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STATUS OF STRIPED BASS IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

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California's striped bass population increased dramatically after its introduction into the Sacramento-San Joaquin Estuary in 1879. Sport and commercial fisheries developed before 1900, but commercial fishing was outlawed by the legislature in 1935. The sport fishery, currently with a 45.7-cm minimum total length limit and 2 fish daily bag limit, is now the major fishery in the estuary.

The importance of striped bass as a sport fish and as an indicator of ecosystem health led to many studies of its life history and population dynamics. These resulted in the present extensive knowledge of sexual maturity (Scofield 1931, Chadwick 1965); spawning times, locations, and requirements (Farley 1966, Radtke and Turner 1967, Turner and Farley 1971, Turner 1976); growth rate (Scofield 1931, Collins 1982); food habits (Stevens 1966, Thomas 1967); mortality rates (Albrecht 1964, Chadwick 1968, Miller 1974, Stevens et al. 1985); migrations (Chadwick 1967, Orsi 1971); factors affecting juvenile production and survival (Calhoun 1953, Turner and Chadwick 1972, Stevens 1977a, Stevens 1980, Chadwick et al. 1977, Stevens et al. 1985); tag loss rates (Smith 1978); and the fishery (Chadwick 1969, McKechnie and Miller 1971, White 1986).

Adult striped bass abundance and mortality rates have been monitored since 1969 with mark-recapture techniques (Stevens 1977b). Reward and nonreward disk-dangler tags (Chadwick 1963) are applied to legal-sized striped bass captured during their spring spawning migration in the Sacramento-San Joaquin Delta and the Sacramento River. Recaptures during tagging in subsequent years and during a creel census are used to estimate abundance; tags returned from anglers through the mail and during the creel census are used to estimate mortality rates. From 1969 to 1976, estimates of the legal-sized striped bass population were relatively stable, ranging from 1.5 to 1.9 million fish (Fig. 1a). Since then, estimated abundance has declined, first to 800,000–1.2 million fish in the late 1970s and 1980s, followed by a further decrease to only 579,000 legal-sized fish in 1994.

The adult striped bass population decline primarily reflects reduced recruitment. Estimates of the abundance of 3-year-old fish, which are the youngest and most numerous component of the adult population, have also declined and were at a record low in 1996 (Fig. 1b).

As measured by an annual summer tow net survey, which began in 1959, (Chadwick 1964, Turner and Chadwick 1972), abundance of young-of-the-year (YOY) striped bass when mean fork length of the year class is 38 mm has declined irregularly, but steadily, since the mid-1960s (Fig. 2). Abundance of YOY striped

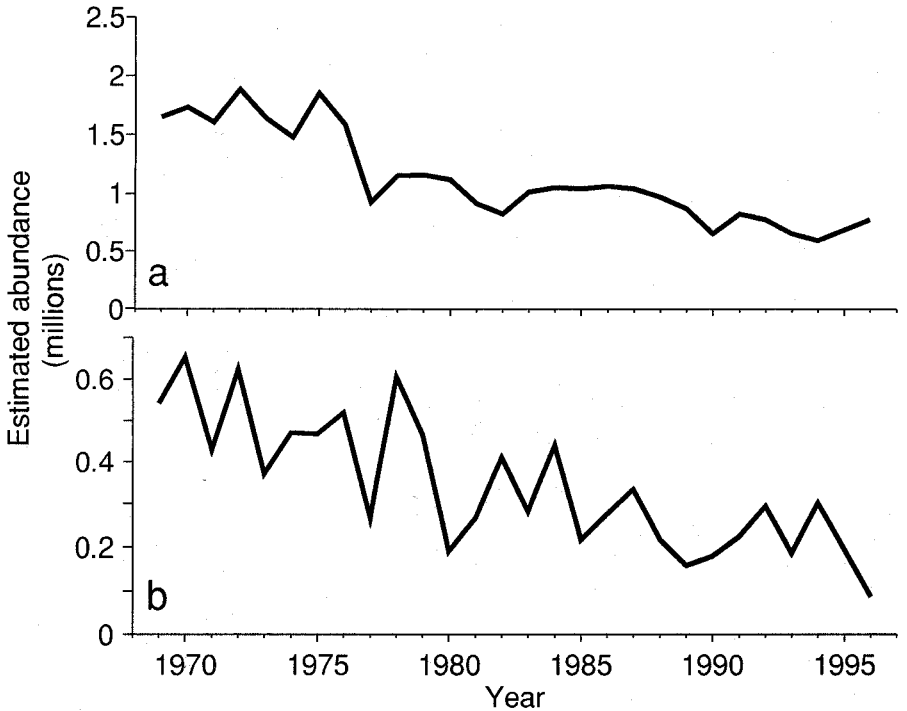

Figure 1. Estimated abundance of a) legal-sized and b) age-3 striped bass in the Sacramento-San Joaquin Estuary, 1969–1996.

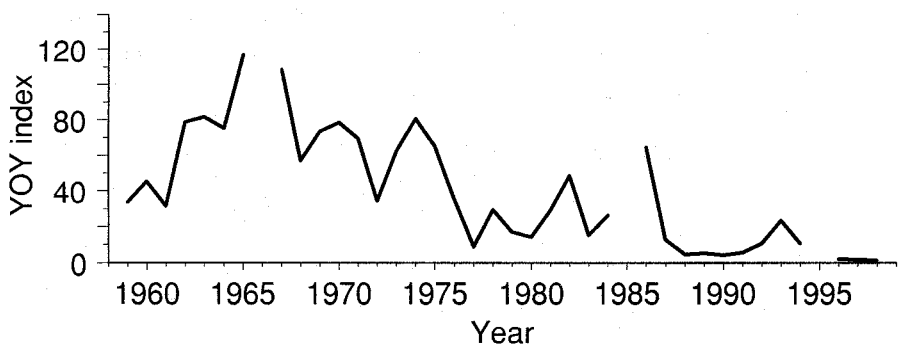

Figure 2. Young-of-the-year striped bass abundance index for the Sacramento-San Joaquin Estuary, estimated in mid-summer when mean fork length of the population is 38 mm, 1959–1998.

bass peaked in 1965, when the index was 117.2. In contrast, YOY striped bass abundance was lowest in 1998, when the index was 1.4. Since 1977, the average YOY striped bass index (16.8) has been only 25% of the average index from 1959 to 1976 (66.6). Evaluations of potential causes of the post-1976 YOY striped bass decline concluded that it probably was caused by some combination of 1) the reduced adult stock producing fewer eggs, 2) reduced food production in the nursery area,

3) increased losses of young fish entrained in water diversions, and 4) toxicity (Stevens et al. 1985).

This decline in production of young striped bass has likely contributed substantially to the decreased recruitment of 3-year-old fish (Stevens 1977a, Stevens et al. 1985). Recent meager year classes provide no expectation for imminent recovery of the depressed adult stock.

In addition to the effect on recruitment of decreased young striped bass production, estimated mortality rates of adults also have changed. Estimated total annual mortality rate has shown a significantly increasing trend since 1969 ($F = 7.35$; $df = 1, 24$; $P < 0.05$) and reached its highest level (0.67) in 1993 (Fig. 3). This change in total mortality is the result of a significant increase in estimated "natural" (due to factors other than legal fishing) mortality rate ($F = 14.1$; $df = 1, 24$; $P < 0.01$), whereas estimated harvest rate exhibited a significant downward trend ($F = 9.89$; $df = 1, 25$; $P < 0.01$) (Fig. 3). The cause(s) of the increase in estimated natural mortality is unknown.

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 California Department of Fish and Game began a hatchery program starting with the 1980 year class, 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 (Fig. 4a).

The hatchery program changed substantially in 1992 as a result of concern over potential predation by striped bass on threatened and endangered species, such as Sacramento River winter-run chinook salmon, *Oncorhynchus tshawytscha*, and delta smelt, *Hypomesus transpacificus*, and all stocking of hatchery-reared striped bass was suspended (Age-1 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,

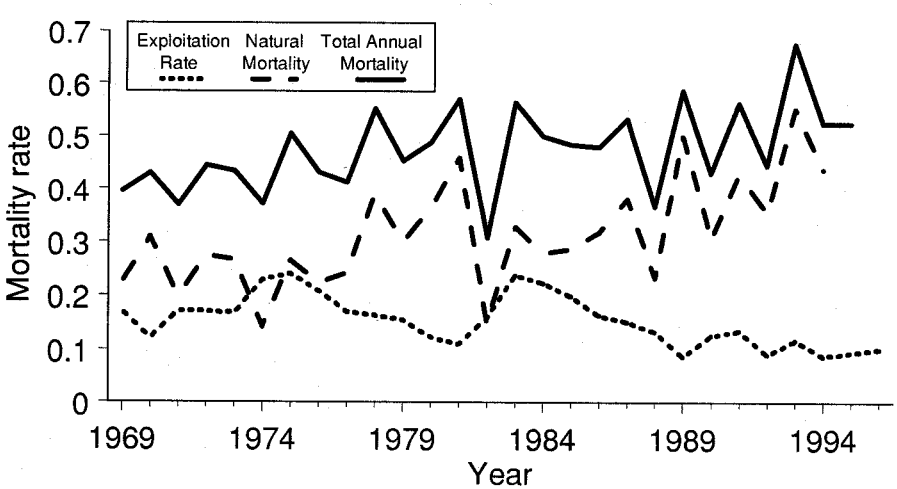

Figure 3. Estimated mortality rates of legal-sized striped bass in the Sacramento-San Joaquin Estuary, 1969-1996.

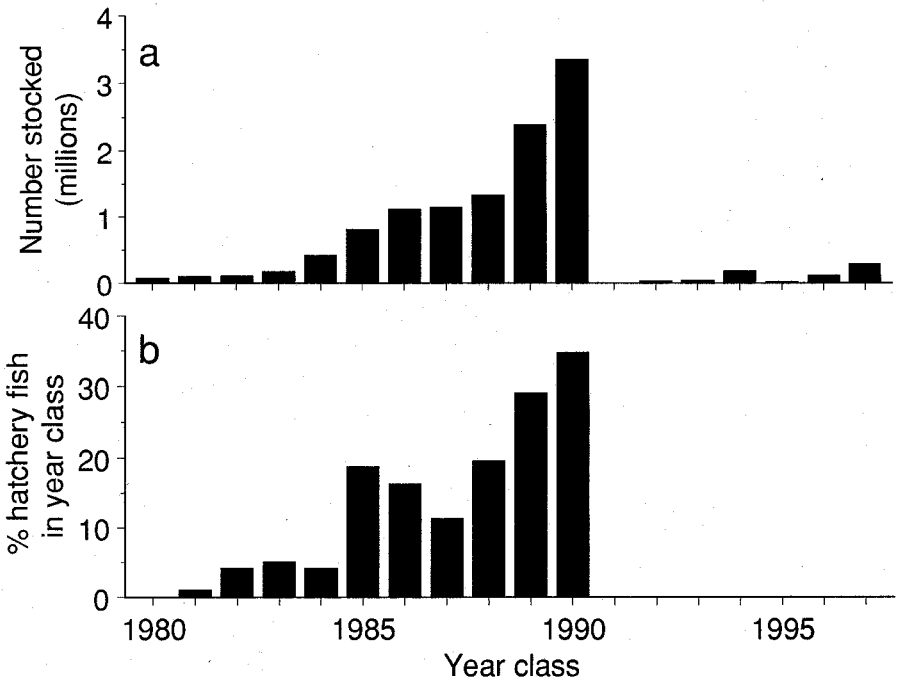

Figure 4. a) Number of hatchery-reared striped bass stocked in the Sacramento-San Joaquin Estuary, 1980–1997 year classes. b) Percent contribution of hatchery-reared fish to each striped bass year class in the Sacramento-San Joaquin Estuary from the 1981 to the 1990 year class. No hatchery fish were marked in 1980 and data have not been summarized for net-pen-reared year classes from 1992 to 1997.

beginning with the 1992 year class released as yearlings in 1993 (Fig. 4a). In 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 1% for the 1981 year class to almost 35% for the 1990 year class (Fig. 4b) (Harris and Kohlhorst[1], in review). The contribution of hatchery-reared striped bass to each year class is linearly related to stocking rate ($r^2 = 0.88$, $P < 0.001$).

Greater stocking of age-1 and age-2 striped bass (up to 1.275 million age-1 equivalents) reared in hatcheries and pens is planned to begin in summer 2000. This stocking is the focus of the Striped Bass Management Conservation Plan being prepared according to federal Endangered Species Act requirements. It is designed

[1] Harris, M.D. and D.W. Kohlhorst. In review. Survival and contribution of hatchery-reared striped bass stocked in the Sacramento-San Joaquin Estuary. North American Journal of Fisheries Management.

to maintain the striped bass population and sport fishery at the present (defined as 1994) level and to be consistent with recovery of listed species (CDFG 1998[2], 1999[3]).

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[2] CDFG (California Department of Fish and Game). 1998. Final striped bass management program environmental impact report. Sacramento, California, USA.

[3] CDFG. 1999. Conservation plan for the California Department of Fish and Game striped bass management program. Sacramento, California, USA.

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