Striped Bass

History of the Fishery

In 1879, 132 young striped bass (*Morone saxatilis*) from the Navesink River, New Jersey were released into the San Francisco Bay estuary at Carquinez Strait. A second plant of 300 fish from the Shrewsbury River, New Jersey followed in 1882. Shortly after these introductions, striped bass experienced a population explosion in the estuary. Commercial harvesting started in the early 1880s, and by the turn of the century, exceeded one million pounds annually. The greatest recorded commercial catch, over two million pounds, occurred in 1903. Subsequently, annual catches declined due to increased restrictions on the fishery.

In 1935, the commercial fishery for striped bass was closed, although the stock was not depleted. The closure stemmed largely from a social conflict between sport and commercial fishing interests which culminated in the closure of the commercial gillnet fisheries for chinook salmon and American shad in 1957. Thousands of striped bass that could not be legally marketed were killed annually in nets fished for these two species. Closure of the salmon and shad fisheries reduced fishing mortality for striped bass, but the magnitude of the reduction cannot be estimated because the precise extent of the incidental harvest is unknown. Some illegal netting continues today.

The striped bass sport fishery has become the most important fishery in the San Francisco Bay estuary and one of the most important fisheries on the Pacific Coast. From 1969 to 1996, a general decline in catch was associated with a decline in striped bass abundance. Over this period, the annual catch varied from about 444,000 fish in 1975 to 52,000 fish in 1994. During the early 1960s, the annual catch of striped bass was even larger, probably around 750,000 fish. In 1985, an economist estimated the annual value of the striped bass fishery to exceed 47 million dollars.

Striped bass angling occurs year-round, but fishing localities vary seasonally in accordance with the striped bass migratory pattern. Tag recoveries indicate that many adults inhabit salt water San Pablo Bay, San Francisco Bay, and the Pacific Ocean in the summer. The proportion entering the ocean varies from year to year. These fish begin returning to the delta in the fall.

Striped Bass, *Morone saxatilis*
Credit: DFG

The distribution of fishing effort and catch has changed substantially over the years. Before the late 1950s, little fishing occurred in San Francisco Bay and the Pacific Ocean. Most of the catch came from San Pablo and Suisun bays, the delta, and rivers upstream. From the late 1950s to early 1980s, however, post-spawning striped bass generally migrated farther downstream and stayed there longer. Thus, fishing improved in San Francisco Bay and the Pacific Ocean and declined in the delta. Also, the use of the Sacramento River as a spawning area appeared to have increased, improving fishing there in the spring. In the 1980s and much of the 1990s, the migrations shifted upstream again with Suisun Bay and the delta providing the bulk of the catch. However, in 1998 and 1999, fishing once again improved substantially in San Francisco Bay and the ocean. While significant environmental changes have occurred, data are insufficient to develop conclusions regarding causes of these changes in striped bass migrations.

Based on tag returns, in the 1970s private boat anglers accounted for about 63 percent, shore anglers for 19 percent, and commercial passenger fishing vessels for 18 percent of the annual striped bass catch. By the 1990s, the private boat portion of the catch changed little (64 percent), but the commercial passenger fishing vessel portion decreased to nine percent and the shore catch increased to 27 percent of the total.

Striped bass are generally caught by bait fishing or trolling, although under some conditions fly-fishing or casting plugs or jigs is effective. Common dead baits include threadfin shad, anchovies, cut sardines, staghorn sculpins (bullheads), gobies (mudsuckers), shrimp, blood worms, and pile worms. Drift fishing with live anchovies or shiner perch is popular in San Francisco Bay and the Pacific Ocean, and live golden shiner minnows or theadfin shad are sometimes are used in the delta. Trolling methods are specialized. Many types of plugs, jigs, and spoons are used in trolling, frequently in double combinations.

Present fishing regulations include an 18-inch minimum length and a daily bag limit of two fish. From 1956 to 1981, the minimum length was 16 inches and the bag limit was three fish. Prior to 1956, regulations were more liberal. A 12-inch minimum length and five-fish bag limit generally was in effect.

Exploitation rates have been estimated almost annually since 1958. They have varied from nine percent (1989, 1992, and 1994) to 28 percent (1963) except for an unusually high 37 percent in 1958. Exploitation in the San Francisco Bay estuary is lower than for historic exploitation

on commercially fished Atlantic Coast stocks, which were exploited at rates as high as 50 to 70 percent annually before a severe population decline in the 1980s led to very restrictive regulations, included fishing moratoriums.

While the primary California population of striped bass is located in the San Francisco Bay estuary, striped bass also have been introduced into many other areas including the lower Colorado River, several reservoirs, and the Pacific Ocean in southern California. Conditions are generally not suitable for striped bass spawning in the reservoirs or in marine waters off southern California, so those fisheries usually depend on maintenance stocking from hatcheries. However, at least two reservoir populations, Millerton and New Hogan, do reproduce successfully. A striped bass fishery also has developed in reservoirs which are part of the State Water Project (SWP) and the federal Central Valley Project (CVP), such as San Luis Reservoir, O'Neill Forebay, and Pyramid and Silverwood lakes. These reservoirs are unintentionally stocked by young bass contained in water diverted from the Sacramento-San Joaquin Delta, and their fisheries have also declined in response to the decline of the "source" San Francisco Bay estuary population.

Status of Biological Knowledge

Spawning and Early Nursery Period. Striped bass begin spawning in the spring when the water temperature reaches 60˚ F. Most spawning occurs between 61˚ and 69˚ F, and the spawning period usually extends from April to mid-June. They spawn in fresh water where there is moderate to swift current. The section of the San Joaquin River between the Antioch bridge and the mouth of the Middle River, together with the other channels in the area, is one very important spawning ground. Another is the Sacramento River from Sacramento to Colusa. About one-half to two-thirds of the eggs are spawned in the Sacramento River and the remainder in the San Joaquin River system. Female striped bass usually spawn for the first time in their fifth year when they are 22 to 25 inches long. Many males mature when two years old and only about 11 inches long. Most males are mature at age three.

Stripers are very prolific. A five-pound, five-year-old female may spawn as many as 250,000 eggs in one season, and a 12-pound, eight-year-old fish is capable of producing over a million eggs. Some striped bass live for more than 20 years; these fish may exceed 50 pounds in weight and spawn several million eggs. Because of this great reproductive potential, striped bass were able to establish a large population within a few years after their introduction in California.

Striped bass typically spawn in schools at night during periods of warm weather when water temperatures rise. On one occasion, DFG biologists observed several thousand striped bass at the surface along the bank of the Sacramento River above Knights Landing. Small groups of from three to six bass were observed splashing and churning in the main current of the river in the act of spawning. At times, five or more groups of bass were observed spawning at one time. Usually a large female was accompanied by several smaller males.

During the spawning act, eggs and milt are released into the water. The milt contains microscopic sperm cells that penetrate the eggs and cause them to begin to develop. While the eggs are still in the female they are only about 0.04 inch in diameter, but upon their release they absorb water and increase to about 0.13 inch in diameter. At this time, they are so transparent that they are virtually invisible.

Striped bass eggs are only slightly heavier than water; so a moderate current will suspend them while they develop. Without any water movement they sink to the bottom and die. The larval bass hatch in about two days, although the length of time depends upon the temperature. Development is faster when the water is warmer.

The newly hatched bass continue their development while being carried along in the water. At first, the larval bass subsist on their yolk, but in about a week they start feeding on tiny crustaceans, which are just visible to the naked eye. After several weeks, they begin feeding on larger invertebrates, such as opossum shrimp and amphipods. At this time, they generally inhabit the delta and Suisun Bay. By late July or August, the young bass are about two inches long.

Status of the Population

Young Striped Bass Abundance

Reduced juvenile production was the principal cause of the adult striped bass population decline between the early 1970s and the early 1990s. Since 1959, the DFG has sampled young-of-the-year striped bass each summer (except 1966). An extensive survey is conducted every second week from late June to late July or early August throughout the nursery habitat. The fish are measured, and when their mean fork length reaches 1.5 inches, a young-of-the-year index is calculated on the basis of catch-per-net-tow and the volume of water in the areas where the fish are caught.

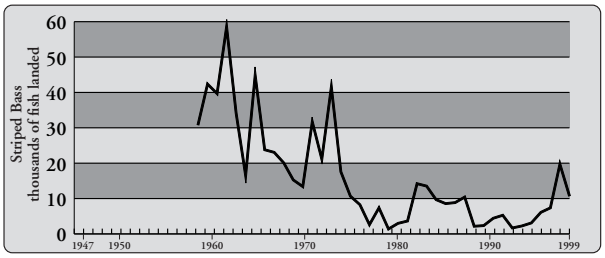
Young-of-the-year striped bass abundance has suffered an erratic but persistent decline from high index levels sometimes exceeding 100 in the mid-1960s to the all time low of only 1.4 in 1998. From 1959 to 1976, average

abundance of young striped bass was more than three times the subsequent average abundance.

Substantial effort has gone into evaluating factors controlling young striped bass production. Initially (1959-1970), annual fluctuations in young bass abundance could be explained by a simple model based on delta freshwater outflow which indicated that young bass production was much greater in years with high spring-early summer flows than in years with low flows. The mechanism causing the most abundant year classes to occur under high flow conditions was unknown. However, one potential explanation was that when flows were high, a lower percentage of the flow to the delta was diverted by the combination of major water projects (CVP and SWP) and local delta agriculture. Hence, under those conditions, fewer young bass would be entrained in diverted water and removed from the estuary. Other potential explanations for the greater abundance in high flow years included: 1) expansion of the nursery area resulting in greater habitat availability and less competition; 2) higher food production; 3) dilution of toxicity; and 4) reduction in predation losses due to more turbid conditions.

In the early 1970s, production of young bass began to fall below the levels expected based on the initial models, and this decline was most acute in the delta portion of their nursery. During this period the SWP and CVP substantially increased their water export from the delta, resulting in greater diversion rates being associated with any particular flow. Minimum estimates of losses, which do not include fish smaller than 0.8 inches, in these water exports were approximately 10 to 30 million young striped bass annually. Maximum loss estimates approached or exceeded 100 million young bass in some years. Contrasting these losses with estimates of abundance at the 1.5-inch stage of about 15 to 30 million fish indicates that significant population impacts could be expected. Potential effects were taken into account by developing a new model which considered the delta and Suisun Bay separately and included both outflow and diversion terms in the delta portion of the model. This model yielded reasonable predictions of young bass abundance from 1959 to 1976 and provided additional evidence that losses of young fish to diversions were an important factor regulating striped bass abundance.

However, since 1977, abundance of young striped bass has been considerably lower than predicted by the 1959-1976 model. Scientists representing various interests, including the DFG, water user groups, universities, and the Oak Ridge National Laboratory, have extensively evaluated potential causes of this decline in abundance, and generally agree that reduced egg production by the smaller population of adults likely is part of the explanation. However, consensus has not been reached on the relative



Recreational Catch 1947-1999 , Striped Bass

CPFV = commercial passanger fishing vessel (Party Boat); Recreational catch from CPFV Logs for Ocean and San Francisco Bay (Sacramento-San Joaquin Delta catches are not included until 1964), CPFV catch was not reported prior to 1960.

importance of various factors that may be at the root of the problem. These factors include losses of young fish to water exports, shortages of important food organisms possibly limiting survival of young bass, toxic chemicals and trace metals inhibiting reproduction and reducing survival, and a shift in global climate possibly resulting in adults straying from the estuary. It has also been suggested that the effect of water exports and adverse factors associated with salinity encroachment may be reduced by density-dependent mortality after the first summer.

Adult Striped Bass Abundance

The decline of the striped bass fishery in the San Francisco Bay estuary between the early 1960s and the present is a direct result of a substantial decline in the striped bass population. The California Department of Fish and Game (DFG) has measured adult (larger than 18 inches, about three years old) striped bass abundance with mark-recapture (tagging) population estimates since 1969.

According to the estimates, the striped bass population averaged about 1.7 million adults between 1969, when the estimates began, and 1976. Abundance declined to as little as 600,000 adults in the early 1990s, but had increased to about 1.3 million in 1998. A combination of much greater catches by the fishery and tag returns suggest that the striped bass population had about three million adults in the early 1960s. The reduction in the adult stock through the early 1990s was principally due to reduced recruitment of young fish. Increased abundance in the late 1990s is unexplained, but may be due to factors allowing greater survival of young fish until they are recruited to the fishery.

Fishery Restoration

As a result of the initial decline in estimated legal-sized striped bass abundance in the late 1970s, and also in response to public pressure for supplementation stocking, the DFG began a hatchery program starting with the 1980 year class that were stocked as yearlings in 1981. The number of fish stocked increased from about 63,000 for

the 1980 year class to almost 3.4 million for the 1990 year class.

The hatchery program changed substantially in 1992 as the result of concern over potential predation by striped bass on threatened and endangered species, such as Sacramento River winter-run chinook salmon and delta smelt, and all stocking of hatchery-reared striped bass was suspended (age-one fish from the 1991 year class were not stocked in the estuary). Instead, 22,000-284,000 fish obtained from fish screens in the southern Sacramento-San Joaquin Delta and reared in floating pens have been stocked annually, beginning with the 1992 year class released as yearlings in 1993. Most years, a fraction of the stocked fish have been externally marked or coded-wire tagged to allow estimation of their contribution to the population.

Hatchery fish have contributed measurably to the population of each year class in the estuary, especially at the higher stocking levels. Estimated percentage of hatchery-reared striped bass in each year class increased from about one percent for the 1981 year class to about 31 percent for the 1989 year class. More recently, fish reared in floating pens have contributed about four percent of the 1994 year class and about 13 percent of the 1996 year class.

Greater stocking of age-one and age-two striped bass (up to 1.275 million age-one equivalents) reared in hatcheries and pens began in summer 2000. This stocking is the focus of a Striped Bass Management Conservation Plan prepared according the federal Endangered Species Act requirements. It is designed to maintain the striped bass population and sport fishery at the present level and to be consistent with recovery of listed species.

Due to the greater genetic diversity of naturally produced fish, the DFG's priority is to stock fish salvaged at the SWP and CVP fish screens in the southern delta and reared for one or two years in net pens floating in the estuary. However, it is unlikely that numbers of salvaged fish will consistently be sufficient to fully support the program, so in most years, net-pen-reared fish will be supplemented with fish produced by aquaculture.

Striped bass spawn primarily during May, but salvaged fish are not available until late May through July. Thus, each year, the number of salvaged fish available for pen rearing will not be known until after artificial spawning would have to occur. The DFG will attempt to ensure sufficient availability of fish each year by contracting with private aquaculturists to begin raising sufficient fish for most of the allotment. After the number of salvaged fish is known, excess aquaculture fish would be disposed of, or perhaps used elsewhere by the DFG or aquaculturists (*e.g.*, reservoir stocking or food market). However, past experience suggests that in spite of efforts to ensure a sufficient supply of fish, stocking goals will not always be met.

Sufficient quantities of these stocked striped bass will be marked to allow evaluation of their contribution to subsequent adult populations and the relative benefits of: 1) conventional aquaculture and pen rearing; and 2) stocking age-one and age-two fish.

Other actions by the DFG include: 1) working through the CALFED Bay-Delta program to plan and implement ecosystem restoration measures that will benefit a spectrum of species, including striped bass; 2) negotiating for mitigation from owners of power plants in the estuary for losses caused by power plant operations and for mitigation from the California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (USBR) for losses at their pumping plants; and 3) increasing study effort to improve understanding of processes controlling striped bass abundance, with study funding coming from several sources including the DWR, USBR, State Water Resources Control Board, Federal Aid to Sport Fish Restoration funds, and sales of striped bass stamps required of all striped bass anglers.

Management Considerations

See the Management Considerations Appendix A for further information.

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