Striped Bass (*Morone saxatilis*) Monitoring Techniques in the Sacramento–San Joaquin Estuary*

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ABSTRACT

Various methods have been used to monitor the striped bass population in the Sacramento–San Joaquin Estuary. Sampling in the spring with towed plankton nets has provided an adequate description of spawning time and area, but this sampling has not adequately measured egg standing crops and larva and post-larva mortality rates. Tow-net sampling effectively measures the abundance of young in midsummer. A midwater-trawl survey is satisfactory for measuring the abundance of young in the fall but not in the winter. Techniques have not been fully evaluated for monitoring one-year-old bass. Catch-per-unit-effort data from sportfishing party boats were useful for monitoring two-year-olds, until a change in angling regulations increased recruitment age. The Petersen method and indices developed from party-boat catches are the best methods for monitoring bass that are three years old and older. Long-term trends in catch can be monitored through postcard surveys and party-boat catches.

Key words: abundance indices, angler surveys, egg and larva surveys, fishing gear, mark-recapture, *Morone saxatilis*, mortality, population monitoring, striped bass

INTRODUCTION

The striped bass population in the Sacramento–San Joaquin Estuary is affected by environmental changes resulting from development of federal and state water projects. Knowledge of impacts of these changes is necessary to develop operating criteria for water projects that will minimize damage to the

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bass population. Assessing such impacts requires population monitoring. This paper describes techniques that the California Department of Fish and Game has employed during the past 40 years for monitoring striped bass at several life stages.

STUDY AREA

The Sacramento and San Joaquin river systems form a tidal estuary with a salinity gradient about 80 km long which extends from San Pablo Bay to the western delta (Fig. 1). River flows into the delta are quite variable and are partially controlled by upstream reservoirs. Flows peak in winter and spring. Kelley (1966) describes this region in detail.

Striped bass utilize the entire estuary and adjacent coastal area. Adult bass spend most of the year in saltwater, but in winter they begin migrating to the delta and rivers upstream for spawning in the spring (Chadwick 1967). The nursery area for young bass is the delta downstream to San Pablo Bay (Turner and Chadwick 1972).

MONITORING TECHNIQUES

Egg and Post-Larva Sampling in Spring

Pump Sampling

From 1967 to 1969, 0.5 HP Moyno utility pumps with a synthetic rubber helical rotor were used to continuously sample eggs and larvae drifting past sites in the Sacramento and San Joaquin rivers (Turner 1976). River water was pumped into containers where eggs and larvae were screened out. Pumping rate was about 35–55 liters per minute. Catches ranged up to 370 eggs and 450 larvae <5 mm standard length (SL) per 24-hr period. Pump sampling was implemented to obtain continuous samples that required only a few minutes of labor daily for sample collection. This method of sampling was terminated, however, because detritus often clogged the screens causing samples to overflow.

Plankton Net Sampling

Since 1963 several plankton nets have been used to capture bass eggs and larvae. L. W. Miller (*personal communication*) has described and evaluated some of these nets in detail.

From 1963 to 1966 the nets most frequently used had a 46-cm-diam mouth and a 102-cm-long cone which was made of 9-mesh-per-centimeter

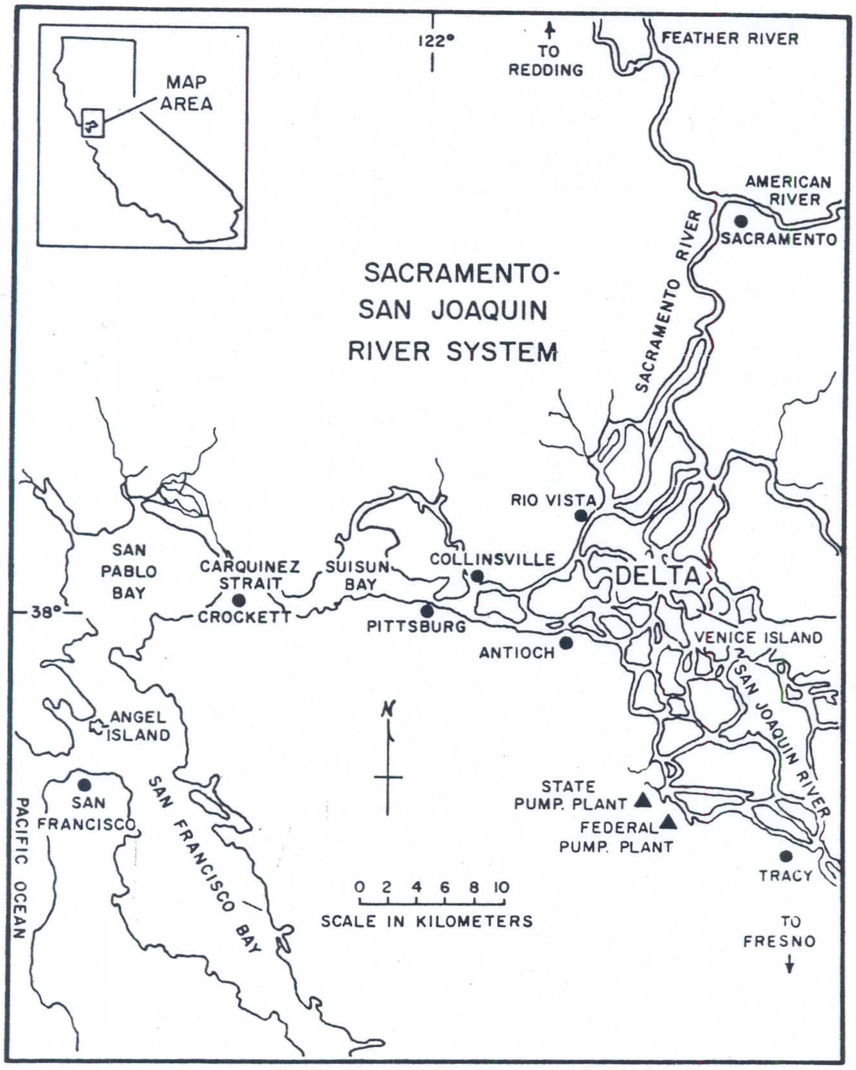

Fig. 1. Sacramento–San Joaquin estuary.

bolting cloth (Farley 1966). Mesh openings varied from about 600–800 μm. A screened metal bucket was attached to the cod end. Pygmy* flow meters often were mounted in the net mouth. Generally two nets were towed, one at the surface and the other about 4.5 to 7.5 m below the surface. A few surface samples were collected from highway bridges by setting nets in the current.

*Model 005–WA–130, Kahl Scientific Instrument Co. El Cajon, California.

About 30 stations were surveyed 2 or 3 days per week during the spawning season (April or May through June). Egg catches indicated when and where bass spawned (Farley 1966, Turner 1976).

From 1967 to 1975, egg and larva sampling was intensified to monitor spawning (Turner 1976) and to measure abundance of eggs and young at various stages for mortality rate estimation (D. H. Allen, *personal communication*). The nets from 1967 to 1974 had a 76-cm-diam mouth and a 3.2-m cone of 7.9-mesh-per-centimeter nylon marquisette (Turner 1976). Mesh openings were about 930 μm. A screened plastic quart jar was attached to the cod end. The nets were mounted on skis and were towed diagonally from bottom to surface to obtain depth integrated samples. The volume of water strained was measured with Pygmy or General Oceanics* meters. Surveys were made every other day during the spawning season. Ten-minute samples generally were taken at 3.2-km intervals from the western end of Suisun Bay to Rio Vista on the Sacramento River and to Venice Island on the San Joaquin River. Catch analyses revealed that the net mesh retained eggs but allowed many bass smaller than 7 mm SL to pass through (Turner 1976).

A more efficient net was used in 1975. This net has a 76-cm-diam mouth and is 2.9 m long. The mesh is 505-μm Nitex netting. This net's cylindrical cone design (Smith et al. 1968) filters water more effectively than the original design, and the mesh retains virtually all larvae. Catches of larvae $\leq$5 mm SL increased more than 50 times with the new net. The new and old net are almost equally efficient on young striped bass of 12 to 16 mm fork length (FL) (L. W. Miller, *personal communication*).

These surveys provide indices of total abundance of eggs and larvae. At each sampling station catches of eggs and larvae per cubic meter of water strained are multiplied by the water volume in the section of river represented by the sample. These products are summed to index the standing crop each sampling day.

These surveys have proven inadequate in two important respects.

1. Standing crop measurements for eggs are much too low in the delta. For example, in 1972 the total bass egg index was 7.5 million (Turner 1976), but as many as 170 billion eggs actually may have been spawned [as estimated from a length-fecundity relationship (Morgan and Gerlach 1950), abundance estimates for spawning females (*unpublished data*), and assuming 45% of total spawning occurred in the sampling area (Turner 1976)]. The magnitude of this discrepancy suggests either huge egg mortality and decomposition shortly after spawning or inefficient sampling. The latter is more likely, considering the lack of evidence for the former in laboratory and hatchery culture.

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*Model 2030 General Oceanics Inc. Miami, Florida.

2. Surveys through 1974 do not demonstrate significant annual differences in larva and post-larva mortality rates calculated from abundance declines over time (D. H. Allen, *personal communication*). Differences in abundance indices measured by a summer survey, however, indicate egg–post-larva mortality rates probably varied from year to year (California Department of Fish and Game et al. 1974). Mortality rate differences may be masked by some combination of the following: (*a*) net efficiency problems, (*b*) sampling error, which may vary between areas of the estuary causing abundance and mortality estimates to vary with annual differences in bass distribution within the sampling area, and (*c*) abundance measurements that are biased by annual differences in migrations to and from the sampling area.

Summer Tow-Net Survey

Various tow nets have measured summer abundance of young bass since 1947 (Calhoun and Woodhull 1948, Erkkila et al. 1950, Calhoun 1953, Chadwick 1964), but a standard survey design was not adopted until 1962 (Chadwick 1964). This survey has been conducted annually (except 1966) ever since. It measures the abundance of bass of 17 to 50 mm FL.

Each annual survey consists of three to five subsurveys that take five days to complete. These subsurveys begin in mid-June and consist of sampling at 30 stations scattered from eastern San Pablo Bay to the eastern delta. They are conducted at two-week intervals until the mean length of the bass in the catch exceeds 38 mm FL. This length is attained between mid-July and mid-August.

Three 10-min, depth-integrated tows are made at each sampling station. These tows are diagonal from bottom to surface to reduce bias caused by variations in the vertical distribution of bass. The net (Calhoun 1953) is mounted on skis. The net's mouth area is about 1.5 m^2 and the net is 5.5 m long. It tapers to 39 cm in diameter at the cod end. The first 3.05 m of the cone is #6 thread webbing of 1.27-cm stretch mesh. The rest of the net is bobbinet with 3.1 holes per centimeter. These holes are about 2.5 mm in diameter. The bobbinet is sewn to the #6 thread webbing so that the webbing forms a fyke 60 cm long inside the bobbinet.

Total bass abundance during each subsurvey is indexed by multiplying the number caught at each sampling station by the volume of water represented by the station and summing these products. Indices of annual abundance are developed by plotting abundance against mean length for each subsurvey and interpolating abundance for selected lengths (Turner and Chadwick 1972). Abundance when the mean length of the population is 38 mm is the primary measure of survival between spawning and midsummer. Annual differences in length frequency distributions and in growth rates bias these indices somewhat (Turner and Chadwick 1972).

The abundance indices are highly correlated with river flows and water diversion rates (Turner and Chadwick 1972, California Department of Fish and Game et al. 1973-1976). These correlations are extremely helpful in evaluating water development plans and in developing water management recommendations (Chadwick et al. 1977), which are the primary objectives of the survey.

This survey, however, apparently underestimates bass abundance when high flows transport young bass to San Pablo Bay (Stevens 1977). Only one station in San Pablo Bay is sampled routinely. Coverage is not more intensive because bass catches always have been small at this station and few bass were caught elsewhere in San Pablo Bay in the 1950s (Calhoun 1953, Chadwick 1964). Although the catches of bass are generally low in San Pablo Bay, significant numbers of bass could inhabit that bay because its volume is large (Kelly 1966).

Fall and Winter Midwater Trawl Survey

Except for 1974, young bass abundance has been sampled during fall and winter each year since 1967. The primary objective is to determine if mortality during this period might vary enough between years to be a major factor causing variations in adult bass abundance.

A midwater trawl with a 3.6- by 3.6-m mouth is the sampling gear. The 17.7-m-long net is constructed of nine tapered panels of netting decreasing from 20-cm stretch mesh (sm) at the mouth to 1.3-cm sm at the cod end (L. W. Miller and D. Drake, *unpublished data*). It is towed by a 9.8-m boat. The trawl is released to the river bottom, and then it is pulled to the surface as it is towed, resulting in depth-integrated samples. Towing speed is about 1.5 knots. Tow duration is 12 min. VonGeldern (1972) describes in detail similar nets and fishing methods.

Each monthly survey (generally August or September to March) takes about six days to complete. One tow is made at each of 87 sampling sites scattered from San Pablo Bay through the delta. Single catches have ranged up to 445 bass, and most bass are 6 to 14 cm FL.

The method of tabulating the catch data is similar to that for the spring and summer surveys. All tows are assumed to strain equal amounts of water. For each of 17 groups of stations, mean catches are multiplied by the total volume of water represented by the stations in the grouping. These products are summed to obtain monthly abundance indices.

This survey has been partly successful. Fall abundance indices are highly correlated with the index from the summer tow-net survey [$r = 0.95$ for an index of abundance 60 days after the summer index is set vs the summer index (L. W. Miller and D. Drake, *unpublished data*)], suggesting that annual differences in mortality between summer and fall are minimal. However, after winter rains the monthly abundance indices are highly variable. They often produce survival rate estimates (calculated from the changes in monthly indices) that exceed 100% between months, an obvious impossibility for which there is no satisfactory explanation. These survival estimates were not improved by increasing sampling effort or adjusting catches for biases associated with water clarity (L. W. Miller and D. Drake, *unpublished data*).

Monitoring of Juvenile Bass

One- and two-year-old bass occasionally are taken in the midwater trawl designed to catch young bass. Catches of two-year-olds are too low to establish meaningful population indices, and the index for one-year-olds has not been evaluated. Attempts to take significantly larger numbers of these bass with a larger trawl (6.1- by 6.1-m mouth) have been unsuccessful.

Monitoring of Adult Bass Population and Catch

Effective methods of monitoring adult bass abundance are necessary to determine if conditions affecting the survival of young bass control the number of bass recruited to the fishery. Several approaches are being examined.

Petersen Mark-Recapture Estimates

To estimate the abundance of adult bass (fish ≥40.6 cm in total length), we have conducted a mark-recapture experiment since 1969. The modified Petersen method (Bailey 1951) is used: $N = M(C + 1)/(R + 1)$, where N = bass abundance, M = number of marked fish released, C = number of fish subsequently censused, and R = number of recaptured marks in the sample.

Gill nets and fyke traps (Hallock et al. 1957) are used to capture bass during their spring migration to the delta. The fish are tagged with numbered disc-dangler tags (Chadwick 1963) and released. The population is sampled through an annual summer-fall census of angler catches in San Francisco and San Pablo Bays and during subsequent spring tagging operations.

About 9000 to 18,400 tags have been applied annually. Seasonal employees stationed at six fishing ports in the Bay Area, Wednesday through Sunday each week from July through November, have observed annually from 18,000 to 39,000 bass and from 128 to 352 of the tags applied the preceding spring. In 1976, they observed 347 tags, including releases from all years, which is about 1.6% of the 22,000 bass censused

The abundance estimation procedures are complicated by sex- and age-sampling biases. Males spend more time on the spawning grounds than females (Chadwick 1967), so roughly twice as many males are tagged. In contrast, censused females slightly outnumber censused males. Three- and four-year-old bass are underrepresented in the tagged sample because many of those fish are not mature and they have not taken up adult migratory patterns (Chadwick 1967). Moreover, larger bass are more susceptible to capture in the gill nets (Chadwick 1967). Hence, all tagging and recapture samples are stratified by sex and age.

Sex is determined for each fish tagged. If milt is extruded, fish are classified male and if not they are classified female. About 75 to 90% of the censused fish are sexed by dissection. The remainder of the censused fish are assumed to have the same sex ratio as this sample.

In order to stratify by age, scales are sampled and lengths are measured on nearly all tagged bass. Scales are obtained from 75 to 90% of the censused bass. Length is measured for virtually all censused bass. A computer program (AGECOM, Abramson 1971) utilizes age-length relationships and length frequencies to apportion unaged fish into the appropriate year classes.

These procedures enable us to estimate abundance of individual year classes and to increase sample sizes for estimates of each year class with each successive sampling period (Figs. 2 and 3).

Two additional problems must be solved in estimating three-year-old bass abundance:

1. Only half of these fish are legal size during the tagging period, and recruitment is not complete until about six months later. Therefore, the marked:unmarked ratio observed during the first census after tagging would grossly underestimate the abundance. Our solution is to estimate abundance starting with the tagging sample taken the following spring (Figs. 2 and 3). This solution results in estimates that are biased slightly high (see evaluation of Ricker's condition 2 later in this section).
2. Few three-year-old females are tagged (maximum number was 230 in 1972). Therefore, this abundance is estimated indirectly by assuming that it is equal to that of the three-year-old males.

Due to the sampling biases, the most accurate annual estimates of total population abundance appear to be sums of the year-class estimates for both sexes, except that the age-3 estimates are first divided by 2 to eliminate fish recruited after the tagging period. These total abundance estimates have varied from 1.6 to 1.9 million bass annually. Estimates unstratified by sex and age (recruitment is estimated from growth rates based on monthly length frequencies and subtracted from the recapture samples) are about 20% lower. They range from 1.2 to 1.7 million bass annually.

Although sums of year-class estimates may yield the best total abundance estimates, relatively small samples result in rather wide confidence intervals on the individual estimates (Figs. 2 and 3). Low correlations for abundance estimates of three- and four-year-old bass vs young-of-the-year indices ($r <$ 0.31, 3 d.f.) and vs flows ($r < 0.58$, 4 d.f.) in the first summer of life may partly reflect this lack of precision.

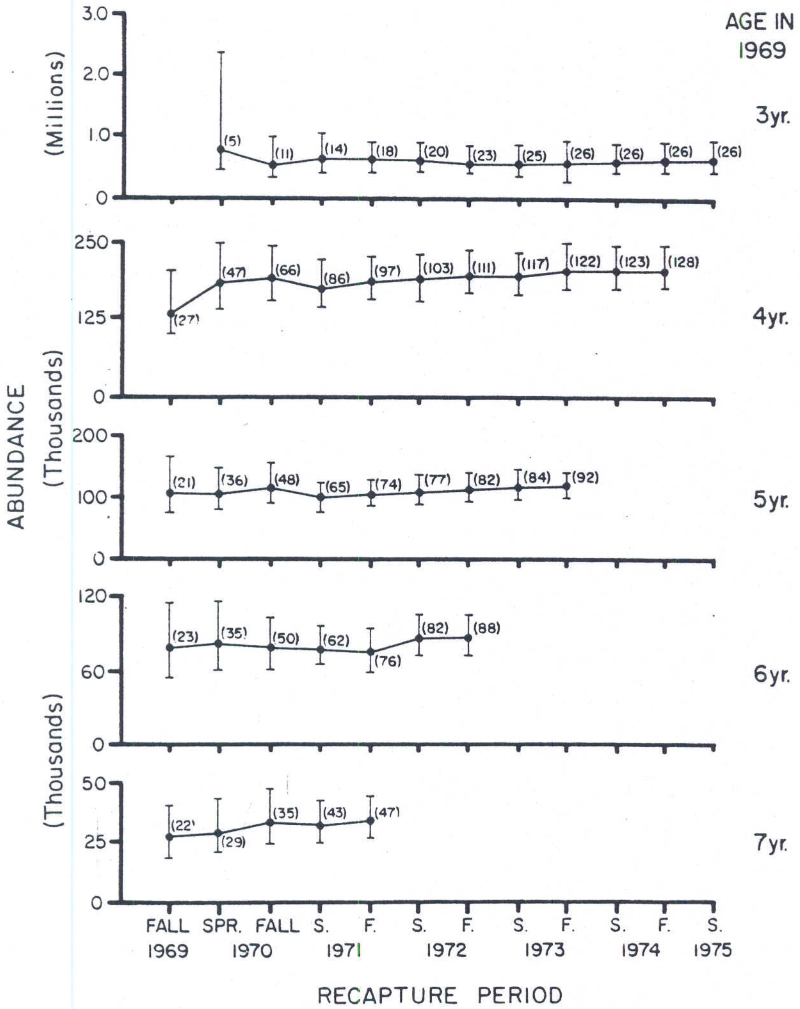

Fig. 2. Effect of cumulative recapture samples on abundance estimates and Poisson confidence intervals for male striped bass tagged in 1969. Abundance of three-year-olds was not estimated in fall 1969 because they were not fully recruited. Samples are not included after fish attained nine years of age (i.e., 1972 recaptures for fish seven years old in 1969) because ages cannot be estimated accurately for older bass. Numbers of tags recovered are in parentheses.

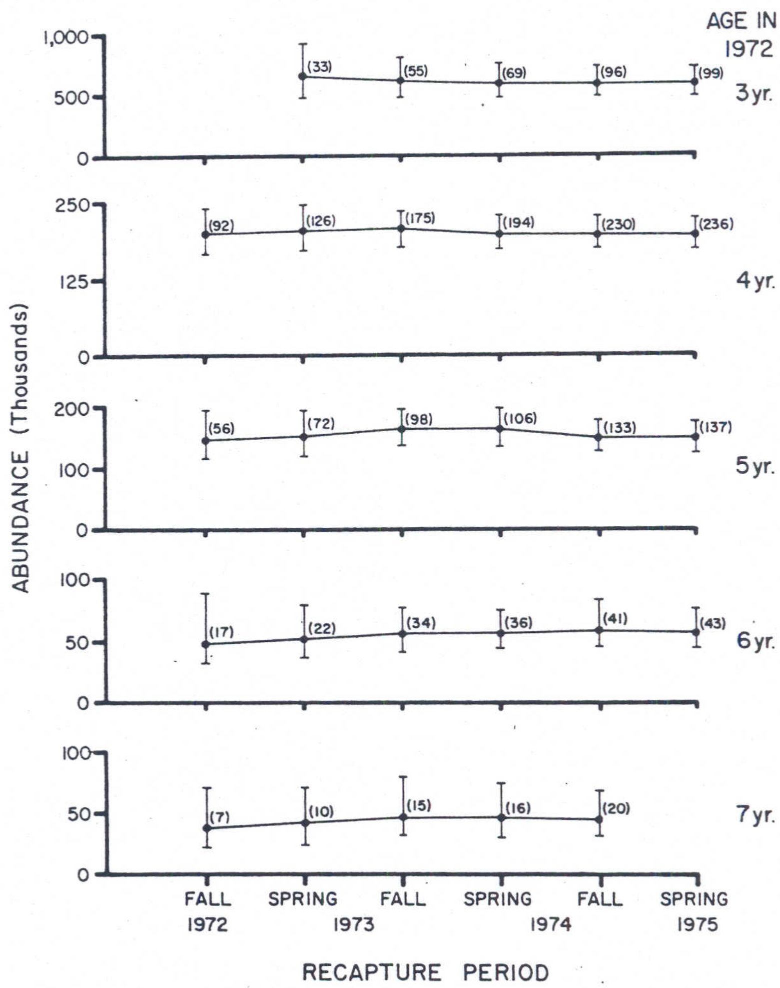

Fig. 3. Effect of cumulative recapture samples on abundance estimates and Poisson confidence intervals for male striped bass tagged in 1972. The abundance of three-year-olds was not estimated in fall 1972 because they were not fully recruited. The abundance of seven-year-olds was not estimated in spring 1975 because that year class was too difficult to classify accurately. Numbers of tags recovered are in parenthesis.

Ricker (1975) lists six conditions required for valid Petersen estimates. These conditions and applicable findings from the striped bass mark-recapture study are reviewed here to improve understanding of the limitations of the study.

1. Marked fish suffer the same natural mortality as the unmarked – mortality probably is somewhat higher for tagged bass than for untagged bass. A few bass die shortly after release, presumably due to tagging and handling. Since 1971, anglers and the tagging crew have recovered 341 dead bass within two weeks or so after tagging. This total is only 0.4% of the roughly 85,000 bass tagged. Although the dead fish that are recovered are removed from the release files, tagged bass that die and remain unrecovered cannot be accounted for.

   Delayed mortality also may occur due to irritation, which is sometimes caused by hydroids attaching to the tags. There is no way of measuring mortality from this source, but fish have been seen with large scars near the tag indicating healing following considerable tissue damage (Chadwick 1963, 1964; *unpublished data*).

   Hence, some unmeasured mortality probably occurs from the above sources. This greater mortality of marked fish would cause overestimates of abundance.

2. Marked and unmarked fish are equally vulnerable to fishing – tagging and handling bass reduces their vulnerability to angling by about one-third to one-half for about one month (Chadwick 1963). Essentially all resampling occurs later. Some of those fish saved by the low vulnerability during the first month probably are caught later and bias abundance estimates downward very slightly.

   Except for Department of Fish and Game gill nets, there is no fishing gear to bias returns by selectively snagging tagged fish. R/C ratios vary for both netted and angler-caught bass (Fig. 4). The ratios for netted bass tend to be somewhat higher, but they are not consistently higher than those for angler-caught bass. The higher ratios for netted bass may result from the nets snagging tags and/or the tendency for bass to return to the area where they were tagged (see condition 4).

   Initially, tagged three-year-old bass are more vulnerable than untagged three-year-olds, because only legal fish are tagged, and recruitment of three-year-olds is not complete until about six months later. Abundance is slightly overestimated (<3.5%, *unpublished data*) from the sampling that starts the following spring, because the higher early catch rates of tagged three-year-olds reduce R/C ratios.

3. Marked fish do not lose their marks – evidence of tag shedding consists of scars and broken tag wires, which have been detected for 297 bass since 1969. During the same period 5281 bass were observed with tags intact. In

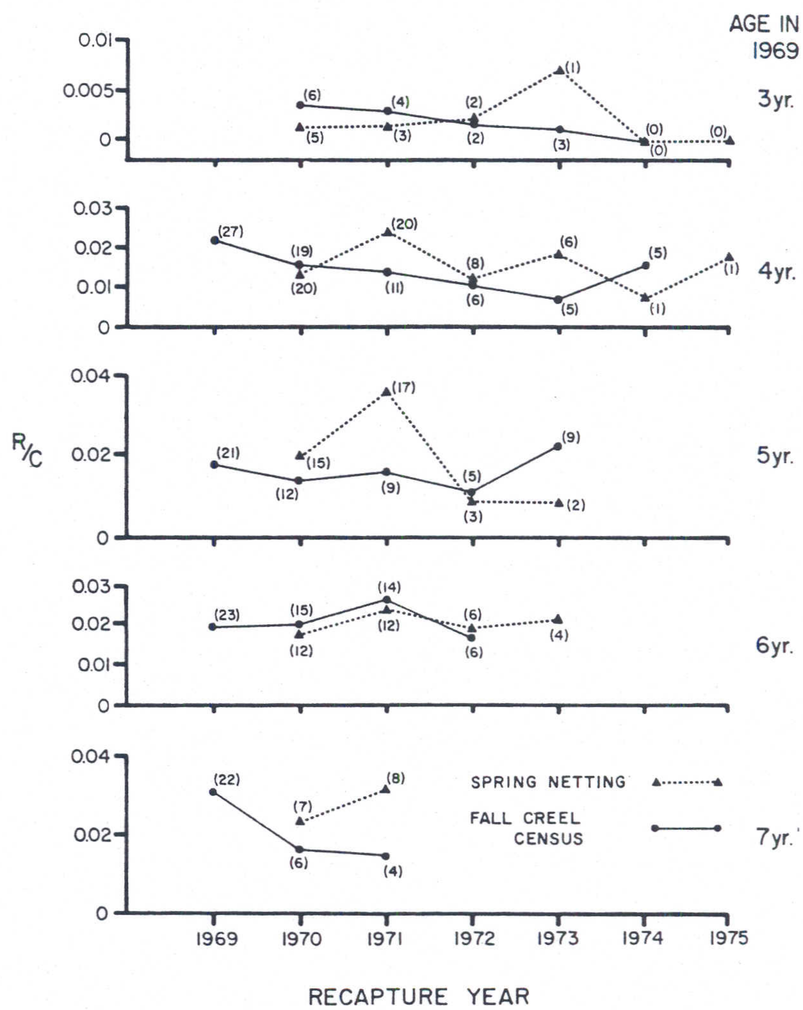

Fig. 4. Ratios of male striped bass tagged in 1969, *R*, to total male striped bass, *C*, observed in various recapture samples. Ratio was not calculated for three-year-olds in fall 1969 because that age group was not fully recruited. Ratios were not calculated after fish attained nine years of age (i.e., 1972 for fish seven years old in 1969) because ages cannot be estimated accurately for older bass. Numbers of tags recovered, *R*, are in parentheses.

1969, 1162 bass were double-tagged. Estimated tag loss was about 5% per year for four years after application. Subsequently, this loss rate appeared to decrease (G. E. Smith, *personal communication*). The effects of shedding on estimates of abundance are probably minimal, since consistent increases in abundance estimates (Figs. 2 and 3) or consistent decreases in R/C ratios (Fig. 4) are not apparent as successive years of recapture data are added.

4. Marked fish become randomly mixed with the unmarked fish – Chadwick (1967) found that summer and fall migrations were similar for tagged bass captured in different areas of the estuary, suggesting that population components are well mixed during the angler census. However, the following spring, individual bass tended to return to where they were tagged. This behavior should increase the probability of capture for tagged bass and may cause spring R/C ratios to be somewhat higher than those in the fall (Fig. 4).
5. All marks are recognized and reported on recovery – there is little likelihood of significant error from this source. Trained observers examine the entire catch used to estimate abundance.
6. Recruitment is negligible during the recovery period – all samples are stratified by year class, and except for three-year-olds (see condition 2), all year classes are fully recruited at the time of tagging.

Population Estimates Derived From Catch and Exploitation Estimates for Part of the San Francisco Bay Fishery

Adult striped bass abundance, $\hat{N}$, was estimated annually from 1969 to 1971 using the equation $\hat{N} = \hat{C}/\hat{u}$, where $\hat{C}$ is the estimated striped bass catch in north San Francisco Bay during the two- to four-month study period in late summer and fall, and $\hat{u}$ is an estimate of the fraction of the population represented by the catch (R. D. Rogers and D. E. Stevens, *unpublished data*). In addition, $\hat{C} = \hat{E} \times \hat{c}$, where $\hat{E}$ is an estimate of the number of fishing hours and $\hat{c}$ is the estimated catch per hour. $\hat{E}$ was estimated from hourly counts of boats fishing during approximately 20 half-day counting periods selected randomly each month. Counting was done from vantage points on Angel Island in the central bay. Census clerks stationed at major fishing ports obtained data with which to estimate $\hat{c}$. Returns of tags applied in the delta during the spring were used to estimate $\hat{u}$.

Catches and abundance should have been overestimated by this technique in 1969 and 1970 because catch-per-hour data, $\hat{c}$, were obtained only from anglers that fished for bass, whereas boats fishing for all species $\hat{E}$ were counted. In 1971 catch-per-hour data were collected from all anglers.

Despite the above bias, abundance appears to be underestimated in all three years. The estimates (after subtracting recruitment estimated from growth rates based on monthly length frequencies) for 1969, 1970, and 1971 are 1.3 million, 1.0 million, and 1.0 million, respectively. These estimates are 19, 38, and 38% less than sums of the year-class Petersen estimates.

Factors causing abundance to be underestimated include the following: (1) fractions of the population represented by the catches, $\hat{u}$, probably were overestimated because the tagged sample is biased toward the older fish, which tend to be harvested at higher rates than the younger fish, which are more abundant (Chadwick 1968, Miller 1974, *unpublished data*), and (2) effort, $\hat{E}$, would be underestimated if all fishing boats were not visible from the counting site.

In conclusion, this method appears suitable only for measuring the general magnitude of abundance.

Recruitment and Population Indices Derived from Sportfishing, Party-boat Catch Records

Party boats are boats taking parties of anglers fishing for a fee. Since 1938, party-boat operators have been required to report angling effort and catches to the Department of Fish and Game. These records have been used (Stevens 1977) to develop two sets of recruitment indices which are highly correlated with delta outflow during the first summer of life.

Before the minimum legal length increased from 30.5 to 40.6 cm in 1956, most bass were two years old when recruited. These recruits dominated the fishery in Suisun Bay, and catch-per-angler-day was used to index their abundance. Catch-per-day was affected by other factors affecting fishing success (e.g., water turbidity and temperature), but multiple regression analysis can be used to minimize this bias. After 1956, catch-per-day on party boats is not an appropriate recruitment index, because few party boats have fished in Suisun Bay and fish size varies too much elsewhere.

From 1958 to the present, total abundance can be estimated annually using party-boat catches in conjunction with tag return data. The concept is $N_t = C_t/u_t$, where N_t = abundance of legal (≥40.6 cm) bass at the start of year t, C_t = total catch during year t of those bass that were legal at the start of the year, and u_t = fraction of the legal population harvested during year t.

Total catches C_t, are unknown, so reported catches on party boats, K_t, are used instead and are assumed to be a constant fraction of the total catches. Annual estimates of the fraction of the population harvested, $\hat{u}_t$, are available from tag returns (Chadwick 1968, Miller 1974, *unpublished data*). The abundance of legal bass, N_t, is then measured by the population index P_t as $P_t = K_t/u_t$.

Recruit abundance, R_t, is calculated assuming all recruitment occurs on May 1, which is approximately the first day used for annual tabulation of catch- and tag-return data. The formula is $R_t = P_t - P_{t-1} \cdot \hat{s}_{t-1}$, where $\hat{s}_{t-1}$ = estimated survival rate of legal bass based on tag returns in year $t - 1$. Since

1956, most recruits have been three years old (Robinson 1960, Miller and Orsi 1969); therefore, this index is assumed to measure abundance of that age class.

These population and recruitment indices are imprecise because (1) the party-boat catch does not form the same fraction of the total catch each year, (2) the fraction of the party-boat catch that is reported varies annually, and (3) recruitment does not consist entirely of three-year-old fish and does not occur instantaneously on May 1. These biases are discussed by Stevens (1977). Their overall effect was evaluated qualitatively by comparing trends in the recruitment index, R_t, with trends in annual mean weights of bass in the party-boat catch. The recruitment index tended to fluctuate inversely from the weights, suggesting that the recruitment index is a reliable indication of recruitment.

Except for 1970, from 1959 to 1974 R_t is related linearly to the logarithm of the mean June-July delta outflow three years earlier ($r = 0.82, P < 0.005$), indicating that river flows early in life affect recruitment.

Recruitment Indices From Creel-Census, Catch-Per-Unit-Effort Data

A roving creel census was conducted during the spring in the delta from 1959 to 1965 (Miller and McKechnie 1969). One objective was to obtain recruitment indices from data for catch-per-unit-effort and age composition of the catch. This goal was not met because the vulnerability of bass to angling apparently varied between years. This technique has yet to be evaluated with data from the San Francisco–San Pablo Bay census used for Petersen estimates.

Catch Monitoring – Postcard Surveys and Party-boat Catch-Per-Unit-Effort Data

Postcard questionnaires designed to measure angler success have been sent intermittently to random samples of buyers of fishing licenses since 1936 (Chadwick 1962, Seeley et al. 1963, McKechnie 1966, Emig 1971, Pelzman 1973) and each year since 1969. A comparison between total catch estimates derived from the post-1969 surveys (California Department of Fish and Game et al. 1975) and total catch estimates derived by multiplying the Petersen population estimates by estimates of the fraction of the population harvested (from tag returns) indicates that postcard respondents exaggerate their catches by a factor of about 6. Catch trends derived from the two methods show only fair agreement (Fig. 5), indicating that the postcard survey is insensitive to relatively small catch fluctuations. There is reasonably good agreement, however, between catch trends derived from postcard surveys and catch-per-angler-day on party boats since 1938 (Fig. 6), suggesting that the

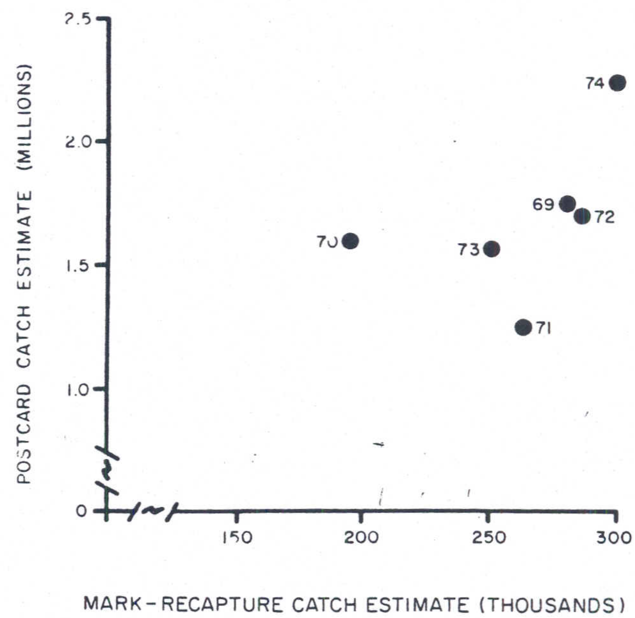

Fig. 5. Comparison between striped bass catch estimates derived from postcard questionnaires sent to anglers and catch estimates derived from mark-recapture studies. Mark-recapture catch estimates equal exploitation rate times the population estimate. Numbers adjacent to points indicate the year.

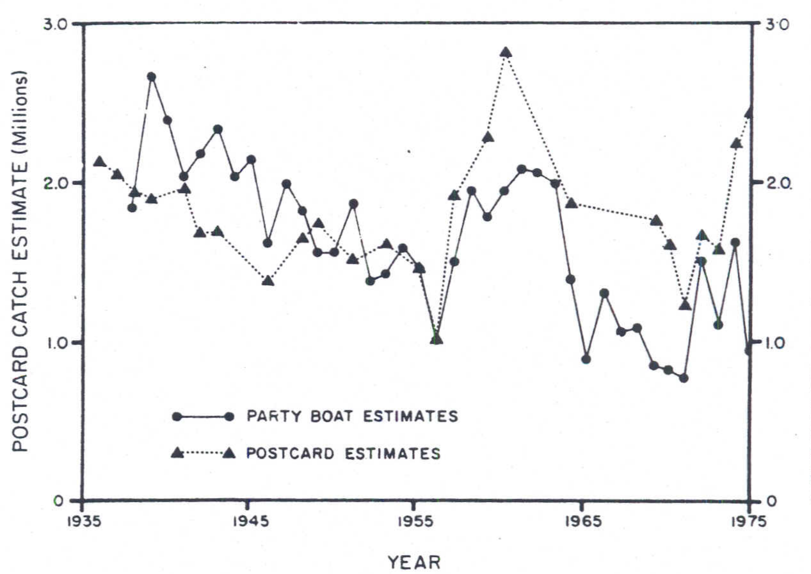

Fig. 6. Relationship between angler success estimates from postcard questionnaires and sportfishing party-boat reports.

postcard survey and the party-boat catch reports both generally depict true long-term catch trends.

Interestingly, the postcard indices have increased relative to the party-boat catch indices over the years. This increase probably reflects party boats catching a reduced fraction of the total catch due to increased ownership of private boats.

SUMMARY

The California Department of Fish and Game has tried several techniques, with varying success, for monitoring striped bass at life stages from egg to adult.

Egg and larva surveys with plankton nets in the spring provide the best descriptions of where and when bass spawn. However, these surveys apparently underestimate standing crops of eggs, and estimates of larva mortality rates do not explain annual abundance differences measured by the summer tow-net survey. These deficiencies probably are partly due to inefficient net designs.

Rather precise abundance-flow correlations indicate that when spring and summer flows are low or moderate, young bass abundance is indexed effectively by an annual, summer tow-net survey. When high flows transport young bass to San Pablo Bay, this survey apparently underestimates bass abundance due to inadequate sampling in the bay.

Sampling with a midwater trawl satisfactorily measures abundance of young bass during the fall. In winter, catches are too variable to provide meaningful indices. The reason for this variability is unknown.

Techniques have not been fully evaluated for monitoring one-year-old bass. Catch-per-unit-effort data from sportfishing party boats effectively monitored two-year-olds until 1956, when a change in angling regulations increased recruitment age from two to three years.

The Petersen method and indices from party-boat catches appear to be the best monitoring techniques for bass three years old and older. The Petersen method has been used since 1969. At the present stage of data compilation, Petersen estimates for individual year classes do not correlate well with abundance indices for young bass of the same year classes or with delta outflows in the first summer of life. This lack of correlation may be partly due to error in the individual estimates associated with small recapture samples, coupled with the small number (six) of data points for each adult year class. Variations in mortality between the first and third year of life also could weaken the correlation. However, a correlation coefficient of 0.82 for the less precise party-boat catch index vs flow over a 16-year period suggests such variations are small relative to mortality variations for younger stages.

Long-term catch trends apparently can be monitored for the entire fishery through postcard surveys and party-boat catch-per-unit-effort data.

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