Stevens

Marine Recreational Fisheries

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Factors Affecting the Striped Bass Fisheries of the West Coast

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This chapter reviews the history of the striped bass *(Morone saxatilis)* fisheries in the Sacramento-San Joaquin Estuary of California and in Oregon. Factors affecting bass abundance and the adequacy of monitoring data and angling regulations also are discussed for the Sacramento-San Joaquin Estuary. Unfortunately, there have been no studies that would provide similar knowledge of stripers in Oregon. The chapter concludes with a forecast of the future of the California and Oregon fisheries.

Introduction of The Species

Striped bass were introduced to the Sacramento-San Joaquin Estuary in 1879. This estuary extends from the delta at the junction of the Sacramento and San Joaquin rivers through a series of embayments to the Golden Gate at the entrance to San Francisco Bay (Figure 1). Initially, 132 young bass from the Navesink River, New Jersey were released into Carquinez Strait. A second plant of 300 fish from the Shrewsbury River, New Jersey followed in 1882. Striped bass from these introductions and/or their progeny spread along the Pacific Coast within a few years. They appeared in the Russian River and Tomales Bay by 1890 (Figure 2). In 1894, two bass were seined at Redondo Beach, Los Angeles County (Skinner 1962).

Within 20 years of the plants their range extended to southern Oregon (Parks 1978). Subsequently, the range has been documented from 40 km south of the California-Mexico border to Barkley Sound, British Columbia (Miller and Lea 1972). However, at present the only populations and fisheries of consequence are in the Sacramento-San Joaquin Estuary and Pacific Ocean within 40 km of the estuary and in Oregon (Parks 1978) in the Coos and Umpqua rivers.

Only one Oregon return from about 150,000 tags released in California from 1958 to 1979 indicates that exchange between the California and Oregon populations presently is almost nonexistent.

Commercial Fishery

California

Apparently, striped bass experienced a population explosion and unusually rapid growth rates soon after their introduction to California. Several bass as large as 8.4 kg appeared in the San Francisco markets between 1880 and 1884. By 1888, several thousand had been in the markets, and commercial fishermen began directing effort toward the species, primarily with drift gill nets. At the turn of the century the annual commercial catch in the Sacramento-San Joaquin Estuary was exceeding 450,000 kg. The greatest recorded catch was more than 900,000 kg in 1903. Subsequently, annual catches declined to about 225,000 kg by 1929. The decline apparently was caused mainly by increased restrictions on mesh sizes, areas open to fishing, open seasons, and size limits (Craig 1928).

In 1935, commercial fishing for striped bass was prohibited in California, although the stock of bass was not depleted (Craig 1930, Clark

1932, 1933). The closure stemmed largely from a social conflict between sport and commercial fishing interests. This conflict eventually culminated with the closure of the commercial gill net fisheries for chinook salmon *(Oncorhynchus tshawytscha)* and American shad *(Alosa sapidissima)* in the estuary in 1957. Thousands of bass were killed annually in the salmon and shad nets and could not be marketed legally. Hence, the closure of salmon and shad fisheries reduced fishing mortality for striped bass. The magnitude of the reduction cannot be estimated, because the

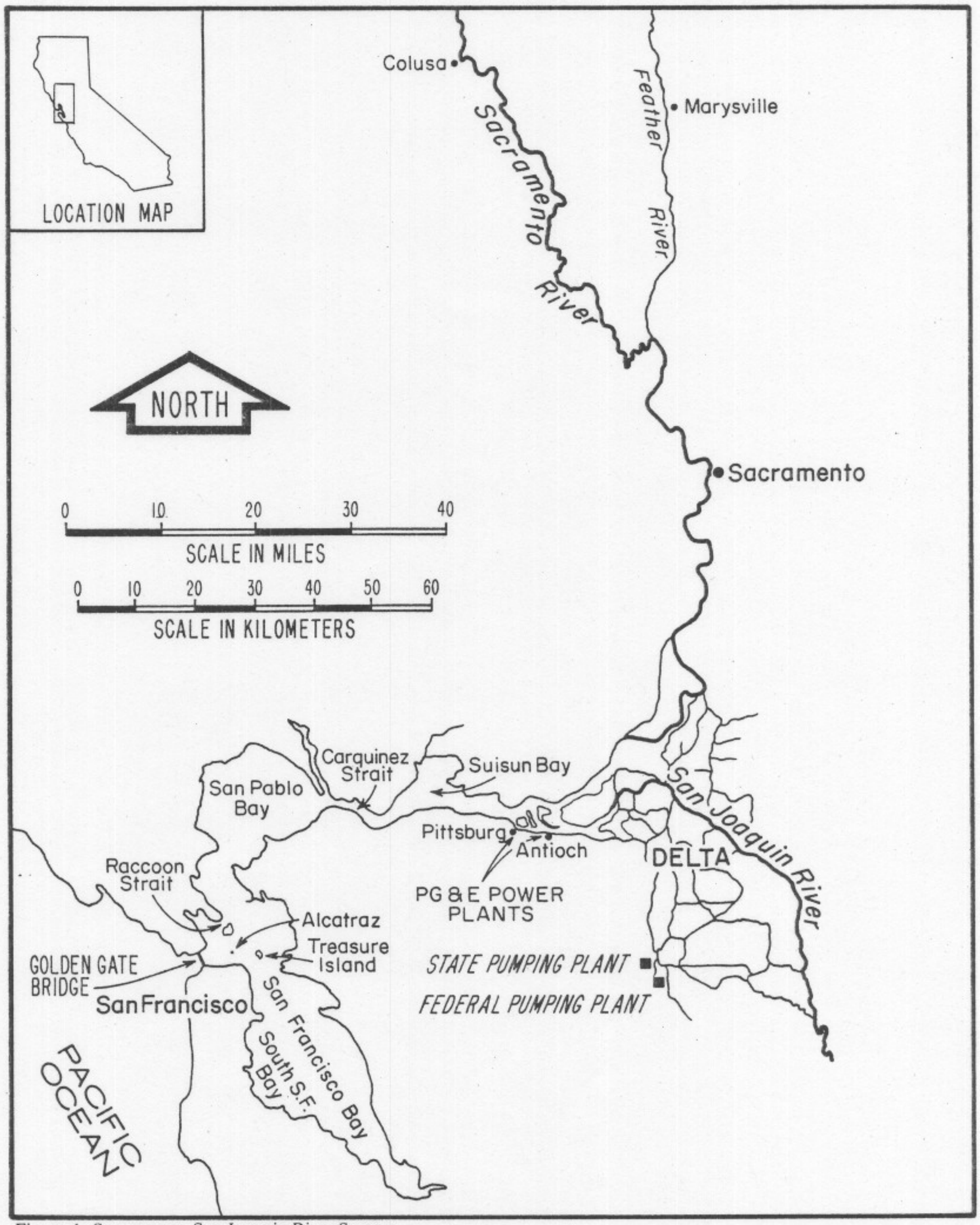

Figure 1. Sacramento-San Joaquin River System.

precise magnitude of harvest is unknown and some illegal netting continued.

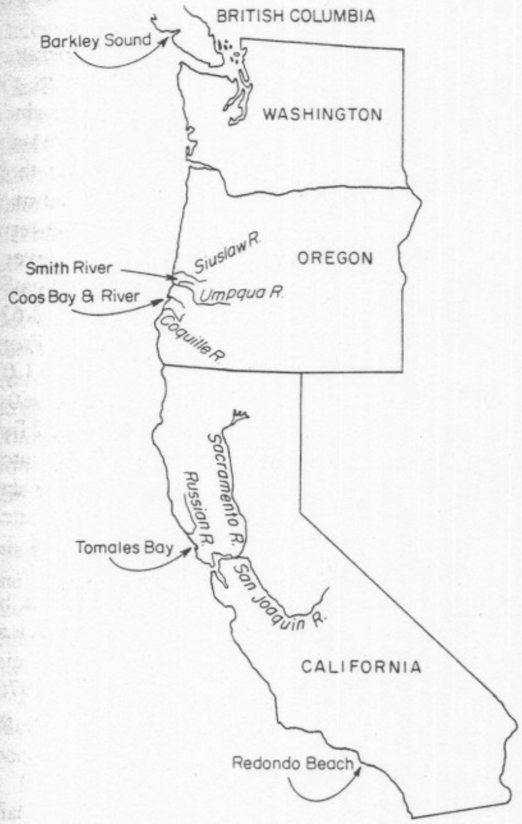

Figure 2. Range of striped bass on the West Coast of North America.

Oregon

The Oregon offshoot, although much smaller than the population established in California, increased to the point where it was fished commercially in Coos Bay in 1922. Subsequently, bass were taken commercially in the Smith, Umpqua, Coquille, and Siuslaw rivers where the bass fishery was more or less incidental to a gill net fishery for American shad. The largest catch was in 1945 when over 113,600 kg were landed. From 1960 to 1974, total commercial catches from the five Oregon rivers ranged from about 12,450 to 31,300 kg. However, in 1976, the commercial fishery for striped bass in Oregon was closed due to pressure on the legislature by recreational fishermen (Parks 1978).

Sport Fishery

California

In California, present sport fishing regulations include a 16-inch (40.6 cm) minimum legal length and a daily bag limit of three bass. Prior to 1956, regulations were more liberal with a 12-inch (30.5 cm) minimum legal length and five-fish bag generally in effect.

Striped bass anglers fish from the Pacific Ocean near San Francisco to the Sacramento and San Joaquin rivers more than 200 km above the delta.

Striped bass angling occurs the year around, but fishing localities vary seasonally in accordance with the striper's migratory pattern.

During the winter, striped bass are spread from San Francisco Bay through the delta and fishing is generally poor because stripers do not feed actively when the water is cold. However, good catches of large fish are made occasionally in the delta.

Fishing success improves as the water warms up in March. Stripers that winter in the bays start moving upstream to fresh water for spawning. During the spring, the bulk of the legal population is spread through the delta, and as far north as Colusa and Marysville on the Sacramento and Feather rivers. Good fishing can be expected throughout the spawning area at this time. Occasionally, some good catches of either early or late spawning bass are made in the bays in the spring.

By mid-June, most legal-sized bass have left the delta and returned to brackish and salt water. During summer and early fall, striped bass fishing reaches its peak in San Francisco Bay. Trollers and live bait drifters make good catches with regularity in Raccoon Strait, at the south tower of the Golden Gate Bridge, and off Alcatraz and Treasure islands. Farther upstream, evening trolling in Carquinez Strait and San Pablo Bay is usually productive. In some years, large numbers of bass migrate into the Pacific Ocean and many are caught by anglers trolling for salmon and by beach fishermen. Summer surf casting from the San Francisco beaches is occasionally successful. Shore angling is sporadically good in some areas of South San Francisco Bay during the spring and summer.

In recent years, the fall migration of bass to the delta has not started until October or November. Previously, this movement had started as early as late August. Its beginning is marked by good bait fishing in San Pablo Bay. Bait fishing in the delta improves gradually with the movement of bass into the area, and then declines as the water temperature drops in the winter.

Most striped bass fishing in the delta is done with cut or whole dead fish, such as sardine *(Sardinops spp.)*, northern anchovy *(Engraulis mordax)*, and threadfin shad *(Dorosoma petenense)*, for bait. In the bay areas there is considerable trolling and live bait fishing. Many types of plugs, jigs, and spoons are used in trolling, frequently in double combinations. Drift fishing with live bait—shiner perch *(Cymatogaster aggregata)*, anchovy, and herring *(Clupea harengus)*—is popular in San Francisco Bay. Staghorn sculpins ("bullheads") *(Leptocottus armatus)* and yellowfin gobies ("mudsuckers") *(Acanthogobius flavi manus)*, either alive or dead, are frequently used in San Pablo and Suisun bays.

Most fishing occurs from shore and private boats. However, commercial passenger fishing boats (commonly known as party boats and charter boats) are an important component of the fishery in the San Francisco-San Pablo Bay area. From 1969 through 1976, anglers on privately owned boats, commercial passenger fishing boats, and shore and pier took 66 percent, 14 percent and 20 percent of the catch, respectively (J. White, Calif. Dept. Fish and Game, unpublished data).

Commercial passenger fishing boat operators have been required to report catches to the California Department of Fish and Game since 1938. Although these boats at present take only about 14 percent of the total catch and their fishing locations and methods have varied over the years, their reports are the best long-term striped bass catch records available (Stevens 1977a). From 1938 to 1977, their annual catch per angler day ranged from 0.78 to 2.63, averaging 1.58. The peak year was 1939. From 1939 to 1956, the average catch declined to 1.02 bass per day. Later in the 1950s and early 1960s, success increased substantially, exceeding 2 fish per day in 1961 and 1962. After 1963, the catch dropped again and was less than 1 fish per day from 1969 to 1971. From 1972 to 1977, the catch rate has fluctuated irregularly between 0.78 and 1.68 bass per day (Figure 3).

To avoid any misconception, it should be pointed out that angler success for the fishery as a whole is lower than that for commercial passenger fishing boats. From 1969 to 1976, annual average catch rates for anglers on

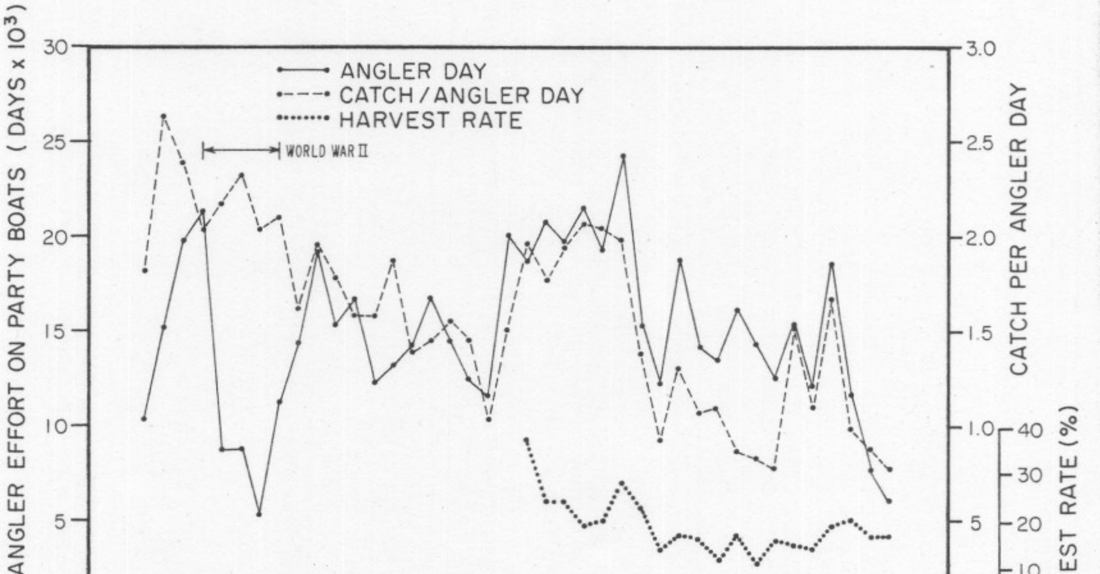

Figure 3. Trends in striped bass angler success, angler effort, and harvest rate in the Sacramento-San Joaquin River system.

commercial passenger fishing boats ranged from 1.4 to 2.4 times higher than catch rates for anglers on private boats in the bays. Also, angler success tends to be lower in the delta and rivers, often below 0.4 bass per day (Miller and McKechnie 1969).

Postcard questionnaires designed to measure angler success also have been used to monitor catch trends. Questionnaires have been sent intermittently to random samples of fishing license buyers since 1936. The postcard respondents exaggerate their catches by a factor of about 6, but there is reasonably good agreement between catch trends derived from postcard surveys and catch-per-angler-day on commercial passenger fishing boats since 1938, suggesting that the postcard survey and the commercial passenger fishing boat catch reports both generally depict true long-term trends (Stevens 1977b). Interestingly, the postcard indices have increased relative to the commercial passenger fishing boat catch indices over the years. This increase probably reflects commercial passenger fishing boats catching a reduced fraction of the total catch because of increased ownership of private boats.

Fishing effort trends closely parallel trends in success (Miller 1974) (Figure 3), presumably because more anglers fish when fishing is good.

In recent years, about 200,000 anglers have fished for Sacramento-San Joaquin striped bass and caught around 300,000 fish annually. In the early 1960s when success was greater, the annual catch was about 750,000 bass.

Harvest rates have been estimated by tagging almost annually since 1958 (Chadwick 1968, Miller 1974, Stevens 1977a). These estimates have varied from 12 percent in 1968 and 1970 to 37 percent in 1958. The harvest rate estimates equalled or exceeded 20 percent in all years from 1958 to 1964 except 1961 when the estimate was 19 percent; however, from 1965 to 1977, the harvest rate estimate reached 20 percent only in 1975 (Chadwick 1968, Miller 1974, Stevens 1977a, unpublished data). This decrease in exploitation apparently is the result of a decline in fishing effort resulting from decreased success since the early 1960s.

Over the years, annual fluctuations in the Sacramento-San Joaquin striped bass catch have been caused by fluctuations in bass abundance (Stevens 1977a), changes in bass migrations (Chadwick 1967, Orsi 1971), development of new fishing techniques (McKechnie and Miller 1971), discovery of more locations which hold bass, and changes in angling regulations. An increase in bass abundance and the development of deep trolling and live bait fishing techniques in San Francisco Bay probably are the major factors responsible for the high fishing success in the early 1960s. The subsequent decline in success appears to be due to a decrease in bass abundance associated with low recruitment in most years since 1961 (Stevens 1977a).

Oregon

Oregon regulations have limited anglers to three striped bass per day longer than 16 inches (40.6 cm) since 1978. Initial restrictions on the fishery occurred in 1947 when a 15-bass per day bag limit was established. At that time there was no minimum length restriction. The daily bag limit was reduced to five fish in 1950, but the minimum legal length of 16 inches (40.6 cm) was not set until 1960.

From the 1940s to the 1960s the fishery was primarily in the Coos Bay area; however, in the 1970s major emphasis shifted to the Umpqua River. The fishery is primarily in tidewater, although a drift boat fishery existed above tidewater in the Umpqua in the mid-1970s. There is no surf fishery for striped bass in Oregon.

Basic fishing techniques are similar to those in California. Bait fishing with cut fish, live sculpins, and shrimp occurs from shore and anchored boats. Plugs, jigs, and rigged fish are used by trollers. Anglers also have developed effective fly and plugging techniques for use in the Umpqua Estuary in the summer (D. Anderson, Oregon Dept. Fish and Wildlife, personal communication).

There are no consistent striped bass sport catch records for Oregon; however, commercial catch sampling and observations of the sport fishery indicate that the fishery depends to a large extent on dominant year classes which have occurred infrequently. Such year classes occurred in Coos Bay in 1940 and 1958. The lack of more recent dominant year classes there has caused fishing to deteriorate in Coos Bay. However, the 1966 year class was large in the Umpqua. It created good fishing and caused angler effort to shift away from Coos Bay in the 1970s (A. McGie, Oregon Dept. Fish and Wildlife, personal communication).

Observations of the Oregon fishery suggest that, as in California, fishing effort tends to increase and decrease with angler success. Hence, effort has been tied largely to the presence of the dominant year classes (A. McGie, personal communication).

Catch and angler effort were estimated for the peak Umpqua fishery from an angler census. In 1972, about 31,500 angler days were expended and 6,000 striped bass were caught. Roughly, 40 percent of those bass were from the 1966 year class. In 1973, effort was about 21,700 angler days and the catch was about 3,300 bass. There are no newer data, but there is no question that catch and effort have decreased considerably during the last several years (D. Anderson, personal communication). Recent catch and effort data are not available for Coos Bay but, in 1950, about 1,200 anglers caught about 2,500 bass (Morgan and Gerlach 1950).

The abundance of bass (largely age 5 and older, but including some 4-year olds) in the Umpqua was estimated during the peak years from tag returns and commercial catch data. These estimates were 56,500 bass in 1972 and 34,500 bass in 1973 (A. McGie, personal communication). In 1972, sport and commercial fishermen each harvested about 9 percent of the Umpqua population, for a total exploitation rate of 18 percent (A. McGie, personal communication).

An exploitation rate of 19 percent was estimated for the Coos Bay commercial fishery in 1950. This fishery caught about 3,400 bass (Morgan and Gerlach 1950). Hence, the sport catch of 2,500 bass would have represented an exploitation of about 11 percent (2,500: 3,400 = 0.11: 0.19), and total exploitation would have been about 30 percent. A minimum estimate of total bass abundance that year was 18,000 fish (Morgan and Gerlach 1950).

Factors Affecting Bass Abundance In California

Knowledge of factors affecting striped bass abundance is needed for intelligent management of the fishery. To obtain this knowledge, studies have been established to learn (1) which factors have the most effect on survival during the first year of life, and (2) how abundant various year classes are when they enter the fishery so the relation between abundance of young and the number of recruits that they produce can be defined.

The studies have demonstrated that bass abundance is controlled principally by environmental conditions, rather than by angler harvest. Effects of flow reductions and water exports from the southwestern delta (Figure 1) have received the most attention (Turner and Chadwick 1972, Stevens 1977a, Chadwick et al. 1977) because water project operations have had substantial impact on the hydrology of the estuary. Power plants and pollution also affect striped bass, but uncertainty exists as to the degree to which they impact the population. This section summarizes what is known regarding the effects of these three factors.

Effects of River Flow and Water Diversion on Survival of Young

Abundance of young bass has been monitored annually from 1959 to 1979 (except 1966). Abundance indices have varied by a factor of 17.7 and from 1959 to 1976 were directly correlated with outflow from the delta and inversely correlated with water diversion rates

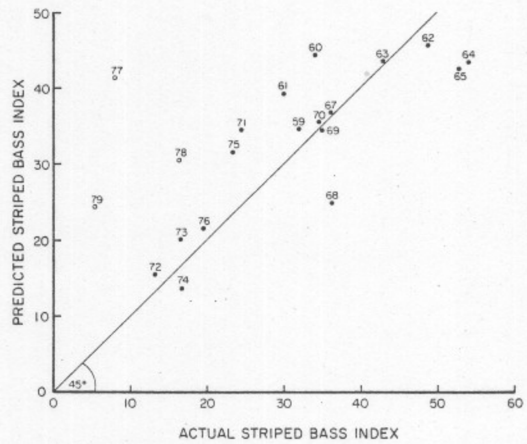

Figure 4. Relationship between actual abundance of young striped bass in the delta (X-axis variable) and abundance predicted from May-June diversions and delta outflow (Y-axis variable). Numbers adjacent to points indicate year over the period 1959-1979. The regression equation used to obtain the Y-axis coordinates of the points plotted in this figure is $Y = -199.5 - 0.23$ (mean daily May-June diversions) $+ 218.0$ (log mean daily May-June outflow) $- 41.5$ (log mean daily May-June outflow)^2; $R^2 = 0.70$. Regression is for the period 1959-1976. Outflows are in cubic meters per second.

during all combinations of months from April to July (Turner and Chadwick 1972, Chadwick et al. 1977). A multiple regression equation using outflow and diversion rates as independent variables explained 69 percent of the variation in abundance of young bass surviving in the delta (Figure 4). Another equation that just uses outflow rates explained about 77 percent of the variation in abundance of young bass inhabiting the estuary west of the delta (Figure 5).

These relationships apparently were caused partly by local agricultural and federal and state water project export diversions removing increased numbers of fish and perhaps their food organisms from the delta as outflows decrease and diversion rates increase. Fewer fish are diverted when flows are high because the diversions take a smaller fraction of the flow and high flows transport more young fish to Suisun Bay where there are few diversions (Chadwick et al. 1977).

Bass are removed roughly in proportion to their abundance by local diversions, most of which are small but unscreened (Allen 1975). The export diversions have louver screens, but these screens are ineffective on bass too small to swim well. The screens do not attain 50 percent efficiency until the bass grow to 19 mm long (about 1 month old). Above 19 mm, screen efficiency increases gradually to about 85 percent for bass longer than 100 mm (about 5 months old) (Skinner 1974). Export diversions now impact bass substantially more than local diversions because they remove more water and because they are so large that they draft water and bass from nursery areas downstream from the diversions.

Another effect of water export pumping is that it causes high flow velocities in the channels which convey water from the Sacramento River to the pumping plants in the southern delta. High velocities reduce standing crops of important food organisms (copepods, cladocerans, and *Neomysis mercedis)* for young bass (Turner 1966, Heubach 1969).

Variations in survival of the young are not controlled solely by diversions, however. Flows probably also affect survival by regulating the

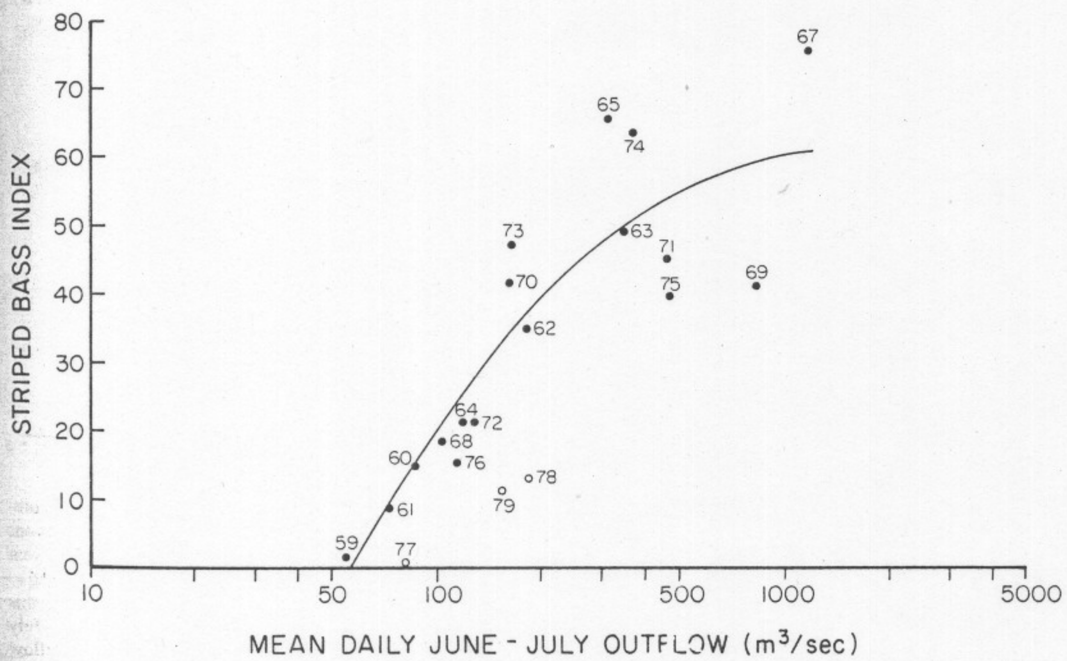

Figure 5. Relationship between abundance of young striped bass downstream from Collinsville (Suisun Bay index), Y, and mean daily delta outflow during June and July. Numbers adjacent to points indicate year over the period 1959-1979. The regression equation for the years 1959-1976 is Y = -257.7 + 204.6 (log mean daily June-July outflow) - 32.9 (log mean daily June-July outflow)^2; $R^2 = 0.76$.

spatial distribution of the young. When high flows disperse the fish over more of the estuary, living space increases and competition for food may be reduced (Stevens 1977a, Chadwick et al. 1977).

In 1977, 1978, and 1979, young bass abundance indices averaged 32 percent lower than expected from the prior relationship between abundance, flow, and diversion rates. Hence, some other factor(s) caused survival to be low. During these years abundance of a major food organism, the opossum shrimp, *Neomysis,* was low too, and the bass index now correlates well ($r = 0.89$) with *Neomysis* abundance for the period when *Neomysis* abundance data are available (1965, 1968-1979) (Lee W. Miller, unpublished data). Data collected by the California Department of Water Resources and U.S. Water and Power Resources Service suggest that primary production also has been relatively low since 1977. However, it is not known if these events represent a chain of causes and effects or if other factors caused them to occur simultaneously. At any rate, it appears that some fundamental change in the factors controlling bass abundance occurred coincident with a severe drought in 1977.

Several approaches are being used to measure recruitment to the fishery. In recent years a major effort has been made to apply the Petersen mark-recapture method (Bailey 1951) to estimate both recruitment and total abundance of legal ($\geq$ 40.6 cm total length) bass. Basically, this method consists of marking a sample of fish, releasing them to mix back into the population of untagged fish, and then resampling the population to estimate the fraction marked. Total abundance is calculated by dividing that fraction into the initial number tagged.

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 resampled through an annual summer-fall census of angler catches in San Francisco and San Pablo bays and during subsequent tagging operations. Extensive data stratification is necessary to compensate for various sampling biases (Stevens 1977b). Scale samples are taken for aging so abundance of individual year classes can be estimated.

From 1969 to 1979, 136,113 bass were tagged and more than 200,000 bass were observed in anglers' catches. Total abundance estimates have ranged from 1.5 million in 1974 and 1976 to 1.9 million in 1972 and 1975. The relation between numbers of bass recruited and their abundance when young is still not clear from this study. The correlation coefficient for the relation between abundance of 3-year old bass and the abundance indices for the same year classes when young is only 0.50 ($N = 7$). However, the relation between 3-year old bass abundance and flow (mean June-July) is statistically significant ($r = 0.76$, $N = 8$), although that relation is tenuous since it is based on so few data points and it accounts for less than 60 percent of the variation in abundance ($r^2 = 0.58$). Additional data points for year classes expected to be either exceptionally large or small may better define the relation between recruitment and survival when young. Since abundance of young bass was low from 1976 to 1979 and these year classes will be recruited from 1979 to 1982, the data necessary to complete this evaluation should be available in 1983 or 1984.

Other less expensive means of measuring recruitment also have been investigated. Two methods are based on commercal passenger fishing boat catch records (Stevens 1977a).

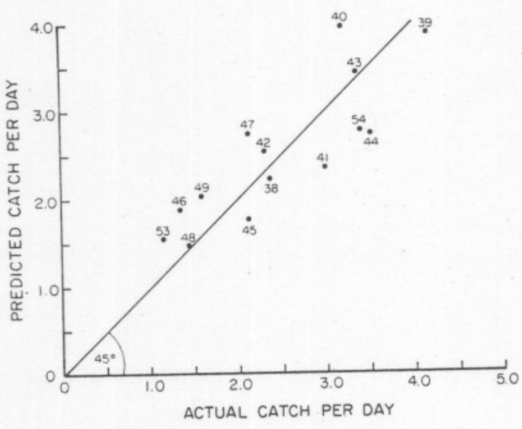

Figure 6. Predicted versus actual fishing success on commercial passenger fishing boats in Suisun Bay (Stevens 1977a). Numbers adjacent to points indicate fishing year over the period 1938-1954. The regression equation used to obtain the Y-axis coordinates of the points plotted in this figure is $Y = -13.11 + 0.91$ (log mean daily June-July outflow two years earlier) - 0.0069 (mean daily delta outflow during the August-November fishing period for the given year) + 0.88 (mean annual sea temperature at La Jolla, California): $R^2 = 0.70$. Outflows are in cubic meters per second and temperatures are in degrees Celsius.

Although the recruit indices developed from these records are imprecise, indices from 1938 to date correlate well with flow during the spring and early summer when the recruits were young (Figures 6 and 7). Thus, they provide evidence that environmental conditions early in life are the most important factors affecting recruitment, indicating that density dependent changes in mortality are not sufficient to overcome variations in early survival.

Power Plants

There are two Pacific Gas and Electric Company (PG&E) power plants which use up to 90 cubic meters per second of water from the striped bass nursery area for "once through" cooling. Chadwick and Stevens (1971) and Chadwick et al. (1977) concluded that mortality caused by these plants was minimal compared to that caused by the water project and agricultural diversions and other environmental factors associated with outflow. This conclusion was based on these circumstances: (1) entrained bass usually were not exposed to lethal temperatures, (2) field tests suggested that few fish were mechanically damaged, and (3) power plant effects were not evident in the statistical relations between young bass survival and flow and diversion rates even though there were two significant increases in

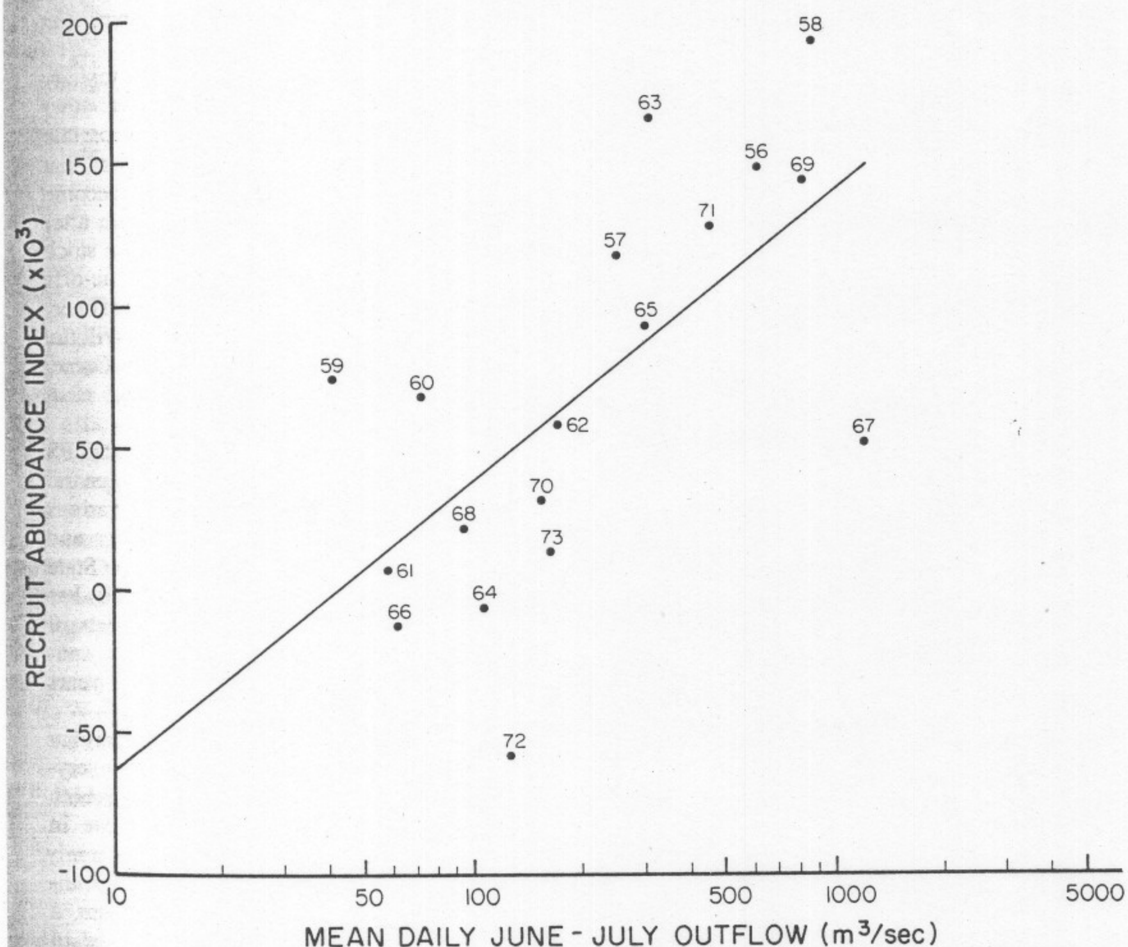

Figure 7. Relationship between index of abundance of three-year-old bass, Y, and mean daily delta outflow during June and July three years earlier (adapted from Stevens 1977a). Numbers adjacent to points indicate year classes over the period 1956-1973. The regression equation is Y = -170085 + 102882 (log mean daily June-July outflow): $r^2 = 0.43$.

cooling water demand (totaling 48 percent of the present demand) during the survival study.

The evidence that recruitment is a function of early survival suggests that whatever losses are caused by entrainment do impact the fishery, however. This impact probably is increasing, as increased power production is causing lethal temperatures (Stevens and Finlayson 1978) to occur more frequently (PG&E 1977) and additional plants are planned. The effects of the power plants are now being reevaluated for PG&E by Ecological Analysts, Inc. for the 316b demonstrations required by the Federal Water Pollution Control Act of 1972. This evaluation which will be based partly on our striped bass monitoring data should better define the significance of losses to the power plants.

Pollution

During the past decade or so, there have been only a few isolated areas in the Sacramento-San Joaquin Estuary where pollution has been obvious. Low dissolved oxygen levels sometimes have caused fish kills in the vicinity of sewage treatment plants and in stagnant areas with high biochemical oxygen demand. On rare occasions, acute toxicants discharged by industry have caused fish kills. Both of these problems have been infrequent and localized enough that they cannot be considered major factors affecting the bass population.

Chronic toxicity is likely the principal pollution problem in the estuary. It has been hypothesized that such toxicity in combination with osmoregulatory stresses is responsible for large annual dieoffs of striped bass in the Suisun-San Pablo Bay area. These die-offs have occurred for at least 25 years in late spring and summer when the bass are migrating from fresh to salt water after spawning. They form an unknown fraction of the 15 to 30 percent annual "natural mortality" (Chadwick 1968, Miller 1974, Stevens 1977a) suffered by the population. Surveys to monitor the die-offs were conducted on a few selected beaches and by boat from 1971 to 1973. From 1,565 to 1,763 bass carcasses were counted during each of these years (Kohlhorst 1973, 1975). However, the total die-off is much larger because (1) the surveys concentrated on the beaches and they form only a small portion of the total shoreline, and (2) many fish must decompose without reaching shore. Various attempts to determine the cause have been unsuccessful.

Regarding the hypothesis that the die-offs are partly caused by chronic toxicity, recent studies by the National Marine Fisheries Service (NMFS) indicate several classes of pollutants occur at chronic levels in striped bass tissues (Whipple et al. MS). Samples and data are still being analyzed, but autopsies of more than 300 bass show prespawning females accumulated both heavy metals (in particular zinc, copper, and iron) and monocyclic aromatic and methyl cyclohexane petroleum hydrocarbons. Additional physiological observations and high rates of parasitism in these fish have led NMFS to hypothesize that these pollutants are detrimental to body, liver, and gonad condition, and possibly the immune response system (Whipple et al. 1979).

In view of the NMFS findings, the toxicity hypothesis seems to have merit; however, other factors still cannot be ruled out as possible causes of the die-offs. Recently, we learned that populations of striped bass which have become established in the Colorado River system after introductions of Sacramento-San Joaquin stock in the 1960s and 1970s undergo similar die-offs after the spawning season (Robert Sumner, Nevada Dept. Fish and Game; William Loudermilk, Calif. Dept. Fish and Game; personal communications) suggesting that genetic factors could be involved.

Whatever the cause of the die-offs, the NMFS studies have identified concerns as to the general well being of the population because the various chemicals potentially affect egg viability and survival of all life stages. As a result, the State Water Resources Control Board (SWRCB) has ordered additional investigation into effects of toxicants on striped bass. SWRCB is contributing $200,000 over the next two years toward these studies.

Toxicity caused by DDT and PCBs has received considerable attention almost everywhere. This attention is well deserved as both compounds are long-lived and accumulate in food chains, although their use has been largely phased out. Although the magnitude of the damage done by these toxicants is uncertain, a recent decrease in concentrations measured in striped bass by the Department of Fish and Game pesticides unit is encouraging. From 1967 through 1972, DDT and its metabolites were consistently present in Sacramento-San Joaquin striped bass flesh at average concentrations between 1.5 and 1.8 ppm (Table 1). However, DDT concentrations declined steadily from 1972 to 1976, when the average concentration measured was only 0.12 ppm. PCB concentrations were measured only in 1972 and 1976 when mean levels were 5.49 and 0.51 ppm, respectively.

Table 1. Mean concentrations (ppm) of DDT and PCBs in flesh of striped bass from the Sacramento-San Joaquin Estuary, California. Sample sizes are in parentheses

Year	DDT and metabolites	PCBs
1964	0.62 (7)	
1965	0.54 (6)	
1967	1.62 (2)	
1969	1.72 (29)	
1970	1.69 (49)	
1971	1.45 (18)	
1972	1.80 (22)	5.49 (22)
1974	0.59 (8)	
1975	0.21 (13)	
1976	0.12 (9)	0.51 (9)

Adequacy of Monitoring Data In California

The various techniques used to monitor the Sacramento-San Joaquin bass population have technical shortcomings such as deficiencies in net design, unexplained variability in sampling efficiency, incomplete coverage of striped bass habitat by some surveys in some years, and sample sizes that are sometimes too small to provide reliable indices. Stevens (1977b) discusses sampling deficiencies in more detail.

Despite the technical shortcomings, the monitoring apparently has provided a reasonably good understanding of striped bass requirements which has resulted in significant recommendations on water project design and operation. Water quality and flow standards imposed by SWRCB from these recommendations have cost the projects millions of dollars in potential development benefits (Chadwick 1977).

Chadwick (1977) also makes another important point, that the conclusions depend strongly on investigations conducted over many years. Short intensive investigations undertaken when a development project is initiated could not provide the insights. Hence, the results demonstrate the value of background data that can only be collected by fish and wildlife management agencies. They also demonstrate a need for postproject monitoring in case new environmental conditions fall outside the range of observations during preproject evaluation.

Whether or not all of the important factors affecting the bass population are accounted for is of some concern. The lower than predicted survival of young bass during the past three years is particularly disturbing. Another shortcoming is the uncertainty regarding the significance of the various toxicants present in bass tissues. The studies recently initiated by NMFS may help provide this answer.

There also is little understanding of factors affecting the carrying capacity of San Francisco and San Pablo bays. Over the years, waste discharges, dredging, and land fill projects have degraded the bay habitat. However, now, planning and regulatory agencies have reduced these problems. Potential effects of declining flows caused by upstream water development are of greater concern. Responding to this concern, the California Department of Water Resources and U.S. Water and Power Resources Service (USWPRS) have agreed to provide funding for a program that started in July, 1979 to assess the effects of flow on the bay system.

Adequacy of Angling Regulations In California

Under present laws the Sacramento-San Joaquin striped bass population tends to ''self-regulate.'' That is, the proportion of the population harvested seems to vary directly with bass abundance. This tendency is exemplified in the decline in angler effort and harvest rates which have coincided with decreased success rates since the early 1960s (Figure 3).

The striped bass harvest probably could be increased somewhat without significantly increasing total mortality. Tag returns indicate that at present about 30 percent of the population dies from natural causes—about twice the fraction harvested. Part of an increased harvest undoubtedly would come from the pool now dying from natural causes.

It is relevant that when catches declined in the 1960s the average size of harvested bass increased, indicating overfishing did not cause the decline. Instead bass abundance probably decreased due to poor recruitment (Stevens 1977a).

Equilibrium yield modelling indicates that angling regulations could be varied over a wide range without endangering the population, but the nature of the fishery could be changed depending on alternative regulations selected (Chadwick 1969). In general, reducing the minimum size limit or relaxing other restrictions would result in greater catches of smaller fish. More restrictive regulations would result in smaller catches of larger fish. Chadwick (1969) concluded that the present 40.6 cm size limit and three-fish bag limit were a reasonable compromise, but also pointed out that a moderate increase in harvest rates would increase numbers of bass caught without significantly reducing the total weight of the catch. He recommended that serious consideration be given to relaxing regulations such as removing some restrictions on night fishing.

Susbsequent attempts to relax regulations have been resisted by organized sportsmen. That resistence seems to stem primarily from an unwillingness to accept the premise that relaxing regulations would be sound biologically. Apparently this is a reaction to the declining angling success associated with the decline in bass abundance since the early 1960s. Hence, present regulations appear reasonably acceptable sociologically, but they are not optimal from the standpoint of resource utilization.

Forecast

California

Short term, the outlook is for reduced catches since legal bass abundance probably will decline from the present levels because of four consecutive years of poor recruitment. Survival of the young from the year classes (1976-1979) to be recruited from 1979 to 1982 varied from 9.6 to 50.9 percent of the average measured from 1959 to 1975.

Longer term, the outlook is more favorable provided water management criteria that have been developed actually improve survival of young bass and provided chronic toxicity is not eroding the population. The water management criteria include maintaining sufficient freshwater flows through the delta and moving the intake for the water project diversions to a location upstream from the nursery area in the delta.

A major step forward occurred in 1978 when SWRCB adopted more stringent flow and salinity standards and other operational constraints on the USWPRS's Central Valley Project (CVP) and the State Water Project (SWP) for the protection of striped bass. The question of whether the federal CVP is obligated to meet such state standards has been the subject of lengthy litigation, but recently a U. S. Supreme Court decision concluded CVP is obligated unless the standards are inconsistent with a congressional directive. While some people question whether the new standards are consistent with congressional directives, the Secretary of the Interior has committed CVP to meeting them voluntarily, subject to certain limited exceptions.

The peripheral canal project has been proposed as an alternative to the present CVP and SWP diversions in the delta. The canal would divert water from the Sacramento River near the northern boundary of the delta above the major nursery area and run along the eastern edge of the delta to the export pumps (Figure 1). Although this concept was first suggested about 15 years ago, conflicting interests have prevented its implementation. Chadwick (1977) discusses some of the actions being taken to help deal with this problem. They include establishing an advisory committee of environmental and conservation leaders, seeking reasonable decisions by regulatory agencies, negotiating between fish and wildlife and water development agencies to establish criteria for project operations, and seeking legislation to correct deficiencies in present law. Only time will tell if these attempts become successful.

Oregon

Inasmuch as the Oregon fishery is so dependent on dominant year classes and inasmuch as no such year class has been recognized since 1966, the short-term outlook is for low catches. No studies of striped bass requirements or environmental management oriented toward striped bass are planned; therefore, in the long term it appears that anglers probably will have to depend on the occurrence of whatever events combine to create dominant classes. On the positive side, an analysis of long-term commercial catch records indicates that average populations are still increasing in the Umpqua, Siuslaw, and Coquille rivers (A. McGie, personal communication), and that the elimination of commercial fishing may result in somewhat larger numbers of bass. However, the occurrence of dominant year classes probably still will be necessary to create a boom in fishing.

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