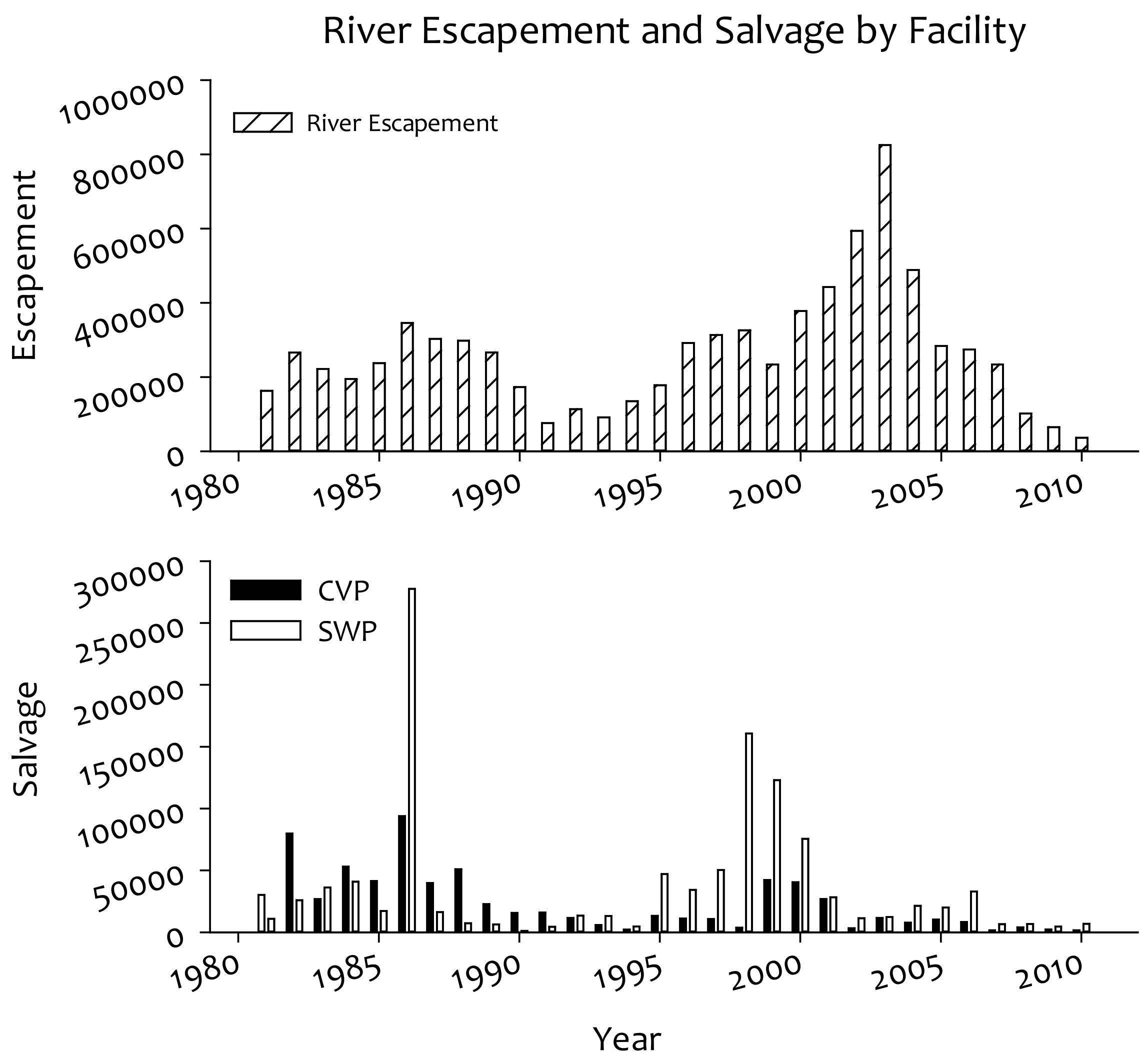

Figure 2. Salvage of untagged juvenile Chinook salmon at the SWP and CVP fish salvage facilities since 1980. Data on total Central Valley adult escapement for the same years are provided as an indicator of juvenile production.

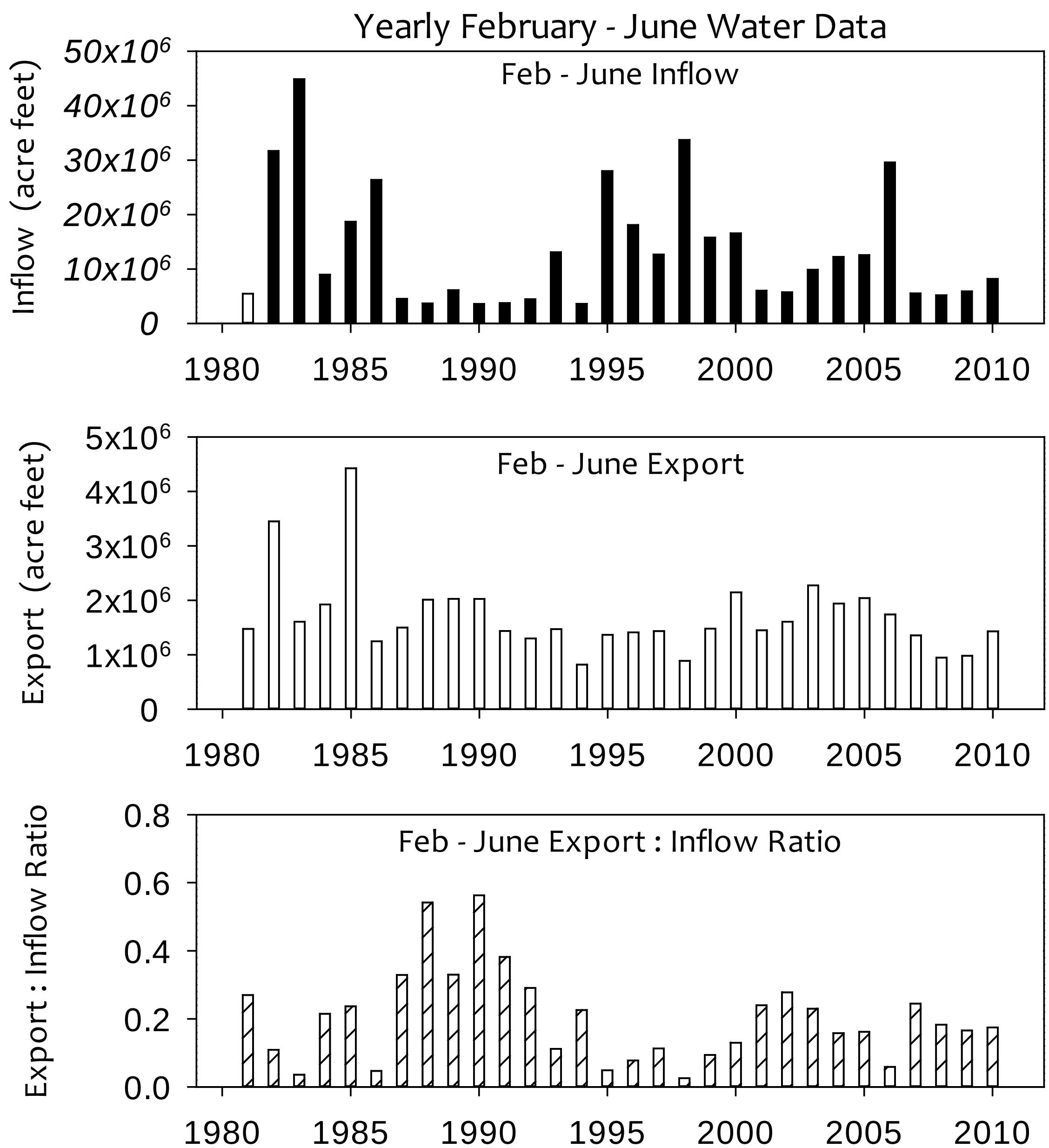

Figure 3. Delta inflow, Exports (SWP + CVP), and Export/Inflow ratios during the months of juvenile salmon migration (February-June) since 1980. Dashed lines representing averages across years before and after 1995 clearly show a substantial (43%) decrease in average E/I ratio following enactment of the Bay Delta Accord/D-1641 that is not apparent in inflow or export data alone. Data are from DAYFLOW (http://www.water.ca.gov/dayflow/output).

It is important to note, however, that these salvage patterns are likely influenced by variation in juvenile production. Years with large numbers of adult spawners are generally associated with higher production of juveniles (Poytress and Carrillo 2010; DWR unpublished data[1]), which may in turn be entrained during their downstream migration. This pattern is generally apparent in the salvage data, where years with low adult escapement generally correspond to the years with lowest salvage levels (Figure 2). When the effects of adult escapement (and subsequent juvenile production) are taken into consideration, the data remain consistent with the previous discussion of raw salvage numbers--there apparently has been a substantial decrease in losses since the Bay Delta Accord and D-1641. To help illustrate this point, Figure 4 shows SWP juvenile salmon salvage in relationship to adult escapement during two periods: 1981-1994 (Pre-Bay-Delta Accord) and 1995-2010 (Post-Bay-Delta Accord). Both periods show a relationship between adult escapement and juvenile salmon, but the period since the Bay-Delta Accord indicates a major reduction in salmon salvage at the SWP. No similar patterns are apparent at the CVP. These results suggest that the Bay-Delta Accord, followed by passage of D-1641 has successfully reduced salmon losses at the SWP. Reduced salvage is not surprising since D-1641 substantially changed export-inflow (E/I) ratios and exports in the Delta during the major period of salmon migration, February-June (Figure 3). Note that this change is apparent in the ratio of export to inflow and exports, but not in inflow. We acknowledge, however, that it is possible that other factors may have contributed to reduced salvage. For example, salmon mortality may have increased during the same period.

[1] Relationship between Feather River adult salmon escapement and estimated juvenile emigration during 1999-2011: Regression results P = 0.031 and r^2(adj) = 0.437. Juvenile emigration was estimated using results from rotary screw traps operated in the High Flow Channel of the lower Feather River. No emigration estimate was available for 2006 and 2007 because of trapping issues.

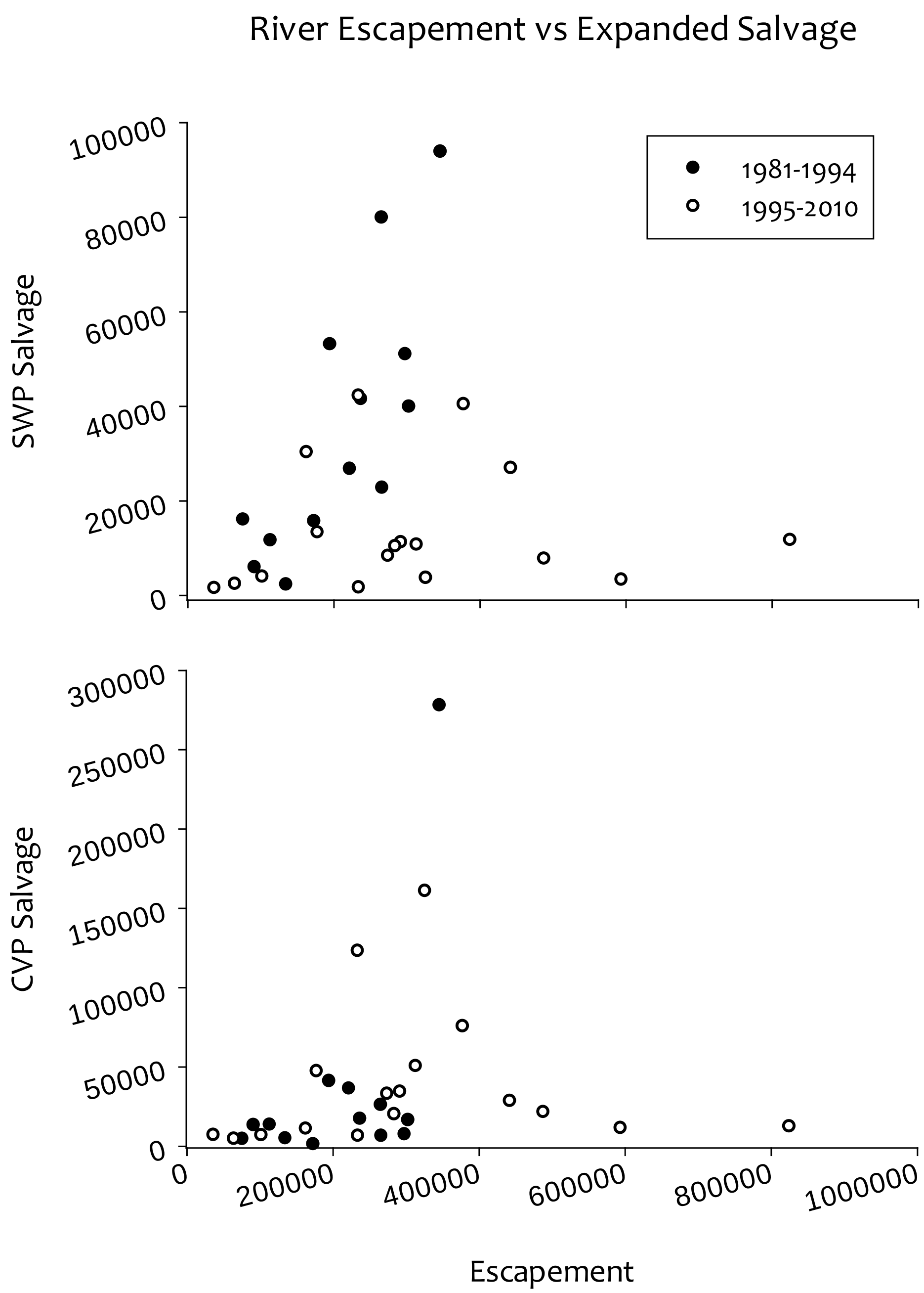

Figure 4. Expanded salvage at SWP and CVP in relationship to Central Valley adult escapement for two time periods: 1981-1994 and 1995-2010.

Level of Certainty: MODERATE – HIGH certainty that export levels under current management conditions are not a major driver of overall juvenile salmon survival in the Delta. MODERATE-HIGH that flow affects salmon survival. MODERATE that recent management actions have reduced losses.

Relevance: The information presented suggests that there has been substantial progress in reducing juvenile salmon losses. Hydrodynamic and entrainment data presented may help to explain why there is stronger evidence for the effects of river inflows on salmon survival than exports. Export management may still be a reasonable approach to reduce (direct mortality) take of listed species, but doesn't appear to be a strong tool to improve the status of Chinook salmon stocks. Operationally, inflows appear to be a more important factor. Nonetheless, we continue to be concerned that other factors (e.g. habitat, life history diversity, reliance on hatchery stocks, ocean conditions) of equal or greater importance have not been sufficiently emphasized.

1.2 Life history diversity is much more important than previously understood

Within the Sacramento-San Joaquin Central Valley and throughout the Pacific coast, the broad diversity of salmon populations is well known with respect to their genetic makeup and life history (e.g., the timing of their spawning and migrations into and out of freshwater). Because salmon typically return to their natal streams to spawn (Dittman & Quinn, 1996), individual populations have historically been adapted to local environmental conditions of their 'home stream' and are essentially reproductively isolated from populations in neighboring drainages. However, salmon populations are distinct not only geographically, but also according to the timing of their migrations as both juveniles and adults. In the Central Valley, Chinook salmon adopt one of four alternative life history strategies, or 'runs': fall, late-fall, spring, or winter runs, named after the season in which adults begin their spawning migration into freshwater. In addition, Chinook salmon have highly variable periods of ocean residence, ranging from a few months to seven years (Williams, 2006). Substantial variability exists even within each major run type: for example, some fall-run Chinook may remain close to spawning grounds for juvenile rearing while others leave upstream areas and travel through the Delta as "fry migrants" (Williams, 2006). Such tremendous life history diversity historically has not been unique to Chinook salmon: steelhead are also famously variable in their life history, and can even complete multiple spawn events in their lifetime, performing several river-ocean migrations.

While the variation in life history diversity has been described for the Central Valley for a number of years, recent analyses have made clear the importance of this diversity for population stability and resilience. Called the 'portfolio effect', life history diversity within a population is a form of 'bet-hedging', akin to the common financial strategy of diversifying a stock portfolio in order to reduce risk (Greene et al., 2010; Schindler et al., 2010). For example, if all salmon hatched within a single year remained in freshwater spawning areas for their entire first year, drought conditions will cause low survival rates for the entire cohort. However, if a fraction of the year class outmigrates at a younger age, they may experience improved survival, thereby affording resilience to the cohort. Without an array of life histories, salmon populations are vulnerable to unfavorable environmental conditions that most severely affect the dominant life history type.

Dependence on a single life history strategy can be catastrophic: in fact, a diminished portfolio effect in the Sacramento River fall run is deemed to be a major contributing factor to its collapse in 2007-08 (Lindley et al, 2009; Carlson and Satterthwaite, 2011), which led to a complete emergency closure of the California and southern Oregon Chinook salmon fishery in spring of 2008. While exceptionally poor ocean conditions were likely a direct cause of the poor adult returns, Sacramento fall run Chinook were particularly vulnerable because of a lack of life history diversity. In fact, adult returns to the Central Valley as a whole are strongly dominated by the Sacramento system, with nearly negligible contributions from the San Joaquin system. Furthermore, across individual drainages within the Sacramento basin, adult return rates largely co-vary, and evidence suggests that this lack of independence among individual river basins has continually increased over the last 25 years (Carlson and Satterthwaite, 2011).

Reduced life history variability is also evident from otolith analyses that have revealed that the vast majority of juvenile salmon outmigrate at parr (56-75mm) or smolt (>75 mmFL) sizes, with a relative minority leaving the Delta as fry (≤ 55mm) (Miller et al., 2010). The latter result is not surprising, given evidence from previous otolith analyses that the Central Valley population is dominated by hatchery-origin fish (Barnett-Johnson et al., 2007), and hatcheries release nearly all of their production at parr or smolt sizes. Furthermore, the genetic structure of the Central Valley Chinook population is largely homogeneous, with no distinction between hatchery and natural-origin fish (Williamson and May, 2005). Thus, the life-history of the fall run Central Valley Chinook population as a whole is essentially one-dimensional, made up of the hatchery strategy.

In addition to the over-emphasis in the Central Valley on hatchery production, loss of rearing habitat in the Delta has probably been a driving factor behind reduced life history diversity. In general, habitat loss can result in reduced genetic diversity for salmonids if the traits associated with lost habitats are heritable (McClure et al., 2008). Beyond loss of habitat area, the quality of existing habitat is also important, as habitat heterogeneity (ie, complexity) may provide a buffer against environmental variation and thus support population stability (Oliver, et al., 2010). Much of the physically and hydrodynamically complex shallow-water rearing habitat for juvenile salmonids in the Delta has been replaced with structurally simple, leveed channels (Nichols et al, 1986), and as a consequence the habitat most likely cannot support the broad array of life history strategies that once characterized the Central Valley salmonids. Thus, restoration of rearing habitat is a critical step toward re-building life history diversity and in turn, population stability.

> *Level of Certainty*: HIGH that life history has been drastically reduced in Central Valley salmonids and its deterioration has contributed to the decline and MODERATE-HIGH that improvements in habitat complexity will enhance life history diversity in the future.
>
> *Relevance*: Recent analyses have demonstrated that life history diversity of Central Valley Chinook salmon is highly degraded, leaving the population particularly vulnerable to significant loss during poor environmental conditions. This current state is largely due to an emphasis on hatchery production and a lack of adequate rearing habitat in the Delta.

1.3 Rearing and resting habitat is the major issue for salmon survival through the Delta

Historically, the Delta was a complex mosaic of channels with dense riparian zones, vast areas of tule marsh, and extensive flood basins (Atwater et al. 1979; SFEI 2012). The current Delta bears little relationship to this earlier landscape, with virtually no riparian habitat, channelized trapezoidal banks, tiny remnants of tule marsh, poor connectivity with floodplain and flood basins, and many water diversions (Baxter et al. 2010; Brown and Bauer 2010). Given these extreme changes, it is no surprise that much of the emphasis in salmon management in the region for the past several decades has been on moving young salmon through the Delta as quickly as possible. This view has been reinforced by tagging and telemetry studies (see below), which suggest that larger hatchery smolts move through the Delta relatively quickly (Michel et al. 2012).

Unfortunately, this management approach ignores the fact that many of the young salmon are currently using the Delta, and does nothing to address a key underlying problem—the lack of rearing and resting habitat. <u>The bottom line is that although multiple actions are needed to recover Central Valley salmon, survival and run viability will continue to be problematic until the issue of rearing and resting habitat is addressed.</u> Some of the key new scientific information relevant to this issue is provided below.

1.3.1 Delta rearing is more important than previously understood, even for larger juveniles.

As noted above, the basic conceptual model for salmon management has been to encourage juveniles to move through the system as quickly as possible. Moreover, most of the emphasis is on larger juveniles, which are composed largely of hatchery fish (Miller et al. 2010). However, this ignores evidence that large numbers of young (i.e., small) fish rear in the Delta. Fry-sized salmon (≤55 mm fork length) are ubiquitous in juvenile fish monitoring surveys in the Delta (Brandes and McLain 2001), suggesting that the estuary is an important rearing area for this life stage. The importance of Delta residency has been confirmed based on coded-wire-tag (CWT) data which suggest that residence of fry migrating through the Sacramento River into the Delta is on the order of a couple months (Sommer et al. 2001). Similarly, catch of naturally-produced juveniles at the base of Yolo Bypass (the Delta's primary floodplain) does not peak until fish are forced off of the floodplain during drainage, suggesting that young salmon rear on seasonal Delta habitat for as long as possible (Sommer et al. 2005). The growth potential during the Delta rearing period may be essential for young salmon to achieve a size and condition that will afford higher chances of survival once they enter the ocean.

There is also surprising new evidence that larger fish may rear for long periods in the Delta. A new study examining the emigration patterns of naturally produced winter-run sized juvenile Chinook salmon suggests that apparent Delta residence time of these fish may be 1-3 months (Del Rosario et al. In review), much longer than the fast movements (e.g. 14-23 km/d) measured using tagged hatchery smolts (Michel et al. 2012). The recent results on naturally-produced fish were based on comparison of catch trends at Knight's Landing (just upstream of the Delta) with sampling locations at the base of Yolo Bypass and at Chipps Island, the downstream limit of the Delta. Additional telemetry and genetic studies are needed to test the hypothesis of extended Delta rearing of larger juveniles. In any case, these results are contrary to the assumed rapid migration of young Chinook salmon and point to the importance of rearing habitat during downstream migration.

1.3.2 Delta channels provide little rearing habitat

The geometry of Delta channels has been transformed from a broad and complex mosaic that included channel, shoals, marsh, natural levees, upland, and flood basins (SFEI 2012) into narrow trapezoidal channels. While these deep trapezoidal channels may be useful from the standpoint of flood conveyance, they provide virtually no rearing or resting habitat for young salmon. To help illustrate this fact, Figure 5 uses a model from Sommer et al. (2004; 2005) to simulate the amount of shallow water habitat in the mainstem Sacramento River as compared to the seasonal Yolo Bypass habitat (to be discussed in more detail below). In this case, the simulation estimates the area of habitat less than 2 meters deep, the typical threshold for littoral vegetation and a range that reflects much of the habitat use by salmon fry and parr. A key point is that the Sacramento River has only a trivial amount of shallow water habitat as compared to the adjacent seasonal Yolo Bypass floodplain. Note that this analysis is not intended as an exact estimate of the amount of rearing habitat in each of the two systems; rather, it is an illustration of the general patterns of habitat availability.

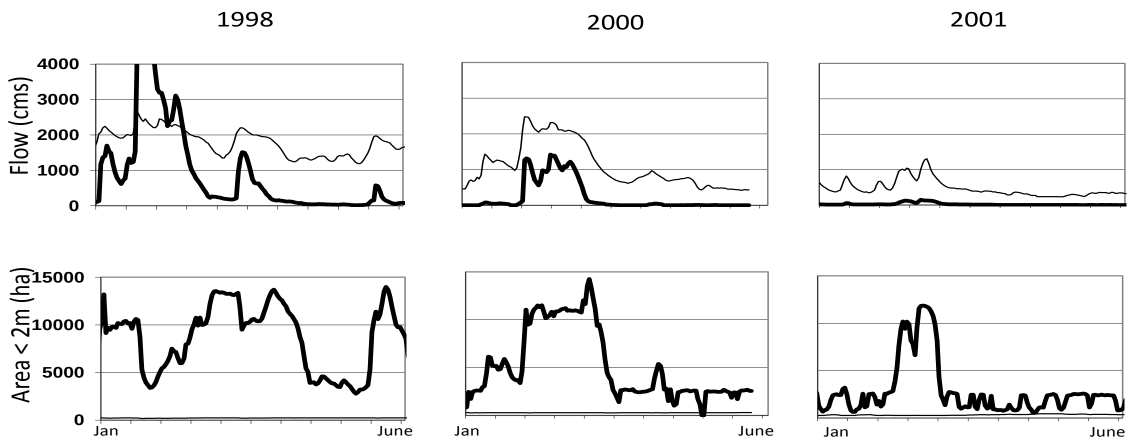

Figure 5. Simulation of the amount of shallow water habitat (area < 2 meters deep) in the Sacramento River (lower panels—barely detectable thin line just above X-axis) and Yolo Bypass (lower panels—thick line). The data were adapted from model simulations by Sommer et al. (2004, 2005) based on actual daily hydrology during 1998, 2000, and 2001 (upper panels: thin line = Sacramento River flow; thick line = Yolo Bypass flow). The simulations are based on results for these two locations for the reaches approximately between Knight's Landing and Rio Vista.

1.3.3 Flow has little effect on habitat availability in Delta channels

Following the previous comment, there is also little effect of flow on the available habitat area in the Sacramento River. As shown in Figure 6 which replots the data in Figure 5 to examine the relationship between flow and shallow water area, there is very little variation in the amount of surface area at increasing flows. For the Sacramento River, which is representative of the majority of habitats found in the Delta, an order of magnitude increase in flow (over the range analyzed) results in less than a 20 percent increase in the amount of shallow area. This result is not surprising given the trapezoidal geometry of the channel. The Sacramento River results are radically different from Yolo Bypass, particularly up to 500 cms, where flow increases over this range result in almost two orders of magnitude increase in shallow area.

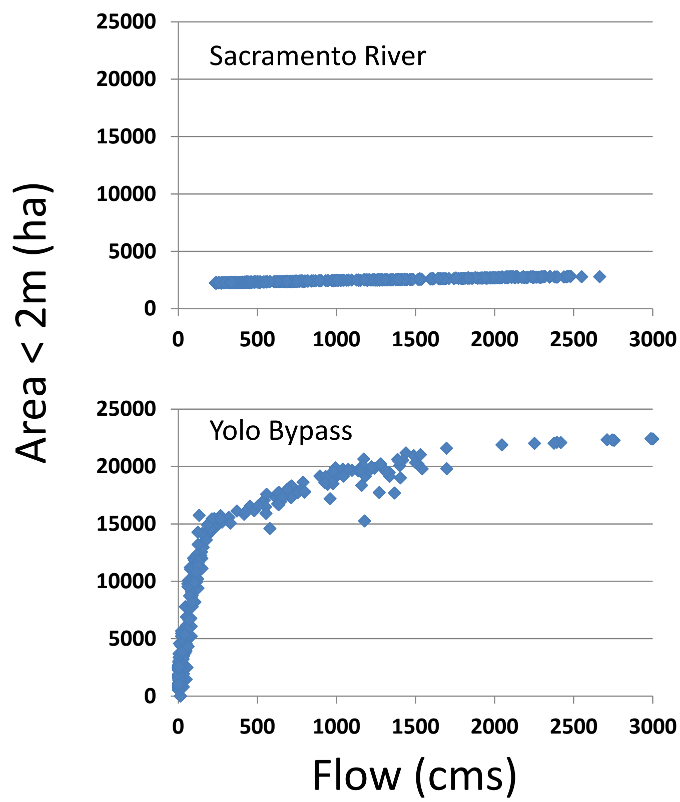

Figure 6. Effect of flow variation on the amount of shallow water habitat (area < 2 meters deep) in the Sacramento River and Yolo Bypass. The data were adapted from model simulations by Sommer et al. (2004, 2005) based on actual daily hydrology during 1998, 2000, and 2001.

1.3.4 Evidence continues to build that seasonal habitat is exceptionally important for rearing.

Historically, the Central Valley had vast areas of floodplain available for rearing of juvenile Chinook salmon. Although the current system has been modified for flood protection (Sommer et al. 2001b), studies over the past 14 years have revealed that remnant habitats still provide exceptional value for downstream migrating Chinook salmon. Studies on Yolo Bypass (Sommer et al. 2001a; Henery et al. 2008) and Cosumnes River floodplains (Jeffres et al. 2008) consistently show superior growth rates for fish rearing on seasonal habitat as compared to the previously-described main river channels. A major reason for this finding is much higher feeding success based on availability of invertebrate food resources (see below). Faster growth and a larger size at emigration appear to be major factors affecting the probability of salmonids surviving to adulthood (Hayes et al. 2008, Satterthwaite et al. 2012). Larger fish may have a competitive advantage upon entering downstream marine conditions, where food availability can be highly variable depending on ocean upwelling (Lindley et al. 2009).

Unfortunately, connectivity is relatively poor between the Sacramento River and Yolo Bypass, so young salmon only have access to this seasonal habitat during very high flow events (Sommer et al. 2001a). For example, the Sacramento River does not spill into Yolo Bypass until flows at Wilkins Slough are approximately 56,000 cfs. As will be discussed below, DWR in partnership with U.S. Bureau of Reclamation, UC Davis, National Marine Fisheries Service, CAL-Trout, and local landowners are trying to address this issue in a pilot project to examine the potential use of agricultural wetlands for salmon rearing. Initial results were highly successful, with excellent salmon growth rates in a small scale study (Katz et al. In prep).

1.3.5 Evidence for the importance of tidal wetlands for salmon rearing

As noted above, the Delta historically had vast areas of tule marsh, but virtually all of this habitat has been lost (SFEI 2012). Nonetheless, recent evidence in naturally restored areas of Liberty Island suggests that tidal wetlands can provide valuable habitat for rearing salmon (McClain and Castillo 2010). There is a strong expectation that this habitat was historically a major area for juvenile salmon rearing (Brown 2003). Indeed, work from the northwestern United States, where there are still large contiguous areas of tidal marsh, shows that tidal wetlands comprise one of the most important habitat types for migrating and rearing juvenile salmon (Shreffler et al. 1990; Bottom et al. 2005a,b; Miller and Simenstad 1997).

1.3.6 Rip-rap is poor habitat for salmonids

The Sacramento River and Delta levees are largely covered by rip-rap, which is known to be poor for young salmon. Detailed studies in the Columbia River found that substrate was the most important predictor of juvenile salmon use of inshore areas (Garland et al. 2002). Specifically, fish appear to avoid substrates larger than around 256 mm diameter as is typical for rip-rapped banks. In addition to the lack of rearing area (see previous section), rip-rap does not provide adequate amounts of terrestrial vegetation, a critical habitat component for food and cover. Studies in multiple locations along the Pacific Coast consistently show that terrestrial insects are a key food source for outmigrating salmon (Rondorf et al. 1990; Shreffler et al. 1990). Terrestrial insects appear to be especially important in the Sacramento River and the Delta, where sampling in the channels shows relatively low levels of these valuable invertebrates (Sommer et al. 2001; Limm and Marchetti 2009). By contrast, Sommer et al. (2001) and Limm and Marchetti (2009) showed high feeding success and growth in vegetated off-channel habitat, where terrestrial invertebrates were abundant.

> *Level of Certainty*: MODERATE-HIGH that availability of rearing habitat is a serious limiting factor for juvenile salmon migrating through the Delta.

Relevance: The current focus of salmon management for fish migrating through the Delta is to try and move fish through the system as quickly as possible. Actions typically considered include increasing flow to speed up migration, and reducing exports to limit entrainment. Ultimately, however, these actions do not address a central issue, the low quality and quantity of Delta habitat for salmon. While multiple actions are needed to restore Central Valley salmon, survival and run viability will continue to be problematic until the rearing issue is addressed.

1.4 Hatchery practices have played a significant role in reducing Central Valley salmon genetic and life history diversity

Over recent decades, significant research has documented a negative impact of hatchery-reared salmonids on naturally spawning populations. A broad range of effects have been noted, from competitive displacement of natural-origin fish, increased attraction of predators, which may have greater per capita effects on smaller wild populations, to deterioration of the genetic diversity the natural-origin population component when hatchery-origin fish spawn in the wild (Reisenbichler and Rubin, 1999; Nickelson, 2003). Many of the negative impacts stem from effects of domestication on both behaviors and the genetic composition of hatchery-raised salmonids: in general, hatchery-reared fish do not possess adequate skills for foraging or avoiding predators in the wild (Brown and Laland 2005). In addition, domestication selection can take place very fast; fitness declines in the wild are observed after only one generation of captive rearing (Araki et al. 2008; Christie et al., 2012). Reduced fitness and the loss of genetic diversity of hatchery fish (Araki et al. 2010) can have profound and rapid deleterious effects on the genetic health of wild populations when domesticated hatchery stock spawn in the wild (Araki et al. 2007).

Recent work on the impact of hatcheries specifically in the Central Valley has suggested that current hatchery management practices have been important drivers behind the reduced genetic and life history diversity that now characterize Central Valley Chinook and steelhead populations. In fact, genetic work on the fall-run Chinook population has shown an overall lack of diversity: instead, the population is genetically homogenous and with no geographic structure (Williamson and May 2005). Furthermore, there was no genetic distinction between hatchery and natural-origin fish, indicating the homogenization of Central Valley fall-run Chinook is due largely to major influxes of hatchery fish that stray onto natural spawning grounds to spawn (Williamson and May 2005). More recent work used sulfur isotopes in otoliths from adult Chinook salmon to determine hatchery vs. natural origin. This work then used these data to estimate the population growth rates of the natural population with and without the contributions from hatchery-origin fish (Johnson et al. 2012). While the apparent growth rate including hatchery fish was positive, the natural origin population (hatchery fish excluded) growth rate was actually less than zero (Johnson et al. 2012). In addition, only about 10% of in-river spawners were natural origin, and hatchery-origin fish clearly dominated the spawning population (Johnson et al. 2012). Dominance of hatchery-origin fish in turn renders the population highly susceptible to highly variable abundance cycles (boom or bust) because the hatchery practices degrade genetic and life history diversity that would otherwise serve as a buffer to environmental stochasticity (Lindley et al. 2009).

While the negative impacts of hatchery programs on Central Valley salmonids are recognized, few attempts have been made thus far towards reforming hatchery practices (Israel et al. 2011). Following earlier parallel processes in the Pacific Northwest, the U.S. Congress recently funded a scientific review of hatchery programs in California in order to identify specific aspects of program management in need of reform, and develop specific recommendations for improvement. In their summary report, the California Hatchery Scientific Review Group (HSRG) recognized the need for hatchery reform to be one of the tools within a broad range of management strategies, including habitat restoration and reformed water management and harvest policies, which target the restoration of natural populations of Chinook salmon and steelhead. The California HSRG recommendations are centered on the need for Central Valley salmon to re-develop local adaptation to sub-drainages, which is critical to the sustainability of natural populations. Specifically, the California HSRG noted that the practice of trucking juvenile hatchery fish to downstream or estuarine release sites should be halted as it promotes widespread straying of hatchery salmon between sub-drainages.

Along with the reform to hatchery release strategies, the California HSRG also developed a series of recommendations for implementation of well-managed, *integrated* hatchery programs. These programs have a goal of maintaining the genetic background of the local natural population by minimizing genetic effects of domestication. This effort is in contrast with *segregated* hatchery program, which aims to maintain a genetically distinct hatchery population by minimizing the contribution of hatchery fish to natural spawning (California HSRG 2012). The California HSRG recognized that segregated hatchery programs are not a feasible goal in California because it is not possible to keep all hatchery fish off of natural spawning grounds. To implement integrated programs, thresholds for the proportion of fish spawning in the wild that are hatchery origin must be developed, monitored, and if necessary, reduced (e.g. via weir structures) to meet program goals. In addition, natural origin fish (at least 10%, as the demographics of the natural population allow) must be incorporated into the broodstock spawned at the hatchery (California HSRG 2012). In order to reliably distinguish hatchery from natural-origin fish and implement target ratios for hatchery and natural origin fish in broodstock populations, the California HSRG recommended that 100% of hatchery fish be marked with a coded-wire-tag. Currently, 25% of all hatchery production is marked and receives an adipose-fin clip, which allows for statistical analyses of trends in the proportion of hatchery fish in the population, but recommended reforms would require identification of all fish as either hatchery or natural origin.

While the changes recommended by the California HSRG would make significant progress towards reducing current negative effects of hatcheries, they must work in concert with habitat restoration, policy reform of water management, and harvest. If all recommended changes are implemented without parallel efforts to improve and expand habitat, it is not reasonable to expect major increases in salmon abundance or population viability.

Level of Certainty: HIGH

Relevance: A heavy reliance on hatchery fish in salmon management in the Central Valley has contributed to a population that lacks genetic and life history diversity, such that local adaptation to individual sub-drainages is no longer present. Recommended reforms from the California HSRG would help to minimize negative impacts of hatcheries, but must be accompanied by habitat restoration in order to re-build healthy, self-sustaining populations of salmonids in the Central Valley.

1.5 Too little is known about the effects of Bay and Ocean conditions on salmon survival

While significant work has been done investigating sources of freshwater mortality for salmonids, relatively little work has been done to understand critical factors affecting survival in San Francisco Bay and the ocean. As these habitats occupy a major portion of the salmon and steelhead life cycles (anywhere from six months to 3 plus years), this represents an important period of uncertainty in our understanding of factors affecting salmon survival, and ultimately, escapement levels.

Generally, estuarine and early ocean residence are considered vital periods for growth in the salmon life history (Quinn 2005). Salmon must grow rapidly in order to take advantage of enhanced food resources in the ocean while minimizing predation risk. A recent 11-year study (1995 – 2005) of sub-yearling fall run Chinook use of the San Francisco Bay (downstream of Chipps Island) and the ocean during the first year of ocean residence demonstrated low growth rates in the estuary, followed by an order of magnitude increase in growth rate after ocean entry (MacFarlane 2010). These results suggest that the San Francisco Bay does not provide a nursery function for sub-yearling Chinook, in contrast to other systems on the Pacific coast (e.g. Reimers 1973). In addition, such low estuarine growth rates may not have been the case historically in the San Francisco Bay, but data are not available for comparison. While estuarine growth rates were very low (on average, 0.07 g/day), this study also showed a relationship between growth rates in the Bay and higher salinity and lower freshwater outflow. In the ocean, growth was positively related to cooler temperatures and upwelling (MacFarlane 2010).

The recent catastrophic collapse of the Sacramento River fall-run Chinook population in 2007-08 also highlighted how crucial ocean conditions probably are to achieving healthy adult returns. Fall-run Chinook enter the ocean during spring months and rely on concurrent coastal upwelling to supply nutrients that support a pelagic food web (Lindley et al. 2009). If upwelling is delayed, young salmon risk starvation and are more likely to be predated. In springs of 2005 and 2006, there were abnormal wind patterns and warmer than normal sea surface temperatures in the California Current, leading to a reduced food supply, and eventually, precipitous declines in escapement (Lindley et al. 2009).

With further study of the ocean phase of the salmon life cycle, it may be advisable to review and possibly reform ocean harvest policies. As in any fishery harvest program, there is a potential for selective harvest of a subset of the population with respect to size and/or age. Selection based on size can cause evolutionary change in target populations, leading to significant changes in the harvestable biomass (Conover and Munch, 2002). Effects of ocean harvest management policies for Central Valley Chinook may be in need of review, as this could be another avenue that currently degrades life history diversity for the population.

Level of Certainty: LOW

Relevance: Additional studies are needed to understand Chinook and steelhead use of the San Francisco Bay and the ocean, as well as conditions that drive growth and survival. Events of the 2007-08 collapse of Sacramento fall-run Chinook exemplify that ocean conditions are extremely important, but key mechanisms are uncertain, as are the likely effects of climate change.

1.6 New tools are being developed that should help improve salmon management

1.6.1 Genetics

When conducting scientific research, monitoring or take estimation for Central Valley anadromous salmonids, it is often necessary to establish the run type and/or geographic origin of juveniles. Historically, this step was difficult or impossible once juveniles emigrated from their natal tributaries, joining the mixed stock population in the main stem Sacramento River or Delta, because there are no external morphological characteristics that distinguish run type among juveniles. In the case of Chinook salmon, for which only winter and spring runs are listed under the Endangered Species Act, identification accuracy has been, and continues to be, a major issue of contention and concern. The reason for this concern is that misidentification of juvenile run origin at south Delta salvage facilities could potentially cause an overestimate of endangered species take, leading to inappropriate curtailment of water exports, or an underestimate of take, leading to imperilment of the endangered population beyond the level established by resource management.

In 1995, development of genetic-based methods for identifying Central Valley salmonids was initiated as part of a conservation hatchery program for winter run Chinook salmon to avoid admixture and hybridization between spawning runs (Hedgecock et al. 2001). This work confirmed that the four runs of Central Valley Chinook salmon that were originally defined by the timing of their spawning runs were also genetically different at the population level (Banks et al 2000).

Another major goal of this genetic research was to replace the Length-at-Date identification approach with genetic identification. The Length-at-Date approach estimates juvenile Chinook salmon run origin from a juvenile's length and the date it was sampled. The Length-at-Date approach is the method currently used at the salvage facilities and throughout the Central Valley to assign run origin to juvenile Chinook salmon. A recent comparison was made between Length-at-Date run assignments and genetic assignments of salvaged Chinook juveniles collected at the salvage facilities over the past seven years. The results of this comparison are not yet published, but were presented at the 2012 IEP conference. This comparison found that the Length-at-Date approach is flawed and unable to distinguish juvenile run origin at the salvage facilities because the two major assumptions underlying the approach are not supported by genetic data, that juvenile fork length ranges between runs are segregated and that juveniles of all runs exhibit similar rates of increasing fork length through the salvage season (Harvey, In prep).

Although scientists and resource managers have been aware of the potential inaccuracy of the Length-at-Date approach, almost since its inception, the complicated sampling regime at the salvage facilities did not meet the requirements of the genetic assignment models, precluding adoption of an alternative genetic-based identification program. In addition, genetically assigning run origin to an individual juvenile salmonid requires a higher level of genetic differentiation between runs than is required to detect a genetic difference between runs at the population level. Initial genetic tests could make accurate individual assignments for only winter run, which had become more genetically differentiated from the other runs after enduring a genetic bottle neck due to extremely low population sizes between 1989 and 1991. Around 2000, genetic tests were developed that also identified spring run juveniles from Butte, Mill and Deer Creek populations with a high level of accuracy. However, these and all subsequent genetic identification tests remained fairly inaccurate at distinguishing between Central Valley fall run, late-fall run and other spring run stocks, including Feather River spring run, partly because of recent hybridization between individuals of these different runs (Banks et al., in review).

The increased speed and reduced costs of genetic analyses have allowed genetic parental-based tagging (PBT) to emerge as a potential method of run identification where traditionally applied genetic identification methods have failed (ISRP/ISAB 2009). With parental-based tagging, the run of a juvenile is obtained by genetically identifying one or both of its parents, thus requiring that the juvenile's parents were previously identified to run based on run-timing behavior, and that the parents were also genetically tested (Anderson and Garza 2005). Recently initiated parental-based tagging programs for Central Valley Chinook salmon and steelhead trout hatchery stocks appear to be a successful and effective means of identifying run and hatchery origin of juveniles because the entire parent population can be easily and dependably sampled (Eric Anderson, NOAA Fisheries, personal communication, August 8, 2012). Parent-based tagging has also been applied to wild populations in small stream systems in Washington State where researchers were able to sample a large and known proportion of the spawning adult population (Scott Blankenship, Cramer Fish Sciences, personal communication, August 12, 2012). Parent-based tagging has numerous advantages over widely used coded-wire tagging systems currently used by many hatcheries, including lower cost, 100% tagging rate of juveniles (if every adult spawner is genetically tested), zero tag loss and non-lethal sampling of juveniles for identification, making it ideal for monitoring hatchery populations (Anderson and Garza 2005, 2006).

DWR is currently implementing two parallel pilot projects using genetic-based identification at the salvage facilities. The first project will use established genetic tests to monitor salvage of winter run Chinook salmon, for which the tests are highly accurate. The second pilot project will use the salvage estimates from the established genetic tests to evaluate salvage estimates of winter run from parental-based tagging. If parental-based tagging proves accurate for non-hatchery winter run, DWR may explore parental-based tagging for estimating salvage populations of other runs that are not as accurately identified by previous genetic tests. However, the ability of a parent-based tagging system to monitor large, wild populations in open systems remains uncertain due to logistical difficulties in sampling an appropriate proportion of the adult spawning population and in estimating the proportion of the adult population that has been sampled, both necessary elements of a parental-based tagging and run identification system (Anderson and Garza 2005, 2006). Some of the genetic and statistical techniques being applied in the pilot project are not fully vetted and in some instances are in the experimental stages. As such, it is uncertain whether these approaches will fully resolve run identification for all Central Valley salmonids.

Genetic approaches for discriminating run origin of California's Central Valley runs have evolved and improved considerably since genetic research was initiated. Eventually, a multitude of complimentary approaches may be needed to sufficiently resolve Central Valley salmonid stock identification and provide the information necessary for managers and operators to effectively evaluate flow options, barrier operations, predator control measures and other conservation actions.

> *Level of Certainty this Information*: HIGH that new genetic tools will improve our ability to identify different races of Chinook salmon.
>
> *Relevance*: An accurate identification method is needed to eliminate the uncertainty regarding ESA status of fish captured in monitoring programs and could eliminate the need to use surrogates or juvenile production estimates to evaluate whether take is near an operational trigger for water project operations. A more accurate identification method will also allow more accurate elucidation of run-specific population size, migration patterns and migration cues, which will in in turn improve the ability to predict and plan for water project operational constraints.

1.6.2 Telemetry and Tagging

In addition to promising results from the genetics field for identifying salmon run type and stock, new tools in telemetry are also likely to afford new insights into salmon use of the Estuary in the future. As discussed above, studies to date have been extremely helpful in providing information on how smolt-sized salmon migration route selection and survival is influenced by flow level and pattern (Perry, 2010; Perry et al., 2010), migration time and the role of environmental factors (Michel et al., 2012) and diel patterns in movement (Chapman et al., 2012). Until recently, tagging technology has been limited to use in smolt-sized salmon and steelhead because the tags have been too large for use in smaller fish. However, new technology will likely open doors for use of acoustic technology in smaller life stages. For example, the Juvenile Salmon Acoustic Telemetry System (JSATS) transmitter has been developed by Lotek, Inc. for monitoring juvenile salmon use of the Columbia River Basin and is already being used in the Sacramento-San Joaquin Delta system in pilot studies.

Level of Certainty this Information: MODERATE-HIGH that new technology will be applied and provide new information on Bay-Delta use by smaller life stages of salmon.

Relevance: Different life stages of salmon may have very different habitat use patterns and migration times/patterns due to different needs for food resources, swimming abilities or whether they are using the Delta as a rearing habitat or simply a migration corridor on their way to the ocean. New acoustic technology that is appropriate for use in smaller sized salmon will shed light on these differences between life stages.

1.6.3 Salmon modeling

Factors contributing to decline of Central Valley Chinook salmon and steelhead populations are known and relatively well understood. However, the relative importance of different factors is uncertain, and this uncertainty diminishes our ability to effectively evaluate alternative management actions. Simulation models provide a framework for organization information regarding the impact of changes in environmental variables (e.g., flow, temperature, exports, harvest, and physical habitat), for quantifying the effects of these changes on the abundance of salmon at each life stage (e.g., development, migration, and maturation), and for evaluating the resulting impact on overall population viability. Both scientists and managers have increasingly recognized the utility of life-cycle models for evaluating salmon population responses to management actions (Ruckelshaus et al. 2002), and a recent review of salmon recovery efforts in California's Central Valley recommended their use (Good et al. 2007). The Interactive Object-oriented Simulation (IOS) model is currently the only Central Valley Chinook salmon life-cycle model that has been published in the peer reviewed scientific literature (Zeug et al. 2012). The range of current models is summarized below.

The Interactive Object-oriented Simulation (IOS) model

The Interactive Object-oriented Simulation (IOS) model is the only life-cycle model that has been specifically designed to incorporate life stages, geographic areas, and influencing factors at a scale closely matching that affected by alternative water management actions. The model was developed by Cramer Fish Sciences (with support from DWR) to simulate the interaction of environmental variables with all life stages of winter-run Chinook salmon in the Sacramento River, the Delta, and Pacific Ocean. IOS has undergone extensive development and interagency review, and has now been peer reviewed and published (Zeug et al. 2012). IOS is the first, and to date only, Central Valley Chinook salmon life-cycle simulation model which has been published and which has been actively used to help plan and evaluate several important projects.

Details of the model are available in Zeug et al. (2012) and in Appendix A. To summarize briefly, fish behaviors modeled by IOS include Emergence (eggs to fry), Rearing, Migration, and Maturation (ocean phase). The IOS model dynamically simulates responses of salmon populations across these model-stages to changes in environmental variables or combinations of environmental variables in the geographical areas specified for each model-stage, and enables scientists and managers to investigate the relative importance of specific environmental variables by varying a parameter of interest while holding others constant; an approach similar to the testing of variables in a laboratory setting. The IOS life-cycle model estimates adult escapement, which is the primary key to population viability over time.

IOS is not a static model, but rather a flexible life-cycle simulation framework which incorporates the best available data- the model is updated continuously as new information and insights become available. IOS is built in a publically available simulation modeling software which enables the simulation of complex processes through creation of simple object relationships and allows users to view model functions and easily make changes to functional relationships as new data or hypotheses become available. IOS model details and calculations are thus transparent to the uses, and knowledge of C++, FORTRAN, or other computer languages is not required to understand or update the model.

Example IOS Application: To demonstrate the utility of the IOS model, four scenarios representing alternative management actions were evaluated by generating 100 Monte Carlo realizations. The management scenarios considered were: (a) baseline with hydrologic conditions and model coefficients as described by Zeug et al. (2012); (b) baseline conditions except with a 1.5^{o} F increase in water temperatures for the spawning life stage; (c) baseline conditions except with a reduction in age-3 and age-4 ocean harvest mortality from 20% to 10% (the most recent winter run Chinook ocean harvest Biological Opinion suggests ocean harvest mortality has been near 20% in recent years); and (d) baseline conditions except with a 5% improvement in survival for those fish entering the interior Delta via Georgiana Slough.

Results from these IOS model runs (see Figure 7) illustrate the considerable stochasticity present in the winter run Chinook salmon population as is fairly typical of all salmon populations. The stochasticity is a result of random variation in many life stage functions, but is particularly driven by variability in smolt to age-2 survival (Zeug et al. 2012). Differences in the relative impact of different management actions are also apparent. Increasing water temperatures during spawning (b) clearly causes the most dramatic change in winter run Chinook spawning escapement over the simulation period. The sensitivity of the winter run population to water temperatures illustrates the importance of managing to protect cold-water pool in Lake Shasta. Changes in rates of ocean harvest also had a fairly dramatic impact on winter run Chinook population trends. Though a 10% reduction in ocean harvest mortality is a hypothetical action, ocean harvest rates are subject to absolute control by managers (unlike hydrologic and ocean productivity factors which are driven by climatic processes) and a recently published study (Pyper et al. 2012) illustrates survival improvements of this magnitude are possible with appropriately managed fisheries. Lastly, improving interior-Delta survival by 5% yielded only slight benefits to winter run Chinook population trends. Since South Delta exports are thought to primarily influence Sacramento Basin fish which enter the interior Delta (via Georgiana Slough or the Delta Cross Channel), this hypothetical management action can be thought of as resulting from habitat enhancements or perhaps reduced export levels. The Delta Passage Model section, provides a more specific analysis of how exports may influence through-Delta survival rates for Sacramento Basin Chinook salmon.

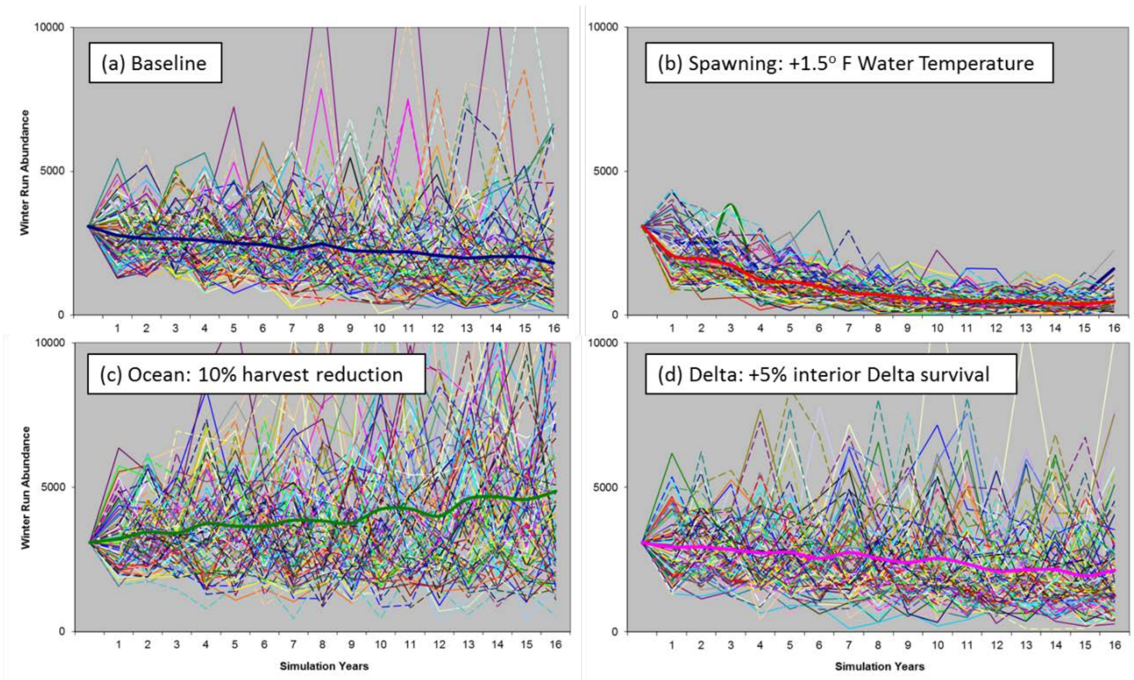

Figure 7. Winter run salmon escapement over 4 generations (16 years) under baseline conditions (a), baseline conditions altered by 1.5 °F temperature increase (b), baseline conditions altered by 10% reduction in age-3 and age-4 ocean harvest (c), and baseline conditions altered by a 5% improvement in interior Delta Survival (d). One hundred Monte Carlo realizations were simulated with the IOS life cycle model for each scenario. The heavy solid line represents mean escapement across all one-hundred realizations.

Delta Passage Model

The Delta Passage Model (DPM) is a stochastic simulation model which was developed by Cramer Fish Sciences to evaluate the impacts of water management actions and conservation measures on the survival of Chinook salmon smolts as they migrate through the Delta. The DPM is not a life-cycle model, but is incorporated as a sub-model in the IOS life-cycle model (described above), comprising the *Delta Passage* model-stage.

A detailed description of the DPM is included in the published IOS life-cycle model (Zeug et al. 2012; see above) and in Appendix A. The DPM is also used as a stand-alone model to analyze Delta survival and routing. To summarize briefly, the DPM simulates migration of Chinook salmon smolts entering the Delta from the Sacramento River, Mokelumne River, and San Joaquin River, and estimates survival through the Delta to Chipps Island. The model can also provide survival estimates for specific reaches or life stages. The DPM can be used to inform which management actions likely have the most benefit for improving smolt survival, as well as locations in the Delta where such actions are likely to have the most benefit—a level of detail which aggregated estimates of survival through the Delta cannot provide. The development of the DPM has been made possible by the results of acoustic tagging studies, which have demonstrated repeatable migration routing patterns at junctions as well as different survival rates among routes.

The DPM utilizes the best available empirical data to parameterize model relationships and inform uncertainty, thereby utilizing the greatest amount of data available to dynamically simulate responses of smolt survival to changes in model inputs or parameters in the model. The DPM is primarily based on studies of late-fall and San Joaquin basin fall run Chinook, but it has been applied to winter-run, spring-run, late-fall run, Sacramento fall-run, Mokelumne River fall-run and San Joaquin fall-run Chinook salmon by adjusting emigration timing and by assuming that all migrating Chinook salmon smolts respond similarly to Delta conditions.

Although studies have shown considerable variation in emigrant size, with Central Valley Chinook salmon migrating as fry, parr, or smolts (Brandes and McLain 2001; Williams 2006), the DPM relies predominantly on data from acoustic tagging studies of large (>140 mm) smolts. Unfortunately, survival data is limited for small (fry-sized) juvenile emigrants due to the difficulty of tagging such small individuals. Therefore, the DPM should be viewed as a smolt survival model only, most applicable to large smolts (>140 mm), with the fate of pre-smolt emigrants not incorporated in the model. The degree to which tagged hatchery fish reasonably represent the behavior of wild fish is not known because ESA concerns limit the use of telemetry on wild fish; nonetheless, the data represent the best available information.

Like IOS, DPM is not a static model, but rather an adaptable simulation framework that can be changed as more data or new hypotheses regarding smolt migration and survival become available.

Example DPM Application: To demonstrate some of the possible applications of the DPM, the following simulations examine through-Delta survival for Sacramento Basin salmon in relation to changing river inflow and South Delta exports. In the first example, exports are varied while holding other model parameters to average values. The simulations suggest that reducing exports from 10,000 to 2,000 cfs, would improve through-Delta survival for migrating fish by less than 2% on average (Figure 8).

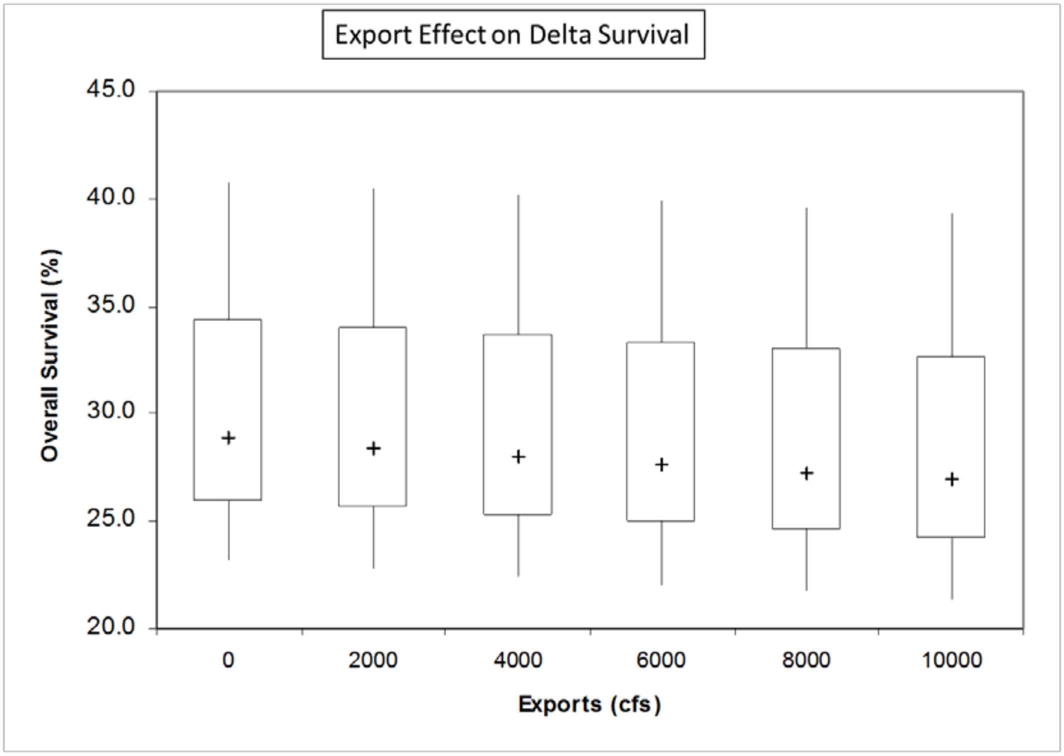

Figure 8. Relationship between through-Delta survival (overall survival %) for Sacramento Basin Chinook salmon and South Delta exports assuming Newman and Brandes (2010) export-survival relationship as implemented in the Delta Passage Model.

As shown in the second example, the model can also be used in a probabilistic approach. The following simulations use various combinations of exports and Sacramento River inflows while holding other model parameters to average values. The model results suggest that Sacramento River inflows can influence through-Delta survival to a much greater extent than exports (Figure 9); a 25% reduction in baseline exports yields little detectible benefit to through-Delta survival. Also, largest improvements in though-Delta survival result from increased Sacramento River inflows, increased exports and combined with hypothetical management actions- these benefits occurred regardless of export levels.

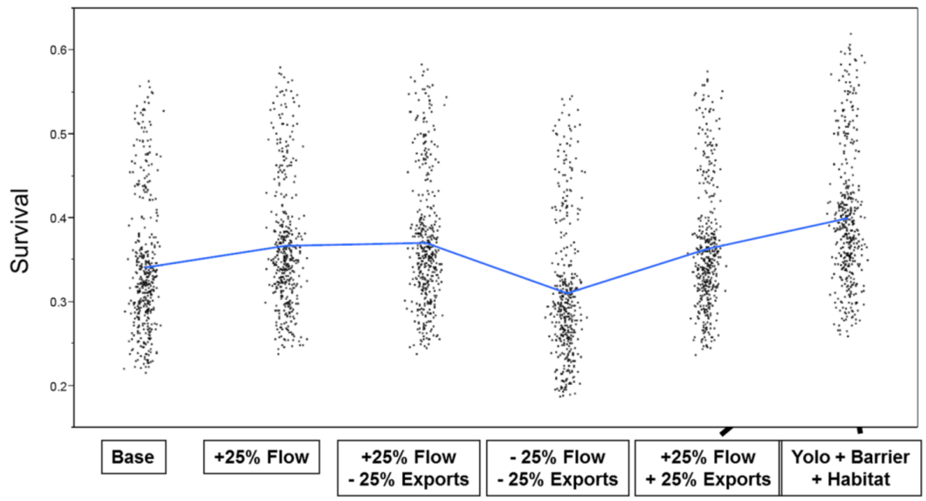

Figure 9. Changes in through-Delta survival with various combinations of exports, Sacramento River inflows, and other management actions as depicted by the Delta Passage Model. Other management actions include increased access to Yolo floodplain (Yolo), non-physical barrier at Georgiana Slough (Barrier), and habitat enhancements in the Sac4 reach (Habitat).

SALMOD Model

SALMOD simulates the effects of habitat changes on freshwater salmon population dynamics. It was developed to link fish production with flow, as described by the Physical Habitat Simulation System (PHABSIM) model. SALMOD was used in the Biological Assessment (BA) for the National Marine Fisheries Service 2009 Salmon BiOp, and is described in the BA as follows:

> "*SALMOD simulates population dynamics for all four runs of Chinook salmon in the Sacramento River between Keswick Dam and RBDD. SALMOD presupposes egg and fish mortality are directly related to spatially and temporally variable microhabitat and macrohabitat limitations, which themselves are related to the timing and volume of streamflow and other meteorological variables. SALMOD is a spatially explicit model in which habitat quality and carrying capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which serve as spatial computation units in the model. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of water temperature in a computational unit. Individual cohorts either remain in the computational unit in which they emerged or move, in whole or in part, to nearby units. Model processes include spawning (with redd superimposition), incubation losses (from either redd scouring or dewatering), growth (including egg maturation), mortality due to water temperature and other causes, and movement (habitat and seasonally induced). SALMOD is*

organized around physical and environmental events on a weekly basis occurring during a fish's biological year (also termed a brood year), beginning with adult holding and typically concluding with fish that are physiologically "ready" to begin migration towards the ocean. Input variables, represented as weekly average values, include streamflow, water temperature, and number and distribution of adult spawners." (BOR 2008, p.9-25)

SALMOD does not simulate the influence of environmental variables on salmonid population dynamics during the river migration, Delta migration, or ocean maturation phases of the salmonid life cycle. Thus, SALMOD is not used to estimate adult escapement; the primary key to population viability over time. It should be noted that the life stages and geographic areas addressed by SALMOD are contained and described in the IOS life-cycle model using similar functional relationships.

OBAN Model

The Oncorhynchus Bayesian Analysis (OBAN) is a statistical model developed by Hendrix (2008) and used to quantify uncertainties in potential outcomes and long-term population viability due to variations in environmental conditions, but not to compare population effects at the spatial and temporal scale of specific management actions. OBAN is described in a recent NMFS review of salmon life-cycle models (NMFS 2012a) as follows:

"*OBAN is statistical life cycle model that includes life stages based on a Beverton-Holt function. OBAN defines the transformation from one life stage to the next in terms of survival and carrying capacity. Unlike the mechanistic models, it does not consider the timing of movement between stages or habitats. Additionally, the survival and carrying capacity parameters are determined by a set of time varying covariates. There is no specific mechanistic relationship between the parameters and the survival and carrying capacity. The weighting terms for the influence of environmental covariates on the Beverton-Holt functions are established by fitting the model to spawner recruit data." (NMFS 2012a, p.5)*

Unlike the IOS life-cycle model, OBAN does not compare population effects at the spatial and temporal scale of specific management actions. Also, to the best our knowledge the OBAN model has not been published in a peer reviewed scientific journal, and no detailed description of model relationships or coefficients is currently available.

NMFS Life-cycle Model

The National Marine Fisheries Service (NMFS) has recently proposed the development of a new life-cycle model for Central Valley salmonids. After holding a June, 2011 Independent Panel Workshop in which existing life-cycle models were reviewed, NMFS concluded that none of the existing models were sufficiently well suited for their use in supporting the OCAP and BDCP

Biological Opinions. An important consideration in this decision was the perceived need for complete ownership and control of the model (NMFS 2012a, p.17). To that end, NMFS proposed the development of their own life-cycle model for winter-run Chinook. The proposal was completed in February 2012 and conveyed to the Bureau of Reclamation and the California Department of Water Resources in March 2012. The initial model is to be completed and available for use by NMFS to evaluate OCAP RPA actions by December 2013. NMFS' approach to the new life-cycle model is summarized in the proposal as follows:

> "*The NMFS life-cycle model needs to be able to translate the effects of detailed water project operations into population effects. There are at least two ways this might be approached: 1) a brand-new coupled physical and individual-based biological simulation model or 2) linking existing physical models to a population-level stage-structured life-cycle model through state-transition parameters that are a function of the environment (as described by the physical models). We are pursuing the latter strategy because we are more certain it will yield useful products in time for the OCAP and BDCP processes, and because it will be easier to analyze, understand and explain model outputs.*
>
> *Our work will proceed on four fronts—development and refinement of the life-cycle modeling framework; application, improvement and integration of physical models; development of linkages between physical model outputs and stage-transition parameters; and assembly of data sets needed to determine the physical-biological couplings and assess overall model performance. Periodically, we will integrate work in these four areas to produce assessment tools ("life-cycle models") that can address increasingly complex management scenarios. Along the way, we will work with interested parties (especially agency staff responsible for the BiOps) to guide development, through periodical workshops and webinars. We will deliver working models, analyses of select scenarios, documentation, and peer-reviewed publications." (NMFS 2012a, p.3)*

The development of the NMFS life-cycle model is just beginning and an initial draft model is over a year from completion. The use of available models such as IOS and OBAN is necessary for the current evaluation and planning of management actions, and to provide important feedback for the development and use of future models such as the proposed NMFS life-cycle model.

> *Level of Certainty*: Low/Medium/High. As noted above, the relative importance of different factors is uncertain, but simulation models provide way to organize information regarding the impact of changes in environmental variables and management actions. Hence, the all the models described contain information with varying levels of uncertainty.

Relevance: Life cycle models represent the best available and future tools to examine the effects of different management actions on the various life history stages of Chinook salmon.

1.6.4 Progress on predation research

Like most species, predation is a major source of mortality for early life-stage salmonids. While consumption by predators is, for the most part, just the end result of the interplay between multiple stressors that weaken fish condition, understanding predation can still provide useful insights to inform conservation decisions. While not directly examining predation, Perry et al. (2010) found highly variable survival rates across several different migration routes through the delta. They found, across two separate releases, that survival was highest in the main stem Sacramento River, while survival was highly variable for north delta (Sutter and Steamboat Sloughs) and central delta (Delta Cross Channel and Georgiana Slough) migration routes. Cavallo et al. (2012) sought to elucidate the effects of predatory fishes on salmonid survival through predator removal experiments (BACI design), and found that juvenile salmonid survival significantly increased after an initial predator removal. However, a second predator removal showed a drastic compensatory increase in the density of predators from the first removal and no subsequent increase in salmonid survival was observed, illustrating the relatively short term benefits of predator removal. Regardless, before and after the first predator removal, the reach survival of their juvenile salmon increased from <80% to >99%, respectively, despite a decrease in salmon survival in the control reach.

New results from bioenergetics modeling efforts on the SFE's striped bass population suggest a robust population of sub-adult striped bass (Loboschefsky et al. 2012) despite the declining trend in young of the year striped bass (Sommer et al. 2007). Sub-adult striped bass are likely major predators of juvenile salmon as they occur in both inshore and offshore habitats and are known to feed on juvenile salmon when they are abundant (Nobriga and Feyrer 2007). Loboschefsky et al. (2012) also found that total, population-level prey fish consumption by adult and sub-adult striped bass were roughly equivalent, indicating that sub-adult striped bass represent a significant source of mortality for native fishes like juvenile salmon.

Level of Certainty: MEDIUM

Relevance: Research to date has yet to quantify the impact of in-Delta predation on the recruitment success of salmon, but research clearly indicates that predation plays a large role in the survival rates of out-migrating juvenile salmon. Further work is needed to elucidate specific geographic areas and predator species which are of highest concern to juvenile salmon survival. Additional work on the interplay between exports and predation losses in the Delta is also needed.

2.0 <u>Pelagic Fishes</u>

The latest information regarding pelagic fishes was covered extensively in Department of Water Resources Workshop #1 contribution. Although the focus of Workshop 1 was the Low Salinity Zone (LSZ), most of the material discussed was of direct relevance to Workshop 2. Some of the highlights of recent progress on pelagic fishes include the following. Detailed information about these topics can be found in our original contribution. Some of the most relevant sections are provided below for reference.

- *There has been significant recent progress in understanding the physics, chemistry, and biology of the LSZ (DWR Workshop 1 Contribution: Section 1).*
- *The key mechanisms for LSZ effects and their relative importance remain elusive. For this reason, it continues to be difficult to identify the relative importance of LSZ position (i.e. flow) management in relation to other stressors (DWR Workshop 1 Contribution: Section 1.2.3).*
- *Key adverse changes to the ecosystem include: contaminant inputs (e.g. ammonia, pesticides), long-term decreases in the sediment load (i.e. turbidity), the proliferation of invasive species including SAV and predators, harmful algal blooms, and a radical change in the food web (DWR Workshop 1 Contribution: Sections 1.2.4-1.4.4; 2.0).*
- *The evidence suggests that many of the pelagic resources of low salinity zone have declined substantially, although responses in 2011 and early 2012 suggest that there is still some resilience (DWR Workshop 1 Contribution: Section 1.2.2).*
- *FLaSH results from 2011 and early 2012 showed improved delta smelt numbers, but the relative contribution of higher flow in fall 2011 remains inconclusive (DWR Workshop 1 Contribution: Section 1.2.2).*
- *Areas outside of the low salinity zone (e.g. North Delta complex) including Liberty Island and Cache Slough are much more important than previously understood (DWR Workshop 1 Contribution: Section 1.1.3).*
- *Many of these factors affecting the ecosystem are difficult to manage (DWR Workshop 1 Contribution: Section 4).*

Suggested near- to long-term actions:

- *Continued research to examine the mechanisms by which these factors affect aquatic species and their habitat.*
- *Implement regulations to decrease loading of key contaminants.*

- *Develop response plans for specific changes such as invasive species (see below)*
- *Continued research to examine the mechanisms by which flow may affect aquatic species.*
- *While much remains to be learned, there appears to be enough information to justify large scale restoration projects if an adaptive management approach is used.*

3.0 Importance of Climate Change for Future Planning

Take Home Points:

- *Most of the Take Home points are similar to those presented in Workshop #1 (see below).*
- *Salmonids are particularly sensitive to climate change.*

Suggested near- to long-term actions:

- *Programs to improve and protect ecosystem conditions will be most likely to meet their objectives if they are designed to function within altered climatic conditions rather than today's climate and hydrology. For example, Delta planning efforts such as BDCP are being designed to function under a range of future climate conditions—not just the conditions that exist today.*
- *Similar planning is needed for many other aspects of Delta management.*

Climate change effects were discussed in extensive detail in DWR's Workshop 1 materials. Some of the key points included the following. Relevant sections are also provided for key points.

- *Ongoing changes in climate mean that past climate and hydrology alone are unlikely to be good predictors of future conditions (DWR Workshop 1 Contribution: Section 3).*
- *The vulnerabilities of the current system will be exacerbated by climate change—we need to improve our planning for it and take actions that improve the system's resilience to expected changes (DWR Workshop 1 Contribution: Section 3).*
- *Expected major changes include flooding of Delta islands from sea level rise, associated salinity increases in the Delta, earlier snowmelt runoff and changes in hydrology, and increased temperature (DWR Workshop 1 Contribution: Sections 3.1-3.3).*
- *Temperature increases are a particular concern for sensitive species such as delta smelt (DWR Workshop 1 Contribution: Section 3.3).*

The expected effects of climate change on pelagic fishes are expected to be similar to those described in our original contribution. Not discussed in our Workshop 1 materials is the sensitivity of salmonids to climate change. As a coldwater species, salmonids are particularly sensitive to temperature changes in spawning habitats, migration and rearing corridors, and marine habitat. One of the most relevant recent studies is by Cloern et al. (2011), who used global climate models to show that there is expected to be a dramatic increase in the number of days with temperatures lethal (>16 C) to winter run Chinook salmon eggs and pre-emergent fry. Similarly, Yates et al. (2009) found that future climatic warming could lead to alterations in the temperature regime for all runs of salmon in the Sacramento River, which could further reduce the already fragmented Chinook habitat. Climate change and associated increases in water temperature may result in excessive spawning and rearing temperatures. Some reservoir operations may help to buffer expected changes, but temperature management is expected to be very challenging particularly for winter and spring runs, which are most at risk because of the timing of their reproduction. While many factors contribute to the increased variability in salmon escapement, there is well-recognized relationship between ocean conditions and salmon survival (Lindley et al. 2009). Some expected due to climate change include higher sea surface temperatures, ocean acidification, changes in circulation patterns, and greater variability in ocean conditions. Recent trends of increasing variability in some of these key climatic indices related to salmon survival have already been observed in the past few decades and have contributed, in part, to the greater variability in salmon escapement (Lindley et al. 2009)..

> *Level of certainty of this Information:*
> MODERATE-HIGH that future runoff and temperature conditions will be different.
> LOW-MODERATE for the specific responses of the biota.
>
> *Relevance to pelagic fishes and salmonid management:* Future temperature increases are expected to result in extreme challenges to the management of delta smelt and salmonids. Changes in runoff amount and/or timing that affect the area of the LSZ and stream flows are highly likely. Operational management to protect these habitats will become more constrained as runoff timing shifts earlier and conflicts with flood control operations at multi-use facilities. Future efforts to protect habitat could have increasingly large trade-offs with other system benefits.

4.0 Recommended Use of BDCP and Related Restoration Activities in Delta Planning

Take Home Points:

- *To address and balance the needs of the diverse assemblage of Delta species, requires a comprehensive approach that takes into account the sometimes competing requirements* *of the Delta's natural resources. Furthermore, flexibility in management actions is of paramount importance in adapting to uncertainty and a changing climate.*

- *BDCP is a comprehensive approach designed to address a suite of stressors to native species and communities*
- *Recognition of the limitations of the current system to respond to needs of declining Delta species necessitates an expansion of the "tool box." BDCP has been developed to address the declining Delta ecosystem*
- *BDCP has relied extensively on the best available scientific information (see above) to develop restoration and operations plans.*
- *The work to date is substantial---staff, resources, information*
- *There is already a major effort to implement restoration projects such as:*
    - *Fish Restoration Program Agreement (FRPA)*
    - *Prospect Island*
    - *Yolo Bypass*
    - *Knaggs Ranch (pilot project to develop monitoring metrics)*

Suggested near- to long-term actions:

- *Support restoration efforts to restore ecosystem processes and improve habitat and life history diversity*
- *Increase studies on the development and application of genetic monitoring to inform management actions*
- *Support efforts to improve hatchery management to decrease impacts to wild populations (e.g. increase the percentage of tagged hatchery fish)*
- *Implement an adaptive management approach similar to the BDCP "Decision Tree" process for the near-term (10 to 15 years prior to dual conveyance) for improving understanding of biological needs for Delta native species. This will have direct application to investigating flow and other protective criteria.*
- *Support investigation and monitoring of near-term restoration actions, 30,000 acres of aquatic habitat in next 15 years*

4.1 Bay Delta Conservation Plan

4.1.1 History of the Bay Delta Conservation Plan

The Bay Delta Conservation Plan (BDCP), under development and refinement since 2006, represents a holistic, ecosystem approach to restore habitat, improve flows for fish, and addresses a myriad of other stressors to fish in the Delta. The BDCP is built upon the best available science, incorporates input from an independent science panel, and draws heavily upon the extensive body of scientific knowledge derived from decades of research and analysis conducted under the CALFED Bay-Delta Program. The BDCP is being developed in compliance with the federal Endangered Species Act, the California Endangered Species Act, and the California Natural Community Conservation Plan and will function to further the achievement of the State's coequal goals of protecting and restoring the Delta ecosystem and providing a more reliable water supply for California.

The BDCP represents a departure from the current species-by-species approach used to regulate the operational impacts of the SWP and CVP on listed species. The BDCP is a joint habitat conservation plan (HCP) and natural community conservation plan (NCCP) that seeks to improve the health of the Delta ecological system using a comprehensive conservation strategy to address the collective impacts associated with the SWP, CVP, and certain existing and anticipated future actions within the area covered by the BDCP. The BDCP takes into account multiple stressors on the ecosystem, the needs of multiple species, and the diverse natural communities that support them, including species listed under the federal and State ESA's as threatened, endangered, or candidates for listing, as well as critical habitat, if any, designated for these species.

Although the plan will cover terrestrial communities and species, it is focused on the aquatic system, and has been specifically designed to address delta and longfin smelt, Chinook salmon (winter, spring, fall and late-fall runs), Central Valley steelhead, Sacramento splittail, green and white sturgeon, and Pacific and river lamprey. The BDCP aims to enhance the Delta's ecosystem processes and function, including seasonal floodplain habitat, intertidal and associated subtidal habitat, hydrologic conditions, and salinity within the Delta estuary, as well as a focus on reducing the direct loss of fish and other aquatic organisms. Specific problems to be addressed include the reconnection of floodplains, the development of new tidal marsh habitat, the restoration of river banks to a more natural state, invasive species control, decreasing water toxicity levels, and aligning water operations to better reflect natural seasonal flow patterns. The BDCP approach does not necessarily conflict with efforts to restore more natural flow regimes, but it is designed to address a broader suite of stressors that will continue to undermine the recovery efforts of less comprehensive strategies.

The goals of the BDCP include creation of 30,000 acres of aquatic habitat over the next 15 years. In all, over its 50-year term, the BDCP calls for up to 113,000 acres of habitat restoration, including 65,000 acres of tidal marsh restoration, 10,000 acres of seasonally inundated floodplain, 5,000 acres of riparian restoration, and 20 miles of channel margin enhancement. Reconnecting floodplains, developing new marshes, and returning riverbanks to a more natural state should boost food supplies and cover for fish throughout the Delta. More information related to the BDCP, including current Plan documents, can be found at the at the BDCP website: http://baydeltaconservationplan.com

4.1.2 Bay Delta Conservation Plan Conservation Strategy

Although the BDCP is not final, and further development and coordination will continue, considerable headway has been made. A recent draft document, State and Federal Principals Joint Recommendations Regarding Key Elements of the Bay Delta Conservation Plan (http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/July_16_2012_Joint_Recommendations_Working_Draft.sflb.ashx) summarizes important information including actions needed to achieve the two coequal goals of providing more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. This draft document further summarizes information such as governance structure, the adaptive management program, aquatic species goals and objectives, and the near-term "decision tree" process. The "decision tree" process is discussed in the document in section 4.1.2.5. The State and Federal Joint Recommendations draft document reflects the current direction of plan development, informed by ongoing efforts, such as the BDCP Effects Analysis, and independent science reviews.

4.1.2.1 Goal of the Conservation Strategy: Approach to Recovery

Fundamental to the development of the BDCP is a recognition of ecosystem driver relationships to natural resources, the complexity of their interactions, how they have been altered through time, and a scientifically based approach to restore those resources of value. Central to this approach is the recognition that functional relationships between key drivers, such as flow regime, and native Delta fish have been eroded, and must be restored to recover declining populations. This requires the use of new tools, beyond those which have been relied on to date with limited success, to respond to known stressors and a dynamic environment. Achieving desired ecosystem outcomes will require more than manipulation of a single ecological stressor. The physical and biological complexities of the Delta ecosystem argue against simplistic single-factor solutions. Restoration of ecosystem health will require more holistic approaches (Baxter et al. 2010). This approach is built on the best available science and takes into account the utility of management tools, such as reducing entrainment and sustaining flows necessary to provide biological benefits, but also recognizes the need to provide additional, integrated measures to recover declining native Delta species. This effort relies on a systematic approach to capitalize on improvements in our knowledge regarding natural communities and the biology of covered species, and move forward despite uncertainty. The conservation strategy provides for the conservation and management of a substantial number of fish, wildlife, and plant species, as well as a variety of natural communities. The conservation strategy is based on the best available science and was built upon the following broad conservation goals (BDCP 2012a):

- Increase the quality, availability, spatial diversity, and complexity of aquatic habitat within the Delta.
- Create new opportunities to restore the ecological health of the Delta by modifying the water conveyance infrastructure.
- Directly address key ecosystem drivers in addition to freshwater flow patterns rather than manipulation of Delta flow patterns alone.
- Improve connectivity among aquatic habitats, facilitate migration and movement of covered fish among habitats, and provide transport flows for the dispersal of planktonic material (organic carbon), phytoplankton, zooplankton, macroinvertebrates, and fish eggs and larvae.
- Improve synchrony between environmental cues and conditions and the life history of covered fish and their food resources within the upstream rivers, Delta, and Suisun Bay, including seasonal water temperature gradients, salinity gradients, turbidity, and other environmental cues.
- Reduce sources of direct mortality, and other stressors, on the covered fish and the aquatic ecosystem within the Delta.
- Improve habitat conditions for covered fish within the Delta and downstream within the low salinity zone of the estuary in Suisun Bay through the integration of water operations with physical habitat enhancement and restoration.
- Avoid, minimize, and mitigate adverse effects on terrestrial wildlife and plants resulting from implementation of measures to benefit aquatic species.
- Expand the extent and enhance the functions of existing natural communities and habitat of covered wildlife and plants that is permanently protected.
- Restore habitat to expand the populations and distributions of covered wildlife and plant species.
- Emphasize natural physical habitat and biological processes to support and maintain species covered by the Plan (i.e., covered species) and their habitat.

4.1.2.2 The Conservation Strategy is Based on the Best Available Science

The BDCP conservation strategy sets out a comprehensive set of conservation measures that are designed to meet a range of identified, measurable biological goals and objectives (BDCP 2012b). The proposed conservation measures include certain actions to improve flow

conditions, increase food production, restore habitat, and reduce the adverse effects of other stressors. The BDCP conservation strategy also recognizes that, as new information and insights are gained during the course of plan implementation, alternative strategies can be employed to respond to uncertainty and advance the biological goals and objectives of the plan. It is possible that some of the criteria and targets established for BDCP conservation measures will prove inadequate, while others will produce better results than expected. To effectively address uncertainties and realize the benefit of new scientific understanding, the BDCP conservation strategy includes an adaptive management program that provides for flexibility in the implementation of the Plan's
conservation actions.

The conservation strategy of the BDCP is built upon and reflects the extensive body of scientific investigation, study, and analysis of the Delta compiled over several decades including:

- Results and findings of numerous studies initiated under the California Bay-Delta Authority (CALFED) Bay-Delta Science Program (now the Delta Science Program) and Ecosystem Restoration Program

- Long-term monitoring programs conducted by the Interagency Ecological Program

- Research and monitoring conducted by state and federal resource agencies

- Research contributions of academic investigators

The development of the BDCP has also been informed by a number of other recent reports and reviews on the Delta, including:

- Reports from the Governor's Delta Vision Blue Ribbon Task Force (January and October 2008)

- Reports from the Public Policy Institute of California (Lund et al. 2007, 2008)

- Reviews by the National Research Council (National Research Council of National Academies 2011).

- Review and report of the Effects Analysis and related appendices from an Independent Science Panel (October and November 2011; May and June 2012)

To ensure that the BDCP would be based on the best information available, the Plan participants engaged in a rigorous process to develop new and updated information and to evaluate a wide variety of issues and approaches as it formulated a cohesive, comprehensive conservation strategy. This effort included a 2009 evaluation of BDCP conservation options using the modified version of the CALFED Bay–Delta Ecosystem Restoration Program's Delta Regional Ecosystem

Restoration Implementation Plan (DRERIP) evaluation process (Essex Partnership 2009). The planning process also uses independent scientific advice at several key stages of the planning process, enlisting well-recognized experts in ecological and biological sciences to produce recommendations on a range of relevant topics.

4.1.2.3 A Suite of Conservation Measures will ensure the BDCP Accomplishes the Goals and Objectives Outlined

The Conservation Strategy has been developed to address many of the known stressors currently limiting native species production, and has specific biological goals and objectives which have been designed to contribute to the recovery of the covered species. Conservation measures were developed to meet landscape-scale, natural community, and species-specific goals and objectives. The conservation strategy includes several types of conservation measures, described below:

- Measures that provide for the development and operation of new water conveyance infrastructure and the establishment of operational parameters associated with both existing and new facilities.

- Habitat protection measures that protect existing functioning natural communities that are not currently protected.

- Habitat restoration/creation measures that restore specific natural communities in areas that do not currently support those communities.

- Habitat enhancement measures that improve existing habitat functions within existing natural communities.

- Habitat management measures that provide for ongoing management of natural communities and habitat to maximize the functional values of BDCP conservation areas over the long term.

- Measures to address other stressors that reduce the adverse effects on covered fish species that result from specific stressors such as predation, toxic constituents in water, or sediment, and illegal harvest.

- Avoidance and minimization measures that ensure that adverse effects of covered activities on covered species are avoided or minimized to the maximum extent practicable.

All conservation measures have been developed at a sufficient level of detail and specificity to ensure their implementation. Because the BDCP is broad in scope and has an extended timeframe for implementation, many of the measures have the flexibility needed to accommodate changes in conditions and methods over time.

Habitat Availability for Salmonids and Pelagic Fishes, Specific BDCP Conservations Measures, and Current Efforts Addressing Habitat

It is important to note that when considering the concept of habitat, it should be done in the context of individual species. As discussed earlier, there is substantial evidence that reductions in access to critical rearing habitats for emigrating salmonids has likely played a major role in undermining the abundance, diversity, and viability of Central Valley populations. Floodplain, tidal marsh, and channel margin restoration under BDCP are intended to represent a major contribution to recovering these stocks. Furthermore, degradation and changes in the Delta ecosystem have likely resulted in shifts in habitat and food abundance and quality for pelagic species. Habitat restoration may provide the most promising approach to recovering these species. Given the likelihood of future changes such as increasing temperatures based on climate change projections, the already fragmented habitat currently available in the Delta may be further degraded. Expanding available habitat is one of the best mechanisms to adapt to this likely scenario.

The BDCP Conservation Strategy relies heavily on large-scale restoration of a variety of tidal wetland habitats distributed throughout the Delta. Over the past 150 years approximately 90% of tidal freshwater and saltwater marsh has been lost from the Sacramento-San Joaquin Delta and San Francisco Bay. The loss of tidal wetland habitat, including seasonally inundated floodplains, subtidal and intertidal freshwater and brackish marsh, and shallow channel margin habitats, has contributed to a shift in the Delta ecosystem and in the biota it supports. The loss of this habitat has contributed to the decrease in abundance and life history diversity of Central Valley salmonids. A growing body of evidence shows that tidal wetlands comprise one of the most important habitat types for migrating and rearing salmon (Shreffler et al. 1990; Bottom et al. 2005a,b; Miller and Simenstad 1997). Restoration of tidal and floodplain habitat has been identified as an important conservation tool to assist in restoring ecosystem functions to benefit native aquatic species of concern (Simenstad and Cordell 2000; California Department of Fish and Game 19 2010; Clipperton and Kratville 2009; Sommer et al. 2001; Moyle 2008; and others). Restoring these, and other natural communities, is intended to expand available habitat for desired species, and support an overall increase in Delta productivity.

BDCP will add an estimated 65,000 acres of tidal environments, 20 – 40 miles of channel margin habitat, and increase the frequency and areal extent of available floodplain habitat distributed throughout the Delta, over the 50 year permit period. This newly created aquatic habitat is intended, and will be designed, to increase production on a large enough scale to provide population level benefits to a variety of native species such as delta smelt and longfin smelt, and specifically for rearing and migrating juvenile salmonids. Effectiveness monitoring will rely on a variety of metrics, including use of newly created habitats by covered species and invasives, production and transport of food from within restored areas, as well as in measurable proximate and ultimate improvements to target species (e.g. growth, survival).

In addition to direct benefits, such as enhanced rearing opportunities, this approach is intended to increase spatial diversity and complexity of salmon habitats and provide for alternative/ redundant migration routes and rearing areas to support life-history diversity and hedge against localized stressors. While many stessors are beyond the scope of BDCP, such as loss of upstream spawning and rearing habitat, deleterious impacts from hatchery fish and poor ocean conditions will continue to pose challenges to recover Central Valley salmon. Restoration of habitat and ecosystem processes in the Delta is a critical step in alleviating current limitations on production and viability.

Although the habitat needs for pelagic species, such as delta smelt and longfin smelt, differ from those of salmonids, direct benefits as a result of habitat restoration is being designed to provide benefits for these species. There is a growing body of knowledge regarding other physical variables that influence delta smelt occurrence. Given the current understanding of the habitat needs of delta smelt and the geographic regions that support them, large scale restoration efforts offer a promising management tool for recovering the species.

Conservation Measures (CM) designed to specifically meet habitat needs are:

- **CM 2 Yolo Bypass Fishery Enchancement** – The BDCP proposes to plan and implement actions to enhance fish habitat by modifying the hydrology to improve the timing, frequency, and duration of inundation.

- **CM 3 Natural Communities Protection** – Provides the overarching mechanism to meet the goals for each natural community group and acreage targets as described in other conservation measures, including guidance for the acquisition of lands and establishment of a preserve system. This would help in providing connectivity among the various conservation land units.

- **CM 4 Tidal Habitat Restoration** – Restores up to 65,000 acres of freshwater and brackish tidal habitat including shallow subtidal aquatic habitat, tidal mudflat habitat, tidal marsh plain habitat, and adjoining transitional upland habitat.

- **CM 5 Seasonally Inundated Floodplain Restoration** – Restores up to 10,000 acreas of seasonally inundated floodplain. The most promising opportunities will be based on benefits to covered fish species, practicability considerations, and compatibility with potential flood control projects.

- **CM 6 Channel Margin Habitat Enhancement** – Enhance channel margin habitat by improving channel geometry and restoring riparian, marsh, and mudflat habitats along levees.

- **CM 7 Riparian Habitat Restoration** – Restore riparian forest and scrub, in association with the restoration of seasonally inundated floodplain, tidal, and channel margin habitat.

Yolo Bypass Planning – BDCP Planning efforts in conjunction with Other Projects

As the largest floodplain in the Sacramento River basin, the Yolo Bypass presents the best opportunity for off-channel rearing habitat. Sommer et al. (2001) and Jeffres et al. (2008) present convincing data that indicate the value of floodplains as juvenile salmonid rearing habitat, leading to accelerated growth when compared with fish that remain in-channel. Juvenile survivability likely improves with size, due to an increased ability to evade predation. Greater sized fish at ocean entry should also translate into greater survival in the marine environment. Sommer et al. (2005) suggest that CWT data from fish releases in 1998 indicate potentially higher survival of floodplain fish, compared to their Sacramento River counterparts.

Currently, during high Sacramento River stages, the Yolo Bypass floods and provides juvenile salmonid access to beneficial rearing habitat. DWR, works with USBR to comply with the NMFS Biological Opinion (2009) and in conjunction with the BDCP efforts, seeks to expand the frequency and duration of access to flooded habitat. Furthermore, the effort will target timing of floodplain inundation that closely aligns with the presence of natural juvenile salmonids. Access to flooded habitat will be limited by available hydrology and the ability to inundate the Yolo Bypass, which is generally at a higher elevation than the Sacramento River stage. Approximately 52% of water years from 1906-2010 had less than average precipitation according to water-year type (DWR 2011). Such conditions increase the difficulty of targeting specific periods and conditions for inundation. Also, climate change is expected to result in more frequent critical water-year types (Van Rheenen et al. 2004), which will further complicate targeting these periods and providing optimal conditions. Despite these constraints, it is expected to increase access to rearing habitat and improve survival rates of juvenile salmonids.

The Yolo Bypass' primary purpose is flood control, however the majority of land is managed for agriculture. Any plan for increasing access to rearing habitat will have to minimize impacts to crops within the bypass. Currently DWR is partnering with USBR and UC Davis to conduct studies on the value of rearing salmon in various land uses.   In addition to this study, various tools will be used to inform design and adaptive management of Yolo Bypass restoration.

Two-dimensional models will be used to assess how potential changes to inundation will affect rearing habitat within the Bypass. These models will increase understanding of the horizontal movement of water across the Bypass, and will be used to determine how well these changes fulfill particular project objectives. These objectives include; increasing acreage of seasonal rearing habitat for biologically appropriate duration, minimization of stranding within the bypass, and increasing primary and secondary productivity within the bypass. Other longer-term benefits to juvenile salmonids will also be assessed.

Mark- recapture studies will be used to help determine survival rates of fish reared on the floodplain. PIT tags and/or telemetry could potentially be used to measure survival of juvenile fish through the bypass. Coded-wire tags may also be used to quantify survival through the bypass and to assess survival to adulthood. Work being conducted by Rachel Barnett-Johnson (USBR) to determine if there is an isotopic signature to Yolo Bypass reared fish could also be used to measure survival to adulthood.

Life-cycle modeling will also be used, in combination with these other methods, to determine population level effects of restoration projects on salmonids. Life-cycle models are important to help identify the potential bottlenecks in the system, and how projects are alleviating those bottlenecks. In addition, they are a means to assess abundance and productivity, which are two of the four parameters used to assess salmonid population viability identified by McElhany et al. (2000). These four criteria (the other two are diversity and population spatial structure) have become central to restoration of salmonid populations throughout the Central Valley.

Pelagic Species Planning – BDCP Planning Efforts in Conjunction with Other Projects

Following the Pelagic Organism Decline, fisheries monitoring data from the low salinity zone (LSZ) has shown an apparent shift in the occurrence of the populations of delta smelt, to fresher regions, and longfin smelt, to saltier regions (further discussed in DWR Workshop 1 submittal). This may reflect a behavioral response to move away from less productive areas such as the LSZ, and take advantage of habitats with higher quality and more abundant food. Creation of new tidal and associated subtidal habitat has the potential to provide direct benefits to delta smelt and longfin smelt.

Liberty Island, which became tidal habitat after flooding in 1997, has been colonized and now supports delta smelt year round in relatively high abundance (see DWR Workshop 1).

The Cache Slough region has also supported large numbers of longfin smelt in winter and spring. There is evidence that restoration of tidal habitat, when properly designed, can enhance local primary and secondary production and can also provide subsidies, through transport, to adjacent pelagic and downstream habitats. Additional restoration throughout the Delta, and expansion of tidal marsh availability in the Suisun region is intended to enhance the aquatic food web and support greater production of delta and longfin smelt.

The BDCP will have specific objectives to meet the goals of increased abundance and long-term population viability of delta and longfin smelt. These objectives are logically linked to actions that are designed to increase the availability and quality of food and habitat for these species, as well as actions designed to reduce entrainment at project diversions. Furthermore, these objectives include measurable targets that can be used to ascertain the effectiveness of the actions and inform adaptive management.

4.1.2.4 Implementation of BDCP will ensure that the BDCP Goals are accomplished effectively

The implementation structure is designed to ensure that sufficient institutional expertise, capacity, resources, and focus are brought to bear to accomplish the goals and objectives of the BDCP, that the entities receiving regulatory authorizations are accountable to those agencies granting the regulatory authorizations, and that the decision-making process regarding the implementation of the Plan is transparent and understandable to the public. It will also help ensure effective and efficient plan implementation and ongoing compliance with the terms and conditions of the Plan and its associated regulatory authorizations. The BDCP sets out a plan and schedule for implementation has been developed to help ensure that (BDCP 2012c):

- Key conservation actions occur early in the permit term to offset expected effects of covered activities and meet the NCCPA requirement for rough proportionality of effects and conservation.

- Conservation actions occur by the implementation deadlines established in the conservation strategy

- Conservation actions occur on a feasible schedule and allow adequate time for landowner negotiation for acquisition, project planning, permitting, funding, design, and construction.

- Related conservation actions or covered activities are grouped together or in the proper sequence.

- Require natural community protection and restoration to occur in almost every time period to ensure that progress is always being made toward the total conservation requirement in year 40.

Stressors to fish populations will be addressed by Conservation Measures in the BDCP

A variety of stressors have been implicated in the declines in fish populations in the Delta, among which are declining physical habitat quality and availability, impaired water quality, reduced ecosystem productivity, increased predation, and general effects related to ecological interactions with a wide variety of nonnative organisms. Biological goals and objectives for the covered fish species focus on aquatic environmental stressors and their effects on fish populations. The information provided here reflects the stressors that have been identified within the BDCP for covered pelagic and salmonid species (BDCP 2012d). Additional information can be found at: http://baydeltaconservationplan.com/Home.aspx

<u>Stressors to salmonids include</u>:

- Reduced staging and spawning habitat
- Reduced rearing and out-migration habitat
- Predation by nonnative species. Predation
- Commercial and Recreational Harvest
- Reduced genetic diversity and integrity
- Entrainment
- Exposure to toxins
- Increased water temperature

<u>Stressors to delta smelt include</u>:

- Reduced food availability
- Reduced rearing habitat
- Elevated water temperature
- Reduced turbidity
- Reduced spawning habitat
- Nonnative species
- Entrainment
- Exposure to toxins

<u>Stressors to longfin smelt include</u>:

- Reduced spawning habitat

- Reduced access to rearing habitat
- Reduced food availability
- Nonnative species
- Reduced turbidity
- Reduced food quality
- Entrainment
- Exposure to toxins
- Predation
  Elevated water temperature

As discussed in the BDCP Conservation Strategy (BDCP 2012e), the principal conservation measures that address stressors to fish species are listed below:

- **CM1 Water Facilities and Operation** - New North Delta intakes with state-of-art fish screens to provide greater operational flexibility, reducing reliance on South Delta exports.

- **CM13 Invasive Aquatic Vegetation Control -** Provides for the control of *egeria*, water hyacinth, and other invasive aquatic vegetation throughout the Delta

- **CM14 Stockton Deep Water Ship Channel Dissolved Oxygen Levels –** Funds the continued operation of the Stockton Deep Water Ship Channel aeration facility to increase the concentrations of dissolved oxygen in the San Joaquin River

- **CM15 Predator Control -** Will reduce populations of predatory fishes and eliminate or modify holding habitat for predators at locations of high predation risk

- **CM16 Nonphysical Fish Barriers –** Installs and operates nonphysical fish barriers that will improve the survival of outmigrating juvenile salmonids by redirecting juvenile fish away from channels and river reaches that have high mortality risk

- **CM17 Illegal Harvest Reduction** – Funds increased enforcement of fishing regulations in the Delta and bays to reduce illegal harvest of covered salmonids and sturgeon.

- **CM19 Urban Stormwater Treatment -** Provides a mechanism and funding for the implementation of stormwater treatment projects in urban areas that will result in decreased discharge of contaminants to the Delta.

- **CM20 Recreational Users Invasive Species Program -** Funds a program designed to implement actions to prevent the introduction of new aquatic invasive species and reduce the spread of existing aquatic invasive species

- **CM21 Nonproject Diversions** – Funds removal, consolidation, relocation, or screening of nonproject water diversions in the Delta

Most of the above conservation measures are evaluated by monitoring actions at the landscape and natural community levels. Monitoring actions specific to covered fish species will evaluate progress towards achieving the fish species biological objectives by tracking population status indicators using methods such as midwater trawls and screw trap collections, counts of entrained and salvaged fish, or counts of stranded fish.

4.1.2.5 Future Conditions are Uncertain, but Long-Term Monitoring, Adaptive Management Strategies, and Flexibility will allow for a Response to those Changes

As a component of the BDCP conservation strategy, the BDCP adaptive management and monitoring program is designed to use new information and insight gained during the course of Plan implementation to develop and implement alternative strategies to achieve the biological goals and objectives more effectively. It is possible that the some of the BDCP conservation measures will be unable to achieve the relevant goals and objectives, while others will produce better results than expected. The adaptive management process will afford the flexibility to allow for substantial changes to be made to the conservation measures to improve the effectiveness of the Plan over time. Monitoring and research will be used to measure Plan effectiveness as well as to assess uncertainties and improve understanding of Delta ecosystems. A detailed monitoring and research plan that identifies specific metrics and protocols will be developed during Plan implementation.

Designing and implementing a logistically feasible, scientifically sound, and technically effective adaptive management and monitoring program is a complicated task. In this light, the adaptive management and monitoring program has been designed to provide sufficient guidance and direction to ensure that it can be implemented and modified through time both to meet the appropriate regulatory standards and, as appropriate, to take advantage of information obtained from existing and ongoing scientific efforts. Some of the monitoring actions that will provide the information necessary include:

- **Compliance monitoring actions**. These actions will provide basic information necessary to track Plan actions and compliance with permit terms and conditions.

- **Effectiveness monitoring actions**. These actions will provide information about the state of the ecosystem. It includes baseline monitoring and status monitoring, and thereby allows determining changes in ecosystem state after conservation measures are implemented, as well as identifying long-term trends in ecosystem condition. The information can be used to assess the response of the ecosystem, natural communities, and covered species, and progress toward achieving the Plan's goals and objectives over time.

- **Research actions.** These actions will address specific scientific questions regarding covered species, natural communities, and landscape-scale processes so that conservation measures can be adaptively implemented to advance biological goals and objectives

BDCP Decision Tree and Adaptive Management

Under the BDCP Adaptive Management Program Plan, a "Decision Tree" process is currently in review and being discussed among federal and State agencies. The purpose of the "Decision Tree" is to provide information to help answer several key outstanding scientific questions. These questions relate to achieving biological goals and objectives that affect how much water may be delivered from the Delta. Depending on the results of the decision tree process, parameters may be adjusted, and the amount of water available for export or needed for outflows could go up or down. Information presented in this document regarding the "decision tree" can be found at:
http://baydeltaconservationplan.com/Libraries/Dynamic_Document_Library/August_BDCP_Public_Meeting_Presentation_8-29-12.sflb.ashx

The decision tree process will focus to refine the initial operating criteria and would be in effect until a new conveyance facility is built and ready for operations, perhaps 10 or 15 years from now. Flexibility does not end at that point, however. Once the conveyance facility is operational, the adaptive management program plan will continue.

A "Decision Tree" is a visual and analytical support tool that prescribes a decision based upon explicit criteria and is being considered for spring and fall outflow operations. The specific criteria lead to a selection of a specific outcome. Then, multiple criteria and associated outcomes result in a "tree" structure that aids in decision-making.

The BDCP is moving toward implementing the "Decision Tree" based upon the following:

- Past experience shows that scientific uncertainties will be reduced by new studies and data during the 10 – 15 years until the new diversions become operational;
- The BDCP habitat restoration will alter Delta flow patterns and habitat quality in the years until new diversion become operational;
- There is good understanding of the requirements of the covered species in order to move toward recovery; and

- Using a “Decision Tree” increases the chances of meeting the biological objectives

A range of potential operations could occur as a result of the “Decision Tree” and these operations would be equally analyzed.

The relationship between the “Decision Tree” operations and the actual operations includes:

- Implementing a decision tree approach offers a way to analyze the effects of the BDCP with uncertainties about initial operations;
- The decision tree establishes the starting point or initial operations, but adaptive management will continue to modify operations as needed; and
- Real-time operations will still be used to optimize day-to-day SWP and CVP operations.

An example for use of the Decision Tree for fall outflow could be:

- Is Fall X2 at ≤74 km in wet years and ≤79 km in above normal years necessary to achieve the delta smelt biological objectives?

If “Yes”, then outcome is “Outcome A” – Fall X2 at less than or equal to 74km in wet years and less than or equal to 79km in above normal years.

If “No”, then outcome is “Outcome B” – D-1641 fall outflow with adaptive management. This outcome indicates that flow is not necessary to achieve the delta smelt biological goals, and could instead be met through the benefits provided by habitat restoration. D-1641 represents the currently implemented operational criteria required by the SWRCB.

The following example is provided to demonstrate the need for increased monitoring to establish baselines, how new information can inform specific actions, and to illustrate the type of experimentally driven adaptive management approach that will be used to address biological objectives.

One of the BDCP biological objectives for all runs of salmon and steelhead which migrate through the Delta is an increase in survival over current levels while emigrating through the plan area. Currently, methods to increase survival during Delta transit are limited, and often rely on actions to essentially move emigrating fish through the Delta as quickly as possible, thereby reducing the time emigrants are exposed to predators or other stressors. This type of action, which is focused on larger, actively migrating juveniles and does little to address those rearing in the Delta, cannot address broader factors contributing to the decline of Central Valley salmonids and is likely unsustainable in the long-term. These actions also circumvent the historical role the Delta played in providing important rearing habitat for juvenile salmonids. Interim through-Delta survival objectives have been put forward and will be iteratively developed as more run-specific survival information is gathered (the majority of current estimates are based on hatchery surrogates). This objective is intended to reduce mortality of juvenile salmonids in the Delta, in much the same way salvage limits and flow standards are, but will be accomplished using additional management tools.

The enhanced "tool box" of conservation measures, such as those listed above (and in addition to habitat restoration), is intended to provide management flexibility while maintaining biological objectives which have been designed to recover these species. Furthermore, this flexibility allows for measures to maintain and increase important factors such as life history diversity and growth, in addition to survival. This approach, which provides additional benefits to Delta emigrants, such as access to higher quality and quantity habitat (e.g. increased access to floodplain habitat in the Yolo Bypass), support enhanced survival in the ocean, and increased viability for Central Valley salmonids.

In addition enhanced monitoring plans, directed research on Delta rearing and migration, and life-cycle modeling will help to estimate what through Delta survival needs to be to support positive cohort replacement rates, as well as contextualizing the importance the Delta plays for Central Valley salmonids. These efforts will also play a key role in determining the contribution BDCP can provide to recovering Central Valley salmonids.

4.1.3 Post-restoration

While it is recognized that the Delta can never be restored to a completely "natural" state, the BDCP conservation actions emphasize the importance of restoring large tracts of Delta tidal marsh, estuarine, and seasonal floodplain habitats of sufficient size and connectivity to substantially increase the extent of physical habitat for covered species (including cover, rearing habitat, nesting habitat, and food resources) and improve overall food web productivity in the restoration areas and adjacent aquatic habitat (Simenstad et al. 2000). BDCP actions will provide improved east-west flow patterns and when linked with habitat restoration areas create opportunities to re-establish important ecological processes associated with the interaction between land and water in a way that is beneficial to fish and that more closely resembles natural estuary function.

4.2 Current DWR Restoration Projects

Successful implementation of restoration actions will require establishing appropriate metrics to measure the biological response of covered species as well as the integration of new knowledge into the recovery strategy. The following examples of near-term actions, as well as other efforts, are intended to provide near-term benefits, and demonstrate a commitment to the restoration approach. Additionally, they will test current hypotheses, and provide guidance for future work.

4.2.1 Fish Restoration Program Agreement

The primary objective of the Fish Restoration Program Agreement (FRPA) between DWR and DFG is to implement the fish habitat restoration requirements of the USFWS and NMFS Biological Opinions for SWP and CVP operations, and Longfin Smelt ITP for SWP Delta operations. FRPA is focused on creating 8,000 acres of intertidal and associated subtidal habitat to benefit delta smelt, including 800 acres of mesohaline habitat to benefit longfin smelt, and a number of related actions for salmonids. In March 2012, the program released an Implementation Strategy for habitat restoration, including restoration targets and a 10-year timeline with acreage targets for meeting restoration requirements. Among the first restoration projects to be implemented under FRPA is Prospect Island, approximately 1500 acres of former agricultural land that will be restored to tidal wetland. Other near-term restoration projects will include Liberty Island/Lower Cache Slough enhancement, Lindsey Slough freshwater tidal marsh enhancement, Lower Yolo Ranch Aquatic Habitat Restoration, and Overlook Club and Tule Red tidal habitat restoration in Suisun Marsh.

Consistent with the BDCP Planning Agreement, the mitigation actions implemented pursuant to FRPA may also, if appropriate, be considered BDCP Early Implementation Actions intended to mitigate ongoing SWP Delta Pumping Facilities impacts on covered fish species. The BDCP Habitat Credit MOA sets forth a process of identifying and evaluating habitat projects intended to contribute toward SWP and CVP acreage requirements under the federal and state Endangered Species Acts, such as the habitat projects currently proposed for implementation under FRPA. The process is intended to provide assurance that acquisition and restoration of lands for habitat projects prior to implementation of BDCP will be credited toward meeting the BDCP restoration acreage objectives. FRPA will be coordinating with the MOA effort as it is implemented to provide for an efficient review, guidance, and approval process on applicable FRPA actions.

4.2.2 The Suisun Habitat Management, Preservation, and Restoration Plan

The Suisun Habitat Management, Preservation, and Restoration Plan (SMP) is a comprehensive plan designed to address the various conflicts in the Suisun Marsh by balancing the protection and enhancement of existing waterfowl and wildlife values, conservation of endangered species, and protection of State and federal water project supply quality. SMP is a flexible, science-based, management plan that is focused on multi-stakeholder approach in the restoration of tidal wetlands and the management of managed wetlands and their functions. FRPA, mentioned above, is engaging where possible as a potential funding partner in upcoming restoration projects in accordance with the SMP.

4.2.3 Yolo Bypass

DWR and USBR have prepared the "Yolo Bypass Salmonid Habitat Restoration and Fish Passage Draft Implementation Plan" in response to actions required by NMFS' 2009 Biological Opinion and Conference Opinion on the Long-term Operation of the CVP and SWP. The implementation plan incorporates the best available science including information developed through BDCP. Ultimately, the implementation plan seeks to satisfy regulatory requirements set forth by NMFS and restoration objectives identified in BDCP. Specific biological objectives aim to increase access for juvenile salmonids onto seasonally inundated aquatic habitat, reduce stranding, increase aquatic primary and secondary biotic production, and improve fish passage for adult sturgeon and salmonids. The implementation plan identifies several habitat attributes required to meet those objectives and describes metrics that will be used to evaluate and adaptively manage the bypass.

The implementation plan is currently in draft form while comments from NMFS and other reviewers are incorporated. DWR and USBR will finalize the plan prior to February 2013, when we expect to file a "Notice of Preparation and Notice of Intent" to prepare a Joint EIR/EIS document for Yolo Bypass restoration actions.

4.2.4 Knaggs Ranch

Although the benefit of floodplain rearing habitat has been well documented for juvenile Chinook salmon in the Central Valley, there is little information about use of specific habitat types within an inundated floodplain. The majority of land within the Yolo Bypass floodplain is managed agricultural lands.

In an effort to provide information that will help inform future restoration efforts on the Yolo Bypass floodplain, DWR has partnered with researchers from UC Davis to conduct a multi-year study investigating salmon rearing in experimentally inundated agricultural fields on the Knaggs Ranch property located in the northern Yolo Bypass. DWR involvement is focused on filling in data gaps and determining appropriate monitoring metrics for planning and implementing BDCP Conservation Measure 2, Yolo Bypass Fishery Enhancement, and requirements of the NMFS Biological Opinion (2009). During the winter 2012 pilot effort, hatchery juvenile Chinook salmon were stocked into an experimentally flooded agricultural field in the Yolo Bypass in order to test methods and inform a larger study design. Preliminary results indicate that growth rates were relatively high for the region, likely due to warmer temperatures and high densities of zooplankton.

The study team is preparing for a larger-scale study in winter 2013 which will compare growth and preferential habitat selection by juvenile Chinook salmon of three different habitat types: rice stubble, disked rice, and fallow agricultural field. In addition to salmon growth, physical and biological metrics will be monitored to better understand the habitat and food web dynamics of the different land use types. The results of this study will contribute to an understanding of the value of different managed habitat types within the floodplain to rearing juvenile Chinook salmon

5.0 Reducing Uncertainty

Alternative flow prescriptions need to be considered in an adaptive, flexible framework, in the context of broader conservation approaches including habitat restoration, and will require balancing multiple management strategies. The efforts referenced above, as well as existing and ongoing research, will continue to provide new information. Flexibility in management actions is of paramount importance in adapting to uncertainty and a changing climate. DWR's SWRCB Workshop #1 submittal details this information.

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Appendix A – Detailed Descriptions of Salmon Models

IOS Model

Model Overview

The IOS model is composed of six model-stages that are defined by a specific spatiotemporal context (Figure 1) and are arranged sequentially to account for the entire life cycle of winter-run Chinook salmon, from eggs to returning spawners.

1) *Spawning* models the number and temporal distribution of eggs deposited in the gravel at the spawning grounds.
2) *Early Development* models the impact of temperature on maturation timing and mortality of eggs at the spawning grounds.
3) *Fry Rearing* models the relationship between temperature and mortality of fry during the river rearing period.
4) *River Migration* estimates mortality of migrating smolts in the Sacramento River between the spawning and rearing grounds and the Sacramento-San Joaquin Delta.
5) *Delta Passage* models the impact of flow, route selection and water exports on the survival of smolts migrating through the Delta to San Francisco Bay. This model-stage also functions as a stand-alone simulation model called the "Delta Passage Model".
6) *Ocean Survival* estimates the impact of natural mortality and ocean harvest to predict survival and spawning returns by age.

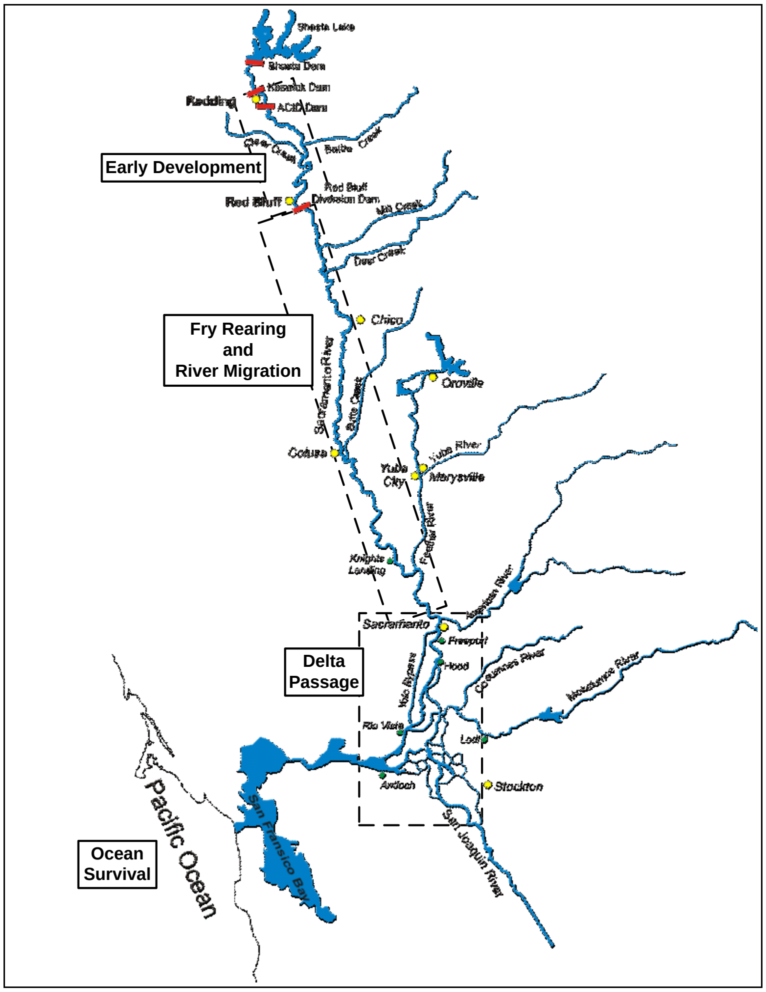

Figure 1. Map of the Sacramento River and the Sacramento-San Joaquin Delta, including approximate areas defined by model-stages.

Additional details of the IOS model can be found in Zeug et al (2012), but to help illustrate the series of operations performed by the IOS model, Figure 2 depicts the life cycle of a population of winter-run Chinook salmon spawning in the Sacramento River and migrating downriver to the ocean before later returning to spawn again. The number and timing of eggs deposited in the Spawning model-stage (1), along with the rates of maturation and mortality in the Early development model-stage (2), determines the abundance of fry emerging to rear in the Fry rearing model-stage (3). The number of fry which undergo river migration (4) is a function of mortality in the prior stage. As fish encounter junctions in the Delta they are routed down various paths with different associated migration speeds and survival rates (4, 5), depending on the proportion of flow entering each downstream reach. Some fish remain in reaches in the northern Delta (Yolo Bypass, Sac1, SS, Sac2, Sac3, Sac4), and some enter the interior Delta through the GEO/DCC reach. As fish enter Delta reaches, their reach survival and migration speed (and therefore travel time) is calculated on the day they enter the reach. During all subsequent days that fish are migrating through a given reach, they are not exposed to mortality, nor are their migration speeds adjusted. For reaches where data are available to inform a relationship with flow, reach survival (Sac1, Sac2, Sac3, Sac4, SS, and Interior Delta) and migration speed (Sac1, Sac2, Geo/DCC) are calculated as a function of the flow on the initial day of reach entry. Likewise, where data are available to inform a relationship with south Delta exports (Interior Delta), reach survival is calculated as a function of south Delta exports as fish enter that reach. Overall survival through the Delta is a combination of survival in each route and the proportion of fish that enter each route. Once fish successfully migrate through the Delta and enter the ocean (6), a proportion survive and mature until Age 2. Those fish that survive to age 2 either return to spawn or continue maturing. Those remaining in the ocean are subjected to natural mortality and harvest, with a large proportion of survivors returning to spawn at Age 3. Fish that do not return at Age 3 are again subjected to natural mortality and harvest before all of the remaining fish return to spawn at Age 4.

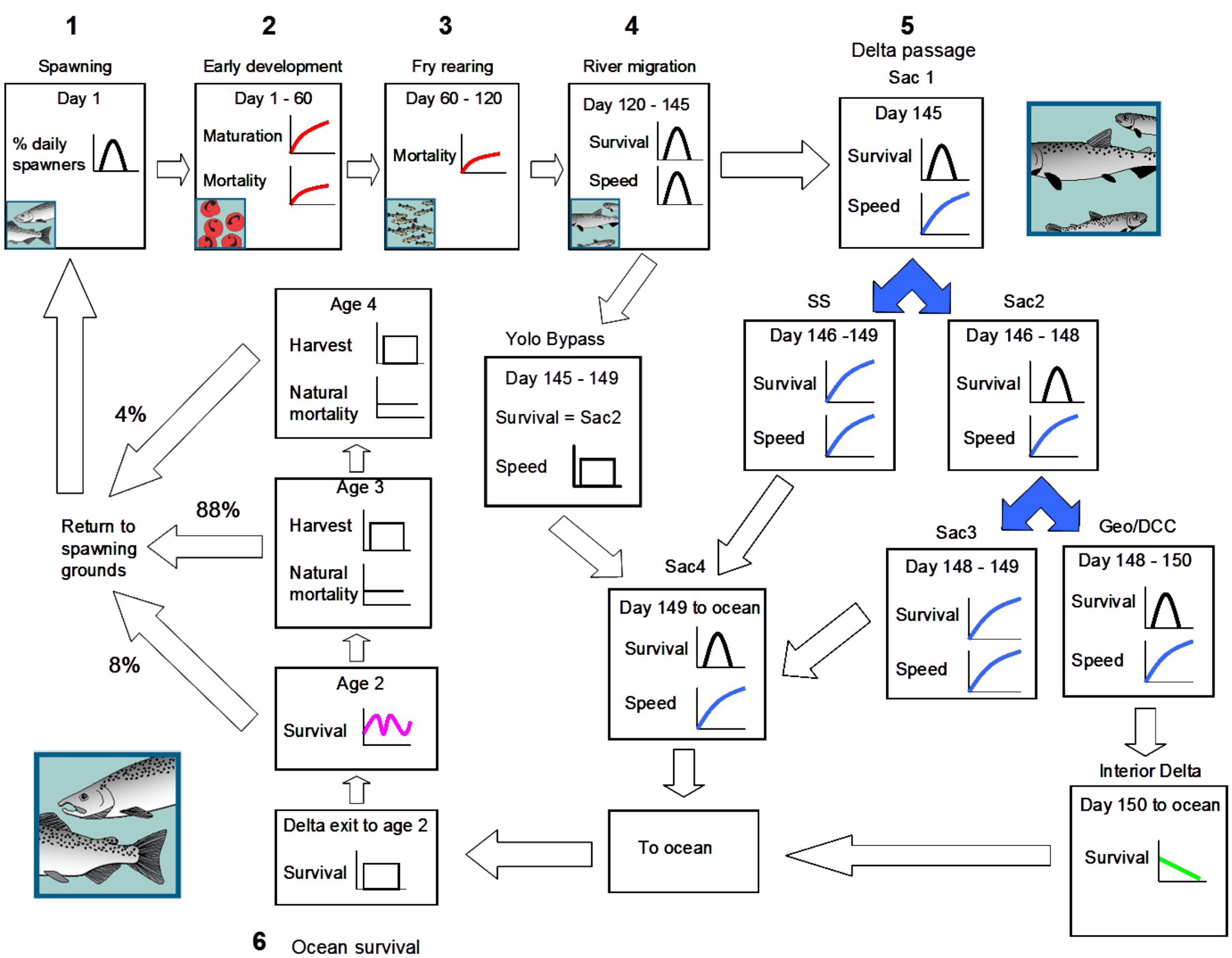

Figure 2. Conceptual diagram depicting the life cycle of a winter-run Chinook population in the IOS model, with the IOS model-stages and environmental influences on survival and development of winter-run Chinook at each stage. Red = temperature, blue = flow, green = water exports, pink = ocean productivity.

Delta Passage Model (DPM)

Model Overview

The DPM is based on a detailed accounting of migratory pathways and reach-specific survival as Chinook salmon smolts travel through a simplified network of reaches and junctions. The biological functionality of the DPM is based upon the foundation provided by acoustic telemetry data (Perry 2010) and coded wire tag (CWT) based studies (Newman and Brandes 2010). Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available.

The DPM is composed of eight reaches and four junctions (Figure 3) selected to represent primary salmonid migration corridors where fish and hydrodynamic data were available. Smolts can enter the model in 3 separate locations: 1) immediately upstream of Fremont Weir on the Sacramento River (Sacramento runs), 2) the head of the North and South Forks of the Mokelumne River (Mokelumne Fall-run, and 3) immediately upstream of the head of Old River on the San Joaquin River (San Joaquin River fall-run). For simplification, Sutter Slough and Steamboat Slough are combined as the reach SS and the forks of the Mokelumne River and Georgiana Slough are combined as Geo/DCC. Due to lack of data informing specific routes through the Interior Delta, or tributary-specific survival, the DPM treats the entire Interior Delta region as a single model reach. However, survival varies within the Interior Delta reach depending upon whether smolts enter from the Mokelumne River, the San Joaquin River or Old River, as informed by different survival data sources.

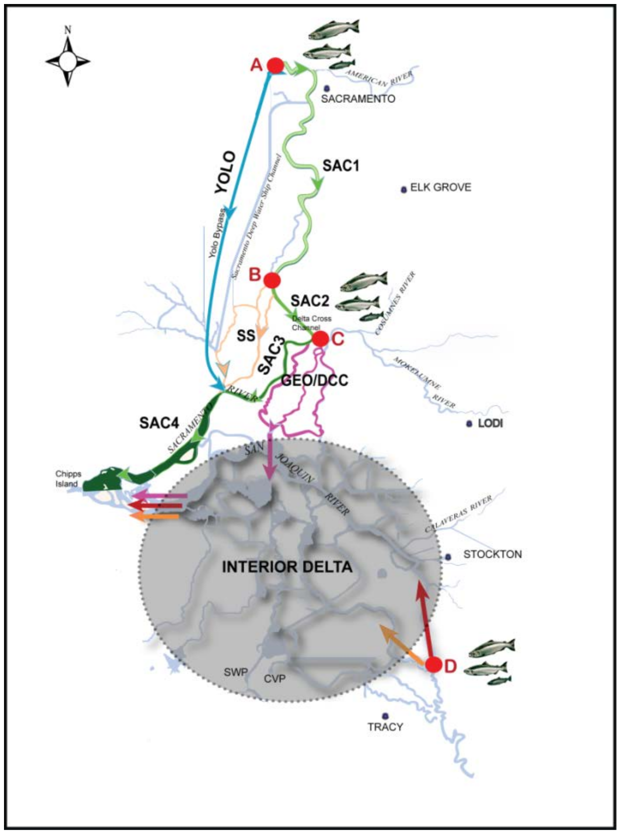

Figure 3. Map of the Sacramento-San Joaquin Delta showing the modeled reaches and junctions of the Delta applied in the DPM. Bold headings label modeled reaches and red circles indicate model junctions. Salmon icons indicate locations where smolts enter the Delta in the DPM.

The DPM operates on a daily time step using simulated daily average flows and south Delta exports as model inputs. The DPM does not attempt to represent sub-daily flows or diel salmon smolt behavior in response to the interaction of tides, flows and specific channel features. The DPM is intended to represent the net outcome of migration and mortality occurring over days, not three-dimensional movements occurring over minutes or hours (e.g., Blake and Horn 2006).

The major model functions in the DPM are: 1) *Delta Entry Timing*, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon, 2) *Fish Behavior at Junctions*, which models fish movement at river junctions, 3) *Migration Speed*, which models reach-specific smolt migration speed and resulting travel time, and 4) *Survival*, which models survival in a specific reach of the river as a function of flow, exports or a probability distribution.

Recent sampling data on *Delta entry timing* of emigrating juvenile smolts for six Central Valley Chinook salmon runs (Table 1) were used to inform the daily proportion of juveniles entering the DPM for each run.

Table 1. Sampling gear used to create juvenile Delta entry timing distributions for each Central Valley run of Chinook salmon. Agencies that conducted sampling are listed: U.S. Fish and Wildlife Service (USFWS), East Bay Municipal District (EBMUD), and California Department of Fish and Game (CDFG).

Run	Gear	Agency	Brood Years
Sacramento River Winter-Run	Trawls at Sacramento, CA	USFWS	1995-2009
Sacramento River Spring-Run	Trawls at Sacramento, CA	USFWS	1995-2005
Sacramento River Fall-Run	Trawls at Sacramento, CA	USFWS	1995-2005
Sacramento River Late-Fall Run	Trawls at Sacramento, CA	USFWS	1995-2005
Mokelumne River Fall-Run	Rotary Screw Trap at Woodbridge, CA	EBMUD	2001-2007
San Joaquin River Fall-Run	Kodiak Trawl at Mossdale, CA	CDFG	1996-2009

Acoustic tagging data are used to inform *fish behavior at junctions*. Perry (2010) found that acoustically tagged smolts arriving at Delta junctions exhibited movement patterns in relation to the flow being diverted. For junction B (Sacramento River-Sutter/Steamboat Sloughs), Perry (2010) found that smolts consistently entered downstream reaches in proportion to the flow being diverted. Therefore, smolts arriving at junction B in the DPM move proportionally with flow. Similarly, with data lacking to inform the nature of the relationship, the DPM uses a proportional relationship between flow and fish movement for junction D (San Joaquin River-

Old River). For Junction A, smolts are assumed to enter Yolo Bypass in proportion to flow movement into the bypass. When available flow data includes Fremont weir spill, proportions are calculated as flow passing over Fremont Weir divided by flow passing over Fremont Weir plus Sacramento River flow at Freeport. When flow data includes only flows within the bypass, all fish enter the Sacramento until flow in the bypass exceeds 500 cfs, then fish enter each route proportional to flow as described above. The 500 cfs threshold accounts for flows into the bypass from west side tributaries (Putah and Cache creeks). For junction C (Sacramento River-Georgiana Slough/DCC), Perry (2010) found a linear, non-proportional relationship between flow and fish movement (Figure 4).

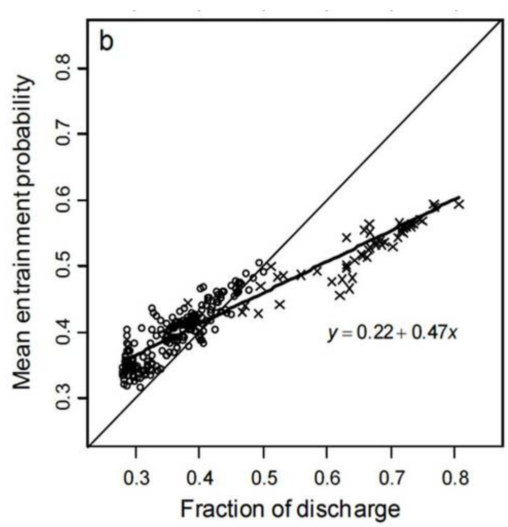

Figure 4. Figure from Perry (2010) depicting the mean entrainment probability (proportion of fish being diverted into reach Geo/DCC) as a function of fraction of discharge (proportion of flow entering reach Geo/DCC). In the DPM, this linear function is applied to predict the daily proportion of fish movement into Geo/DCC as a function of the proportion of flow movement into Geo/DCC. A circle indicates when the DCC gates were closed and X indicates when the DCC gates were open.

With the exception of exports at the SWP and CVP pumping plants, flow though the Delta is modeled using daily (tidally averaged) flow output from the hydrology module of the Delta Simulation Model II (DSM2-HYDRO; http://baydeltaoffice.water.ca.gov/mod-eling/deltamodeling/). Exports at the CVP and SWP pumping plants are modeled using monthly flow output from the hydrologic simulation tool CALSIM II (Ferreira et al. 2005) that is "disaggregated" into mean daily exports based on historical patterns.

The DPM assumes a net daily movement of smolts in the downstream direction. Smolt *migration speed* in the DPM affects the timing of arrival at Delta junctions and reaches which can affect route selection and survival as flow conditions or water exports change. Smolt migration and travel time in all reaches except Yolo Bypass and Interior Delta for Sacramento or Mokelumne fish is a function of reach-specific length and migration speed as observed from acoustic tagging results (Table 2).

Table 2. Reach-specific migration speed and sample size of acoustically-tagged smolts released during December and January for three consecutive winters (2006/2007, 2007/2008, and 2008/2009; Perry 2010) and associated flow data (gauging station ID; http://cdec.water.ca.gov/) used develop a logarithmic relationship between migration speed and flow.

Reach	Gauging Station ID	Release Dates	Sample Size	Speed (km/day) Ave.	Min	Max	SD
Sac1	FPT	12/05/06-12/06/06, 1/17/07-1/18/07, 12/04/07-12/07/07, 1/15/08-1/18/08, 11/30/08-12/06/08, 1/13/09-1/19/09	452	13.32	0.54	41.04	9.29
Sac2	SDC	1/17/07-1/18/07, 1/15/08-1/18/08, 11/30/08-12/06/08, 1/13/09-1/19/09	294	9.29	0.34	10.78	3.09
Sac3	GES	12/05/06-12/06/06, 1/17/07-1/18/07, 12/04/07-12/07/07, 1/15/08-1/18/08, 11/30/08-12/06/08, 1/13/09-1/19/09	102	9.24	0.37	22.37	7.33
Sac4	GES[a]	12/05/06-12/06/06, 1/17/07-1/18/07, 12/04/07-12/07/07, 1/15/08-1/18/08, 11/30/08-12/06/08, 1/13/09-1/19/09	62	8.60	0.36	23.98	6.79
Geo/DCC	GSS	12/05/06-12/06/06, 1/17/07-1/18/07, 12/04/07-12/07/07, 1/15/08-1/18/08, 11/30/08-12/06/08, 1/13/09-1/19/09	86	14.20	0.34	25.59	8.66
SS	FPT-SDC[b]	12/05/06-12/06/06, 12/04/07-12/07/07, 1/15/08-1/18/08, 11/30/08-12/06/08, 1/13/09-1/19/09	30	9.41	0.56	26.72	7.42

a = Sac3 flow is used for Sac4 because no flow gauging station is available for Sac4
b = SS flow is calculated by subtracting Sac2 flow (SDC) from Sac1 flow (FPT).

Survival through a given route (individual reach or reaches combined) is calculated and applied the first day smolts enter the route. For routes where literature or available tagging data showed support for responses to environmental variables, survival is influenced by flow (Sac1, Sac2, Sac3 and Sac4 combined, SS and Sac4 combined, Interior Delta via San Joaquin River, and Interior Delta via Old River) or south Delta exports (Interior Delta via Geo/DCC). For these routes, daily flow or south Delta exports occurring the day of route entry are used to predict survival through the entire route (Table 3). For all other routes (Geo/DCC, Yolo, Sac4 entering from Yolo), survival is uninfluenced by Delta conditions and is informed by means and standard deviations of survival from acoustic tagging studies (Table 3).

Table 3. Route-specific survival functionality for each Chinook salmon run. For routes where survival is uninfluenced by Delta conditions, mean survival and associated standard deviation (in parenthesis) observed during acoustic tagging studies (Perry 2010) are used to define a normal probability distribution that is sampled from the day smolts enter a route to calculate route survival.

Route	Chinook Salmon Run	Survival
Sac1	All Sacramento runs	function of flow
Sac2	All Sacramento runs	function of flow
Sac3 and Sac4	All Sacramento runs	function of flow
SS and Sac4	All Sacramento runs	function of flow
Yolo	All Sacramento runs	0.8
Sac4[a]	All Sacramento runs	0.698 (0.153)
Geo/DCC	Mokelumne Fall-run	0.407 (0.209)
	All Sacramento runs	0.65 (0.126)
Interior Delta	Sacramento runs and Mokelumne Fall-run	function of exports
	San Joaquin Fall-run via Old River	function of flow
	San Joaquin Fall-run via San Joaquin River	function of flow

a = Although flow influences survival of fish migrating through the combined routes of SS - Sac4 and Sac3 - Sac4, flow does not influence Sac4 survival for fish arriving from Yolo.

To help illustrate the series of operations performed by the DPM model, Figure 5 depicts the "migration" of a single daily cohort of salmonid smolts entering from the Sacramento River and migrating through the DPM. It is important to remember that cohorts of differing numbers of smolts enter the Delta each day during the migration period of each salmon run. As fish encounter junctions in the Delta they are routed down one of two paths, depending on the proportion of flow entering each downstream reach. In some cases (Junctions A and B) fish routing is directly proportional to flow, while in other cases (Junction C) fish routing, although linear, is not directly proportional to flow. As fish enter Delta reaches, their reach survival and migration speed (and therefore travel time) is calculated on the day they enter the reach. During all subsequent days that fish are migrating through a given reach, they are not exposed to mortality, nor are their migration speeds adjusted. For reaches where data are available to inform a relationship with flow, reach survival (Sac1, Sac2, Sac3, Sac4, SS, and Interior Delta via San Joaquin River) and migration speed (Sac1, Sac2, Geo/DCC) is calculated as a function of the flow on the initial day of reach entry. Likewise, where data are available to inform a relationship with south Delta exports (Interior Delta), reach survival is calculated as a function of south Delta exports as fish enter that reach. Because portions of a single cohort of fish migrate through different routes in the Delta, portions of the cohort will experience differing overall survival rates, differing migration rates, and differing arrival times at Chipps Island. Overall survival through the Delta for the cohort is then the combination of survival in each route and the proportion that enters each route.

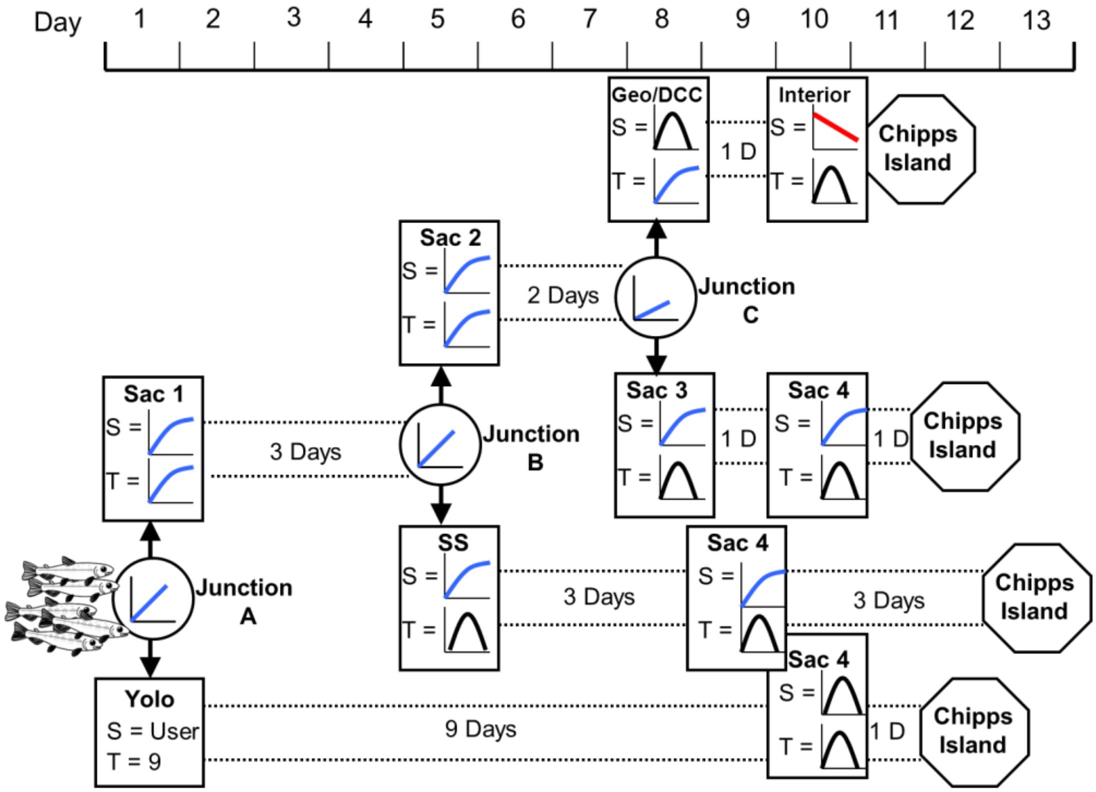

Figure 5. Conceptual diagram depicting the "migration" of a single daily cohort of smolts entering from the Sacramento River and migrating through the Delta Passage Model. Day of the model run is indicated at the top of the diagram. Circles indicate Delta junctions, where the proportion of fish moving to each downstream reach is calculated, and rectangles indicate Delta reaches. The shape of the relationship for each reach-specific survival (S), reach-specific migration speed (T), and proportional fish movement at junctions are depicted. Relationships that are influenced by flow (x variable) are colored blue, relationships influenced by south Delta exports are colored red, and relationships that are calculated from a probability distribution (and not influenced by flow or south Delta exports) are colored black. Dotted lines indicate migration time through the previous reach, and the Chipps Island icons indicate when fish from each route exited the Delta.