

**Department of Fish and Game Comments on Key Issues of  
the State Water Resources Control Board's June Workshop for Review of  
Standards for San Francisco Bay/Sacramento-San Joaquin Delta Estuary\***

The Department of Fish and Game (DFG) has reviewed the key issues for this workshop and has the following comments:

**Issue 1.       WHAT FACTORS, EXCLUDING DIVERSIONS, CONTRIBUTE TO THE  
DECLINE OF FISH AND WILDLIFE RESOURCES IN THE BAY-DELTA  
ESTUARY?**

Concerns have been expressed that the search for causes of the decline of fish and wildlife has focused on water management while not fully considering how other factors may be contributing to the declines or inhibiting recovery of these resources. These other factors include: 1) non-native species introductions, 2) food limitation, 3) toxic substances, 4) harvest by humans, and 5) land reclamation.

**Introduced Species**

Introductions Prior to 1950 - In the century between 1850 and 1950, humans introduced many fish and invertebrate species into the estuary. Some introductions were a deliberate attempt to diversify the fish fauna. The native freshwater fish fauna was much less diverse in California than in the eastern United States. Hence a concerted effort was made to transfer freshwater and anadromous gamefish from the East to California in the last half of the 19th century. Many invertebrates were also introduced, largely incidental to various commercial activities such as culturing oysters.

By 1950, the aquatic resources had changed dramatically. For fish, the change was most dramatic in freshwater. For example, 17 of the 30 species salvaged at the State Water Project (SWP) fish screens in 1980 were introduced species, with 13 having been introduced prior to 1950. In 1991, 7 of the 10 most abundant fish salvaged at the SWP screens were

\* Presented by Perry L. Herrgesell, Chief of Bay-Delta and Special Water Projects Division, June 14, 1994

introduced. In contrast, only 5 of the 64 most common species collected from San Francisco Bay upstream through Suisun Bay during the 1980s were introduced prior to 1950. Thus, the shift from native to introduced fish is much greater in the freshwater portion of the estuary than in the salt and brackish water portion.

The sport catch of introduced species--striped bass, white catfish, largemouth bass, bluegill, etc.--in the estuary far exceeds the catch of native species.

These introductions must have affected the abundance of native fishes, but little historical information exists on the original abundance of native fishes. The most certain consequence probably was the elimination of Sacramento perch from the estuary. The perch is a primitive member of the sunfish family and may not have competed well with several members of the same family introduced from the East, although another major consideration is that the perch's natural habitat was changed drastically when levees were built to "reclaim" the vast tidal marshes in the late 1800s.

The striped bass has the greatest public visibility among the early introduced species for several reasons: 1) striped bass support the single most important sport fishery in the estuary, 2) their introduction may have influenced the abundance of other species, 3) more recent introductions may have influenced their abundance, and 4) they have been severely impacted by water management during the past three decades (WRINT-DFG Exhibits 2 and 3).

Striped bass were introduced into the Sacramento-San Joaquin Estuary in the late 1800s and within several years supported a thriving commercial fishery. They are higher order predators in aquatic systems and are quite voracious in their eating habits. Stevens (1966) found that in delta channels, the diet of adult striped bass consisted primarily of fish, but consumption of native fish was nominal. In more saline portions of the estuary, principal foods were their own young, anchovy, shiner perch, herring, and bay shrimp (Thomas, 1967).

Data gathered in Clifton Court Forebay suggest that the incidence of predation on native species, such as chinook salmon, in some localized situations is substantially higher.

Starting in 1982, striped bass were stocked by the Department of Fish and Game (DFG), largely as mitigation for various projects, in an effort to maintain the population in the Sacramento-San Joaquin Estuary. The DFG stopped stocking in 1993 due to concerns that stocking of striped bass was adding predators to the system which might eat winter-run chinook salmon; however, it has not been shown that the cessation of striped bass stocking has measurably benefited the populations of native fish species that are potential prey.

As for their effect on other species, it is reasonable to expect that a top predator like striped bass, which became a dominant fish in the estuarine ecosystem, must have decreased the abundance of some other species. The absence of historical information precludes specific estimates of such effects.

Historically, the greatest concerns have been for effects on salmon abundance. Young salmon sometimes have constituted a substantial part of the diet of bass in the Sacramento River upstream from the estuary but few salmon are eaten by bass in the estuary except at sites where millions of smolts are released from hatchery trucks. Clifton Court Forebay is a localized exception. Since salmon probably experience little or no density-dependent mortality in the estuary or ocean, whatever losses of young fish occur due to predation by bass ultimately decrease adult salmon abundance, but the magnitude can not be quantified with existing information.

On the other hand, salmon and bass coexisted in much greater abundance in the past than they do today. Further, the available historical information on population trends does not suggest that high periods in bass abundance coincided with lower populations of salmon (Chadwick and von Geldern, 1964), as would be expected if bass were a major factor limiting salmon abundance.

It is certainly not logical to believe that recent declines in salmon abundance in the face of a rather rapidly declining bass population were caused by striped bass.

As for the potential effect of bass on delta smelt, bass rarely ate delta smelt when the smelt and bass were both abundant. For example, Thomas (1967) found delta smelt in less than one percent of bass stomachs in most locations and seasons. The decline in smelt abundance in the early 1980s followed a substantial decline in bass abundance. Hence, it is not logical to believe that bass played a significant role in the recent decrease in smelt abundance. Actually, it is legitimate to ask the opposite question, i.e. If bass play a significant role in controlling the abundance of delta smelt, why didn't the smelt population increase following the 50 percent decrease in bass abundance during the 1970s?

Introductions Since 1950 - We believe the effects of primary concern to the SWRCB can be further narrowed, because it is not reasonable to attempt to restore the estuary to its pristine condition. It is species declines during the recent decades of major water development that have created public concern and controversy. For example, the delta smelt was quite abundant from 1950 to about 1980, when it became scarce enough to result eventually in its being listed as a threatened species. The issue is not whether species introductions in the 1800s caused the delta smelt to be scarcer from 1950 to 1980 than it would have been otherwise, but whether introduced species contributed significantly to the change which occurred in about 1980.

The frequency of deliberate introductions has slowed since 1950, but accidental introductions probably have not decreased. The major source of accidental introductions has apparently been the discharge of ballast water by ships.

Among fishes, threadfin shad, introduced deliberately as a forage fish in the early 1960s; inland silversides, transported by runoff from Clear Lake where it was introduced

illegally in an attempt to control gnats; yellowfin goby; and chameleon goby have been the principal new species. The gobies apparently came from the Orient in ship ballast water.

The changes in invertebrate populations have been more dramatic than those for fish since 1950. Several new species of zooplankton have dramatically changed the species composition in the brackish and freshwater portions of the estuary. A clam, *Potamocorbula amurensis*, introduced in 1986 has dominated benthic populations, particularly in Suisun Bay, a newly introduced amphipod, *Gammarus daiberi*, and a copepod, *Pseudodiaptomus forbesi*, have become major foods of young striped bass.

The ecological significance of these changes is uncertain. The most widely accepted judgment of a major consequence is the virtual disappearance during the summer and fall of the dominant native copepod, *Eurytemora affinis*, near the upper end of the salinity gradient. An oriental copepod, *Pseudodiaptomus forbesi*, largely replaced *Eurytemora* in the late 1980s. *Eurytemora* populations declined sharply during 1988 apparently in response to predation by the more recently introduced *Potamocorbula* clam.

Observations related to *Eurytemora* illustrate both the approach biologists use in making judgments about the consequences of species introductions and the uncertainties about the ultimate ecological effects. *Eurytemora* populations fell after *Potamocorbula* became abundant in Suisun Bay. Laboratory evidence indicates *Potamocorbula* can eat *Eurytemora*. Those observations support, but do not prove, the hypothesis for the causes in *Eurytemora*'s decline. In any case, the consequences for fish are uncertain.

*Eurytemora* had been the principal initial food for striped bass larvae near the upper end of the salinity gradient. Much work has been done to try to determine whether food supply limits striped bass production. Most biologists interpret that a degree of food limitation exists, probably through slowing growth, thus increasing mortality rates. Yet no direct evidence of starvation of bass has been found. Bass have changed their diet as the composition

of the available food supply has changed, and no general relationships have been found between food supply and bass mortality. Thus the changes in food supply caused by recent introductions are apparently not a major factor contributing to the decline of striped bass. Even if that is so, the changes in food supply might inhibit the recovery of some fish species.

Trends in the abundance of various fish species also have been examined to try to identify coincidences between trends which might indicate one species causing another to decline. No declines in abundance have coincided with increases in introduced species to the extent necessary to imply cause and effect.

A recent question has been raised about that conclusion in regard to delta smelt and inland silversides. Dr. William Bennett, U.C. Davis, has hypothesized that concentrations of silversides in delta smelt spawning areas may have decreased delta smelt abundance by eating smelt eggs and larvae. This hypothesis was suggested by his observations of predation by silversides on striped bass larvae in confinement and because silversides may be more abundant than DFG surveys indicate since shoreline areas are not sampled as extensively as midchannel areas. He points out that this could be particularly significant for delta smelt which probably spawn principally in inshore areas. Bennett's hypothesis needs to be examined in light of the recovery of smelt during 1993, apparently in response to optimum delta outflows.

The best summary of the effects of introduced species is that introductions have caused major changes in the fish fauna in the estuary, particularly in fresh waters. The most obvious effects on fish populations occurred due to introductions in the 19th century. Introductions since 1950 have caused substantial changes in aquatic invertebrates and established large populations of several species of smaller fish, but they have not coincided with the principal declines in other fish populations. Hence there is not a strong empirical case for recent introductions being a principal cause of the decline in species such as striped bass and delta smelt. Conversely, uncertainty exists both as to effects introductions may have had on some

species and as to whether the introductions may make the recovery of previously abundant species more difficult.

### **Food Limitation**

Many biologists suspect that food limitations may have played some role in the decline of fish populations, with most of this evaluation effort having been directed towards striped bass. Among the reasons for this suspicion are the fact that zooplankton are less abundant in this Estuary than in Atlantic Coast estuaries where large populations of bass occur. Also, the abundance of a number of components in the food chain has decreased since 1970 even though total zooplankton abundance is about the same as it was 20 years ago.

While some degree of food limitation probably exists for striped bass, no direct evidence of starvation has been found, and bass have changed their diet, including eating recently introduced species of copepods and amphipods. In that regard, it is interesting to note that Larkin (1979) in summarizing predator-prey relationships in fish stated, "To be sure the growth and survival of the predator may not be precisely the same with a different prey, but in general these will be minor considerations. The moral is not to expect big changes for a predator that loses a species of prey".

### **Toxicity**

Forty years Ago, a number of adverse effects of pollutants were obvious in the estuary. These included low dissolved oxygen at several locations, fairly common kills of fish and obvious visual or olfactory changes associated with discharges. Today, after hundreds of millions of dollars spent to upgrade waste treatment, many fewer obvious signs of pollution exist.

The major question is whether toxic deposits or continuing discharges, including those from nonpoint sources, cause toxic effects sufficient to affect the abundance of species significantly. Various sublethal effects have been documented well, but pollutant-effects

experts are uncertain of the consequences of such effects, particularly as they relate to whole populations of fish.

One aspect of toxicant effects is that they are potentially confounded with flow effects. The magnitude of flow certainly dilutes concentrations of toxicants, particularly in the upper portion of the estuary. As one moves downstream, tidal action becomes of increasing importance in determining rates of dilution. Within San Francisco Bay, tides are the dominant force determining dilution, except when relatively high flows (approximately 40,000 cfs) induce two-layer circulation.

Although pollutant effects have been identified for a number of species, potential effects have been examined more thoroughly for striped bass than for other species. Hence the following discussion will focus on striped bass.

One source of information concerns periodic pesticide occurrence in runoff from the Sacramento and San Joaquin rivers. Biologically significant concentrations occur periodically, even during pulse flows resulting from storms. Bioassays have demonstrated lethal effects for several invertebrates and striped bass larvae, both in the Sacramento and San Joaquin rivers. Also liver necrosis typical of exposure to toxic chemicals has been found in young bass in the wild. Yet no corresponding increase in mortality rates for young bass has been measured, and stringent controls, which clearly decreased rice field pesticide loading in 1991 and 1992, produced no corresponding increase in young bass abundance. Although the decline in the abundance of young striped bass since the early 1970s is closely correlated with the amount of rice pesticides used along the Sacramento River, the failure of the abundance of young bass to increase in response to improved regulation of pesticides in 1991 and 1992 indicates that the correlation does not reflect a cause and effect relationship.

For apparently healthy adult striped bass, studies initiated by National Marine Fisheries Service and followed up on by DFG found body burdens of various hydrocarbons and heavy



metals, including mercury, frequently exceeding U.S. Food and Drug Administration action levels. Eleven years of sampling found some evidence of poor health, such as egg resorption. However, no strong direct links were found between specific pollutants and fish health. Some indications of improving health also were found during the eleven years (e.g. decreases in body burdens of some pollutants, decreases in egg resorption rate, increases in fecundity).

Another concern is the striped bass die-off which has occurred each spring and early summer near the upper end of the salinity gradient for more than 40 years. Most deaths are of adult striped bass, with several thousand carcasses counted in some years. Several attempts to determine the cause of the die-off have been unsuccessful, although recent University of California led studies have found evidence of liver damage and higher concentration of various hydrocarbons in moribund than control fish.

To reiterate, clear evidence of some harm from toxicants exists and warrants more effective management but overall consequences cannot be estimated. Given the major pollutant abatement actions during the last 20 years and some evidence of lessening effects of pollution, we find it difficult to believe that pollutants are a principal cause of the widespread decline in fishery resources which has occurred in the last 20 or so years.

### Legal Harvest

Striped Bass - DFG has measured the proportion of the bass population harvested by anglers periodically between 1958 and 1968 and annually since 1969. Since 1969 anglers have harvested an average of 19% of legal-sized bass annually with a range of 10 to 30%. No trend is evident over this period.

While these harvest rates are well within safe limits for a sustaining striped bass population, angling regulations were made more restrictive in 1982 to increase protection for the declining population even though excessive harvest was not the cause. Prior to 1982, the minimum length limit was 16 inches. In 1982, the minimum length was increased to 18 inches

and the daily bag limit reduced from three to two fish. The respective legal length limits are equivalent approximately to bass being 3 and 3-1/2 years old.

In contrast, the combined angling and commercial harvest rates for striped bass in Chesapeake Bay were on the order of 50% annually, with harvesting starting at age 2.

The subject of safe harvest limits is discussed in more detail in the next section on illegal harvest.

White Sturgeon - The risk of overfishing sturgeon is much greater than for striped bass, primarily because sturgeon do not mature until they are approximately three times as old as bass and they do not spawn annually. In fact, no sturgeon fishing was permitted in California from 1917 until 1954 because sturgeon had become so scarce, due largely to overharvesting by a commercial fishery.

In 1954, a tightly regulated sportfishery was opened--one fish per day bag limit, with minimum sizes ranging between 40 and 50 inches at various times since 1954. Currently there is a 46 inch minimum size and a 72 inch maximum size to protect older more fecund spawners.

DFG has measured harvest rates periodically since 1954. Annual harvest rates were less than 8% until 1984, when they increased to 9 to 11%. Concern that those higher rates were approaching dangerous levels resulted in adoption of the current more restrictive size limits. Subsequently, harvests have fallen to less than 5%. DFG is confident that sturgeon regulations are preventing overharvest.

Salmon - Management of the salmon fishery is complicated by there being both a sport and commercial fishery in the ocean and by the presence of several regulatory bodies. The freshwater sportfishery is small in relation to the ocean fishery but has been increasing.

Regulation was simplified and strengthened in 1976 by passage of the U.S. Fishery Conservation and Management Act which provides for regulation of ocean fishing on the Pacific Coast through the Pacific Fishery Management Council under the leadership of the Secretary of Commerce.

In recent years, the Council has drastically curtailed the ocean fishery for salmon in an attempt to meet spawning escapement goals. The target escapement for the Sacramento River system fall-run chinook salmon is a range of 122,000 to 180,000 adults, a goal which was not achieved in 3 of the last 4 years. No target is set for the San Joaquin system due to local habitat degradation and an inability to selectively manage the ocean fishery to promote San Joaquin escapement.

Harvest rates have not been measured for the entire salmon population as they have for striped bass and sturgeon. Instead the total catch of salmon south of Point Arena has been related to escapement in the Sacramento system to get an index of harvest rates. These rates have increased by an average of about 5% since 1970, but fluctuations throughout the period have been far greater than the average increase, with the highest rate being about 60% greater than the lowest. A limitation of the harvest rate index is that a substantial portion of the salmon from the Sacramento system migrate north of Point Arena. Those salmon have received additional protection from stringent regulations north of Point Arena to protect Klamath River stocks.

Another issue concerning harvest regulations is the possibility that the increase in fishing effort supported by hatchery production has resulted in overharvesting wild stocks.

Ocean harvests clearly reduce spawning escapement substantially, but the most reasonable conclusion is that the fishery is not the principal factor limiting production. The best empirical evidence for that conclusion is the abundance of San Joaquin stocks. San Joaquin stocks provide good production in wet springs and poor production in dry springs.

Total stocks fell to less than 1,000 spawners as a result of the 1959-61 and 1976-77 droughts. Within two generations, spawning escapement rebounded to about 40,000 and 70,000 fish, respectively. That would not have been possible if overharvesting rather than spring flows had been the principal limiting factor.

Other Fishes - Largemouth bass harvest rates by anglers in the Delta were measured from 1980 through 1984. Rates were consistently about 30%, which is substantially less than largemouth harvest rates in many California reservoirs.

White catfish harvest rates by anglers were measured in the mid-1950s and again from 1978-1980. Catfish do not migrate very much, so harvest rates vary at different locations, presumably due to local differences in the amount of angling. In the latter study, harvest rates in different areas of the Delta ranged from 10 to 38%. Estimates of harvest in the 1950s were in the same range.

Summary - A summary of legal harvest of various fishes is that in all cases harvest undoubtedly decreases the number of spawning adults and the average age of adults. Within limits, that is an inevitable consequence of harvesting any wild or domestic animal population.

The real questions are whether harvests are sufficient to inhibit the population's ability to maintain itself or to be responsible for observed changes in abundance. In every case where harvest rates have been measured for fish populations inhabiting the Bay-Delta system, no evidence was found indicating that the rates were either excessive or primarily responsible for recent declines in fish stocks. Any contention to the contrary must be viewed in light of concurrent declines in fish species that are not subject to either commercial or recreational harvest.

## Illegal Harvest

Illegal harvest is more difficult to estimate than legal harvest, due to its clandestine nature. Some illegal harvest undoubtedly occurs for every species subject to fishing. A major goal of DFG is to minimize illegal take sufficiently to prevent harm to the resource and assure a socially acceptable division among resource users. DFG does not condone any illegal harvest and within the limits of its resources responds whenever evidence of illegal take is uncovered.

Within the Bay-Delta, the principal question is about illegal harvest concerning salmon and striped bass. DFG believes that illegal take of salmon does not have a significant effect on the resource as a whole; this includes harvests by foreign fisheries.

Illegal take consequences are potentially greater for striped bass. They involve the illegal harvest of both legal and sublegal-sized bass. The magnitude of both is uncertain but the potential consequences of the take of legal-size bass can be evaluated with more certainty based on results of the tagging program.

Illegal take of legal-sized bass includes both taking more than the two fish bag limit using legal angling techniques and harvesting with illegal nets and setlines. Bass taken both ways are sold illegally for food.

In analyzing tag returns, tags returned to DFG are assumed to have been caught legally by anglers. While that is undoubtedly largely true, tags from some illegally taken fish are probably returned as some tags have rewards as high as \$20 for their return. To the extent tags from illegal fish are returned, illegal take would be included in the estimated harvest rates described in the section on legal harvest.

In addition to estimating harvest rates, biologists analyze tag returns to estimate total mortality. The difference between total mortality and harvest rates is generally called natural

mortality. In reality, estimates of natural mortality are a combination of natural mortality, illegal harvest, and perhaps some legal harvest. The latter would occur if techniques used to estimate how many anglers fail to return tags from fish they catch underestimate that number.

The bottom line for the purpose of assessing illegal take is that estimates of total mortality include illegal take even though we can not estimate the percent of mortality caused by illegal take. Thus some insight into the combined effect of legal and illegal take can be derived from trends in total mortality.

From 1969 to 1973 and in several earlier years, total mortality averaged about 41%. After that it gradually increased to a plateau through the 1980s averaging 49%. DFG biologists estimate that this increase in total mortality of adults only could account for about 25% of the decline in adult abundance observed since 1969.

That 25% is the maximum incremental impact of illegal fishing, assuming all of the increase in total mortality were due to illegal fishing. We do not know whether any of the increase is due to illegal fishing, and it seems unlikely that all of it would be. For example, sea lions eat adult striped bass. Since they have increased their numbers and range within the estuary, sea lion predation likely has contributed to the increased mortality. If mortality due to pollution has increased, that also would be reflected in the increase in natural mortality estimates.

Another perspective on total mortality is provided by experience on the east coast. Some stocks there, including the largest stock which inhabits Chesapeake Bay, were being harvested by sport and commercial fisheries at a rate which resulted in total mortalities on the order of 70% per year. Also, the Chesapeake fisheries started at age 2, rather than California's practice of limiting legal harvest to age 3-1/2 and older. Most Chesapeake biologists concluded overharvesting was the principal cause of bass declines observed on the

east coast during the 1980s. They also concluded that total mortality on the order of 50% is sustainable.

The second portion of illegal take is the catch of sublegal bass. Historically, that has resulted almost entirely from anglers keeping some sublegal bass, but in recent years there has been some fishing with small mesh nets and setlines.

Only the crudest of estimates exists. DFG wardens believe they contact about 2% of anglers. Given that and the number of sublegal bass observed, they estimate that the take of sublegal bass is at least 500,000 fish.

The issue is not new. In the summer of 1957 or 1958, DFG biologist H. K. Chadwick spent a day patrolling with a warden, so the warden could document his concern over the take of sublegal bass. Mr. Chadwick saw a considerable number of sublegal bass being kept. Hence the issue concerns both the present magnitude and how that differs from the past.

Contrasting the estimated illegal catch with the estimated  $\pm 400,000$ , 3-year old bass in the population now, it is very likely that illegal take reduces the production of adult bass. The illegal catch estimates are very uncertain, and we have been unable to identify a way to improve them, so we can not estimate the consequences of illegal catch more precisely. Actions to reduce illegal take are clearly warranted, and have been implemented through DFG's Delta Bay Enhanced Enforcement Program (DBEEP), funded by DWR and USBR. However, the fact that illegal harvest of bass is not a new problem, and that it is well documented that increased mortality of younger bass is caused by the water projects (WRINT-DFG Exhibits 2 and 3), it seems unlikely that the harvest of sublegal bass is the dominant factor causing the decline in adult bass abundance since 1969.

## Land Reclamation

Land reclamation caused major ecological changes both in the estuary and throughout the Central Valley. It destroyed most of the tidal marshes in the estuary and seasonally flooded wetland upstream from the estuary. The latter probably caused the extinction of the thick-tailed chub, a minnow which spawned in seasonally flooded vegetation, and loss of tidal marshes may have been largely responsible for the demise of the Sacramento perch.

The vast majority of land reclamation occurred before 1920, so there is essentially no factual information available to estimate its consequences. The main issue for present purposes is whether modest rehabilitation of tidal or seasonal wetlands might have substantial value for rehabilitating fisheries.

The most significant may be for splittail. This native minnow has been proposed for listing under the Federal Endangered Species Act. Splittail often spawn over beds of submerged vegetation and the production of young is consistently much better in wet than dry years. Those two facts may be related: the amount of seasonally flooded vegetation may be great enough in wet years to cause the better production. Increasing the availability of wetlands at low flows might be an effective management strategy for splittail, but it would be experimental and require substantial tracts to increase production significantly.

Increased wetlands would undoubtedly cause other ecological changes, including increasing the production of organic detritus, but the actual nature of the changes is uncertain and large scale restoration would be necessary to have much effect on basic processes, such as increasing the base of the food chain through production of detritus. In the short-term, restoration cannot be accomplished by breaching levees. In the delta and even in Suisun Marsh, subsidence has been so great that breaching levees creates bays rather than marshes. Using dredge spoil to recreate wetlands may offer some potential.



## References for Issue 1

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**ISSUE 3: WHAT EFFECT DO UPSTREAM WATER PROJECTS, OTHER THAN THE CVP AND SWP, HAVE ON THE FISH AND WILDLIFE RESOURCES OF THE BAY-DELTA ESTUARY?**

The tributaries to the Delta are a critical component of efforts to restore the health of the Bay Delta Estuary. These rivers and streams provide important migration, spawning, and rearing habitat as well as inflow to the Delta.

Water development on the tributaries has affected fisheries habitat in a number of ways. It has resulted in modifications to flows. On non-CVP and SWP streams, flows are diverted from upstream reaches to preserve the quality of water delivered for urban uses or to supply irrigation water for agricultural areas. This results in low flows virtually year round in some rivers. On the SWP and CVP rivers, reservoir storage has resulted in a major shift in the seasonal pattern of flows (i.e. high summer flows and low winter and spring flows).

Water development has also resulted in loss of upstream holding, spawning, and rearing habitat because dams and diversion structures now block access for migrating salmon and steelhead. For example, in some streams, dams block access to the cooler water in canyons upstream that formerly provided critical summer holding habitat for spring-run chinook salmon. Spring-run salmon are no longer found in these streams because no summer holding habitat remains.

Reservoirs act as heat storage facilities in the summer months. In some cases, downstream water temperatures reach lethal or near lethal levels when reservoirs are drawn down and water is released from the upper levels of the reservoir.

In some tributaries, there is substantial fish mortality due to entrainment through unscreened or poorly screened diversions.

Gravel resources necessary for salmon and steelhead spawning have been depleted. Dams impede the replenishment of gravel by preventing the movement of new gravel from upstream areas and replacement from stream banks is limited by erosion control and bank stabilization activities and the reduced frequency of high flow events.

Actions to improve fisheries habitat, including increased instream flows in tributaries, are an essential part of the overall restoration of the Bay-Delta estuary and Central Valley fisheries. In recognition of this, the Department of Fish and Game prepared an Action Plan which recommends various habitat restoration measures. The recommendations we consider to be the most important, relative to these proceedings, are the proposed increases in instream flow and the temperature criteria for the different rivers. These recommendations are summarized in Table 3 of the plan on pages 9 through 16 of the Action Plan. DFG flow recommendations were also presented in the draft California Water Plan in Table 8-3. We have prepared the attached graphs summarizing our recommendations for the various rivers. These graphs depict the range of currently required flows and the DFG proposed flows. In addition, there are flow fluctuation and water temperature conditions DFG would like to see implemented, however, these graphs illustrate the magnitude of the changes DFG would like to see implemented.

The recommendations for the Yuba and Mokelumne rivers are already being considered by the SWRCB in other hearings and the SWRCB has scheduled a hearing for July of this year when the recommendations on the Merced River will be presented. Action by the SWRCB in these proceedings could include integration of the results of the hearings on the Yuba, Mokelumne, and Merced rivers into the Bay-Delta process.

The current allocation of Delta outflow responsibility, which depends primarily on storage on the Sacramento, American, Feather rivers, and to a lesser extent on the Stanislaus River, has clearly contributed to the ecological imbalance of the Bay Delta Estuary. In order to restore the ecosystem's productivity, we must look at the system as a whole. As the new

standards for the Bay Delta are crafted, the SWRCB should develop a methodology to require diverters other than the SWP and CVP to provide a "fair share" contribution to Delta outflow. In WRINT-DFG Exhibit No. 30, we provided some suggestions regarding methods that could be used to allocate Delta outflow requirements.

One approach would be to designate a volume of storage in each reservoir over a certain size for use in meeting Delta standards. The amount of water from each source could vary by water year type and may also be related to other factors such as total storage capacity or a ratio of storage to unimpaired flow. Other factors related to fisheries habitat include carryover storage needs and relative inadequacy of current flow requirements. Water rights and priority considerations are also obvious considerations. DWR and USBR could be given the discretion to call for the water to be released as needed up to the amount needed to meet Bay Delta standards.

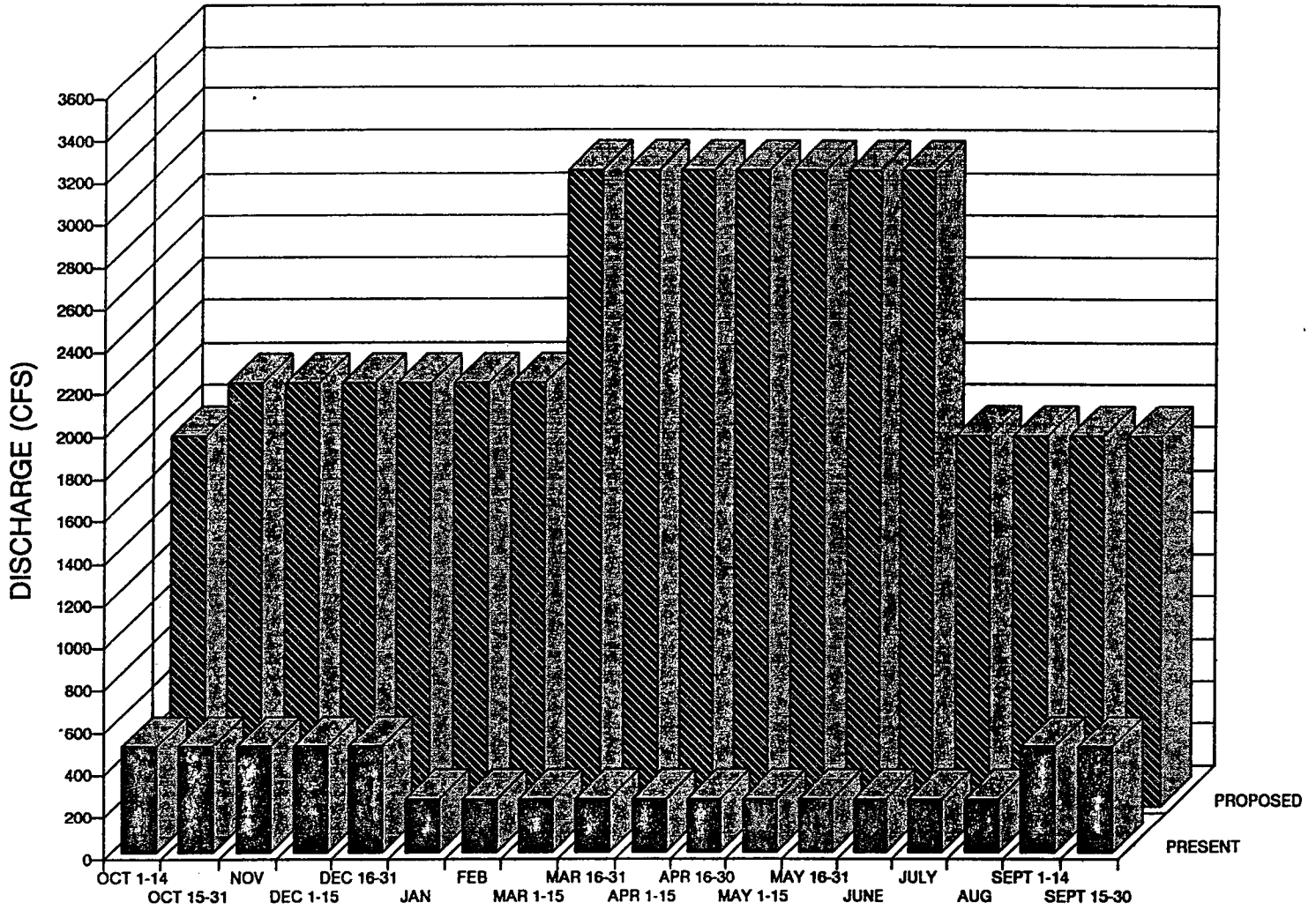
Another method which could be considered is to model the expected hydrology of the Central Valley using the recommended flows proposed in the DFG Action Plan and summarized here today. This model run could reveal if and when additional flows are needed to protect the Bay Delta Estuary. The SWRCB could then assign additional outflow requirements to the various tributaries based on the ratio of unimpaired flows in the various tributaries.

We suggest that the SWRCB consider these and other alternatives in allocating responsibility to meet Delta outflow among all water users. This will ensure that the Delta is managed as an ecosystem and that the water needs to protect the Delta do not deplete upstream storage on any river to the point where salmon runs downstream are adversely affected by high water temperatures.

One additional concept the SWRCB should consider including would be a mechanism that allows a third party to acquire water to provide additional protection above the Bay-Delta

standards which may be set. Under Water Code Section 1707, existing water users can petition to change their place of use and purpose of use to benefit fish and wildlife even if that change does not involve diversion of water. When we have considered using this code section to provide for Delta outflow, there has been some question about whether the existing regulatory strategy in D-1485 would allow for dedication of additional water for outflow above the standards set in D-1485. The new Delta standards should include a mechanism that allows acquisition of additional water to provide for improved flows in the Delta over and above the standards. We recognize that there may need to be some minimum quantity set because of the difficulty of measuring relatively small amounts of water in the Delta.

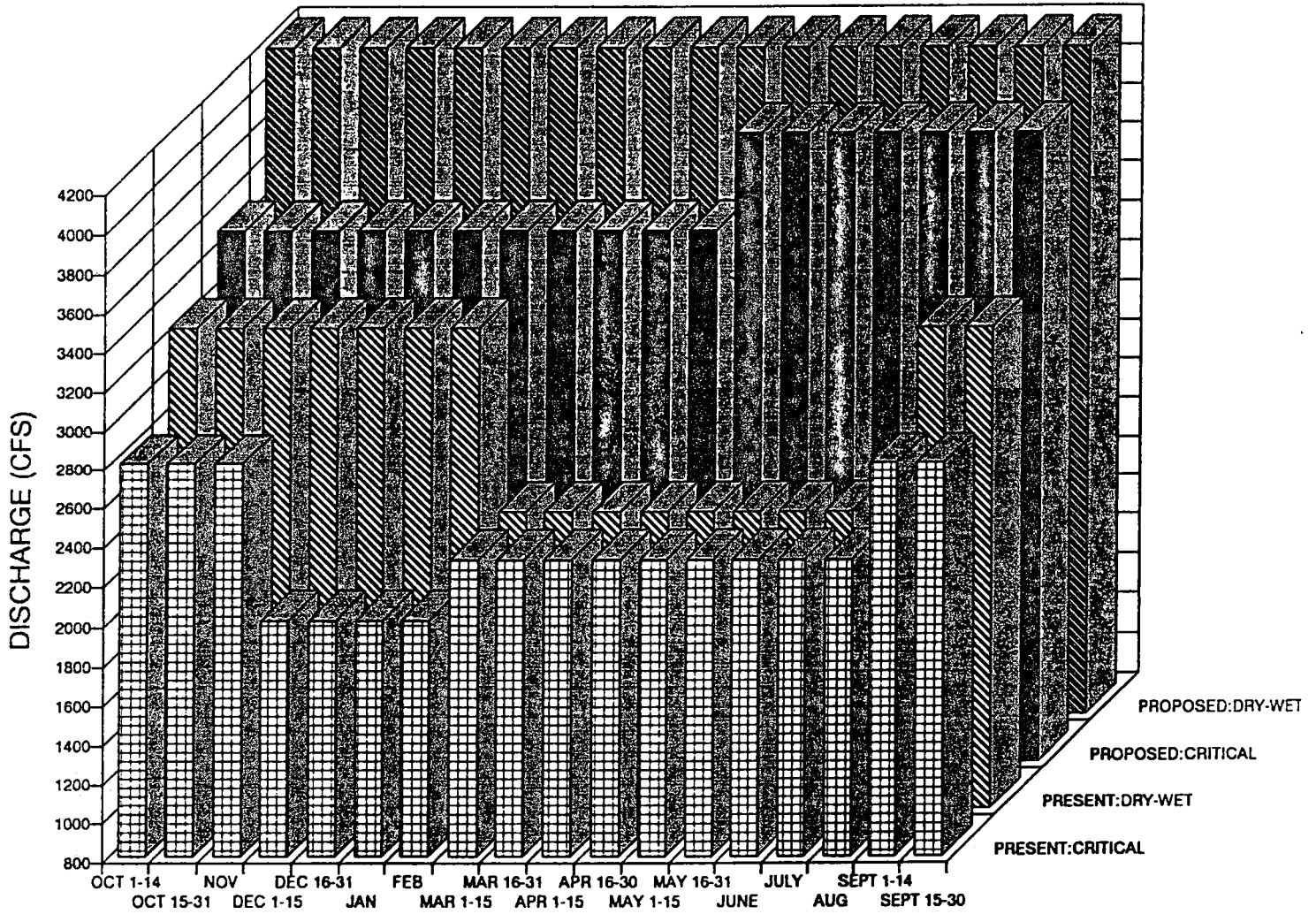
## LOWER AMERICAN RIVER



Present Flow Regime From D-893

Proposed Flow Regime From Physical Solution in EDF v. EBMUD Which Is Within Range Identified in Snider and Gerstung, 1986

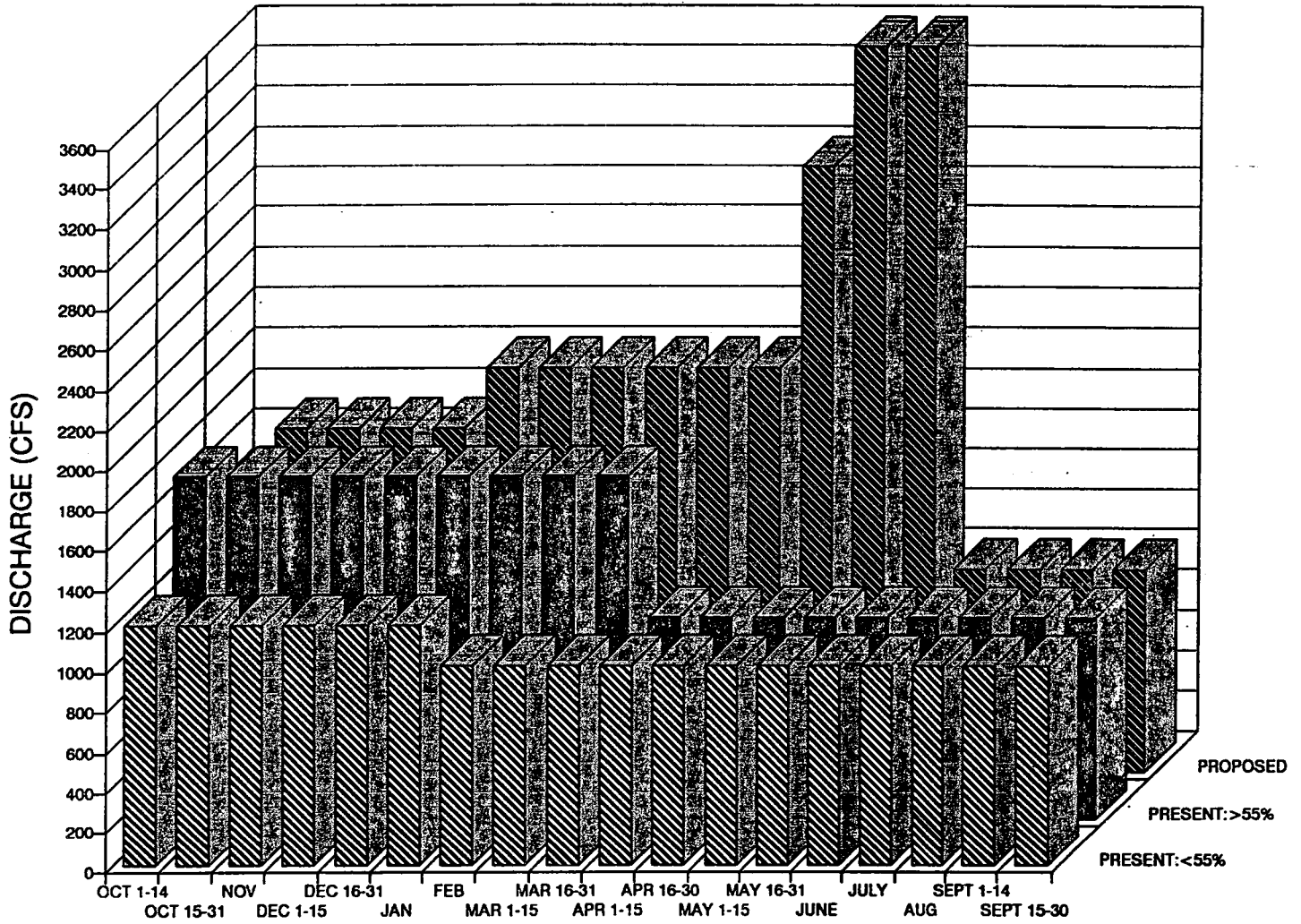
## SACRAMENTO RIVER AT KESWICK DAM



Present Flow Regime is From 1982 Agreement

Proposed Flow Regime is From WRINT DFG EXHIBIT No. 14  
 Dry-Wet is Defined as Carryover Storage > 2.8 MAF  
 Critical is Defined as Carryover Storage < 2.8 MAF

## FEATHER RIVER BELOW THERMALITO AFTERBAY

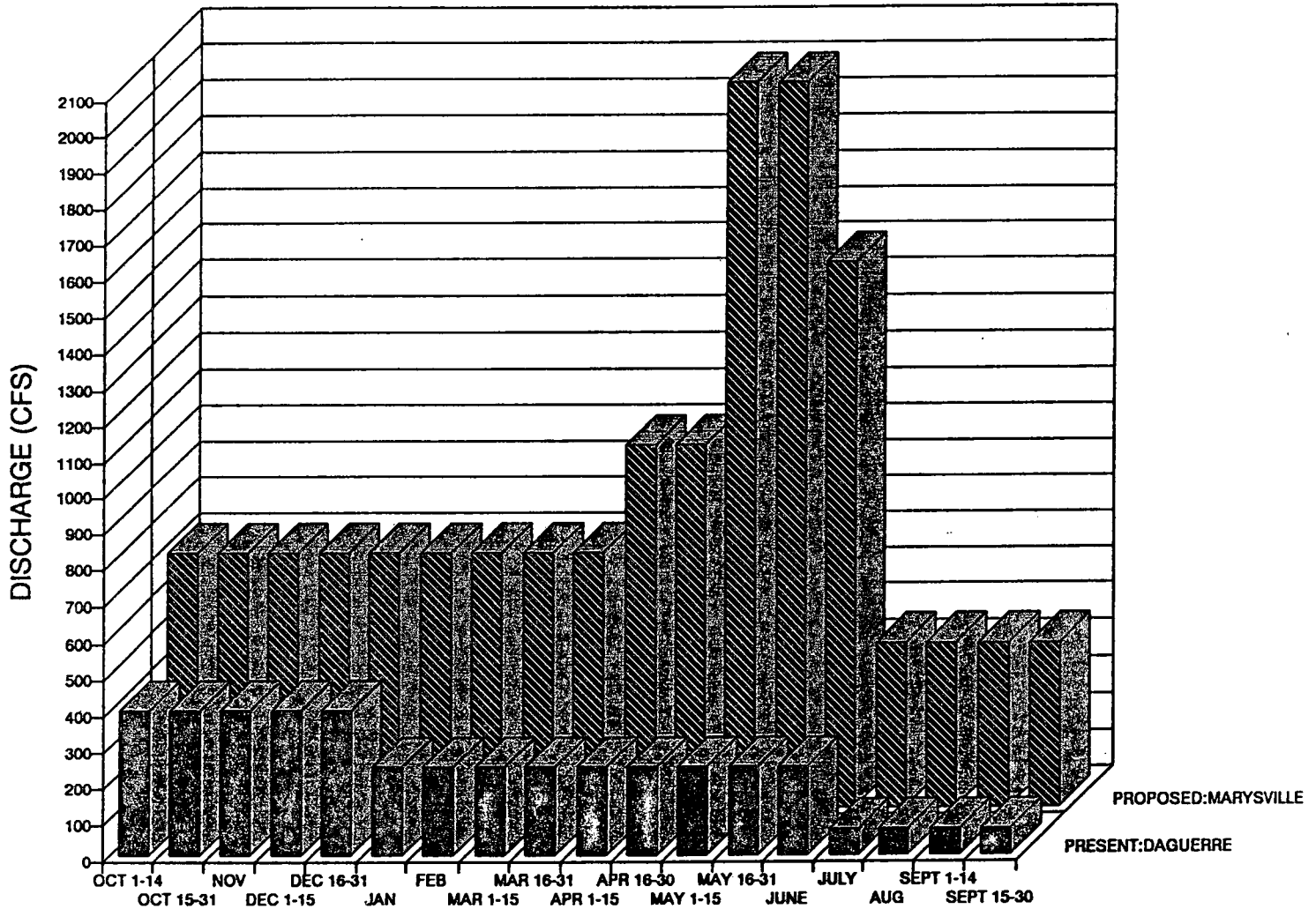


Present Flow Regime is From 1983 Agreement

Proposed Flow Regime is From WRINT DFG EXHIBIT No. 23



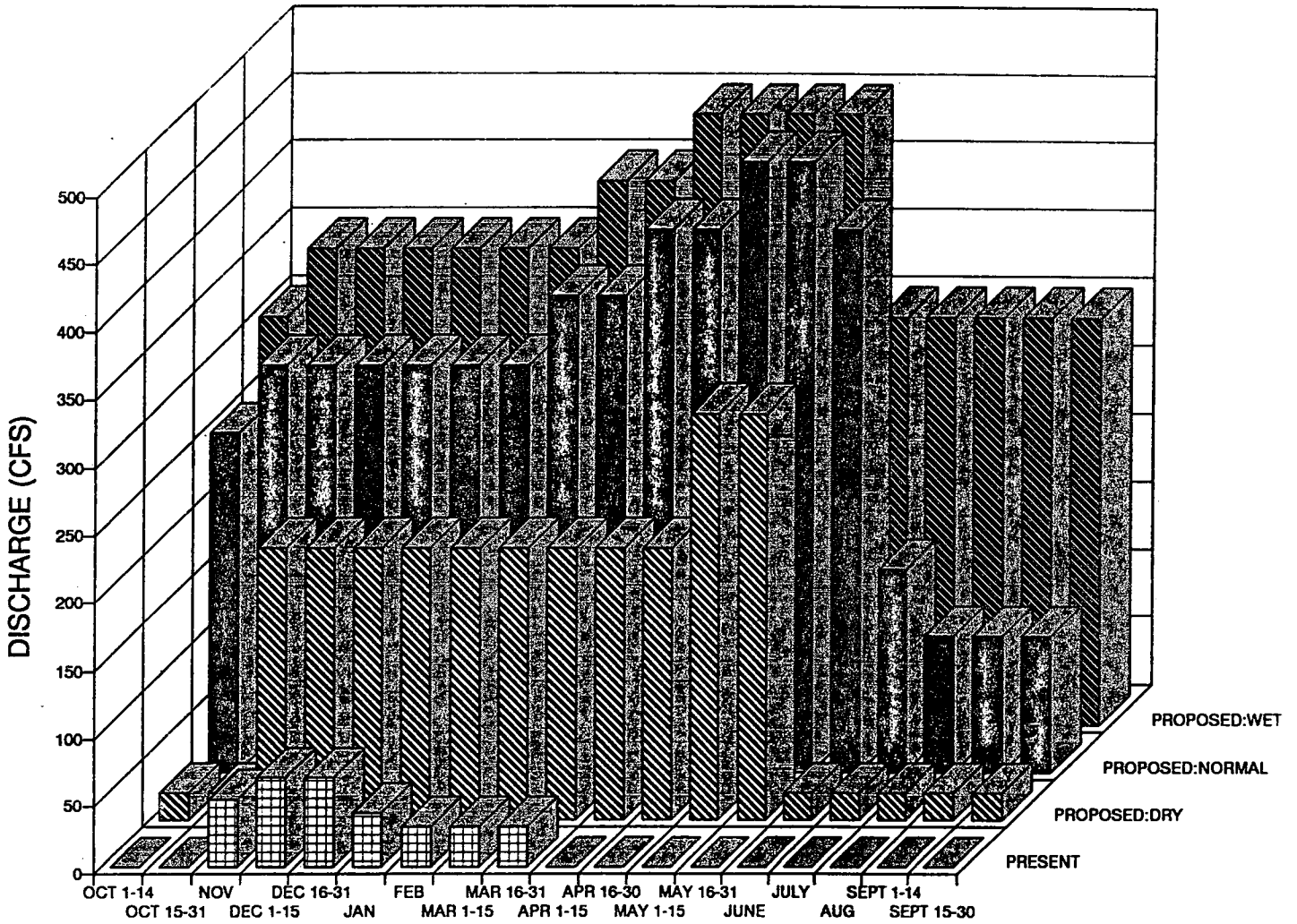
## YUBA RIVER AT DAGUERRE AND MARYSVILLE



Present Flow Regime is From 1965 DFG/YCWA Agreement and is Measured at Daguerre Point Dam

Proposed Flow Regime is From 1991 Lower Yuba River Management Plan and is Measured at Marysville

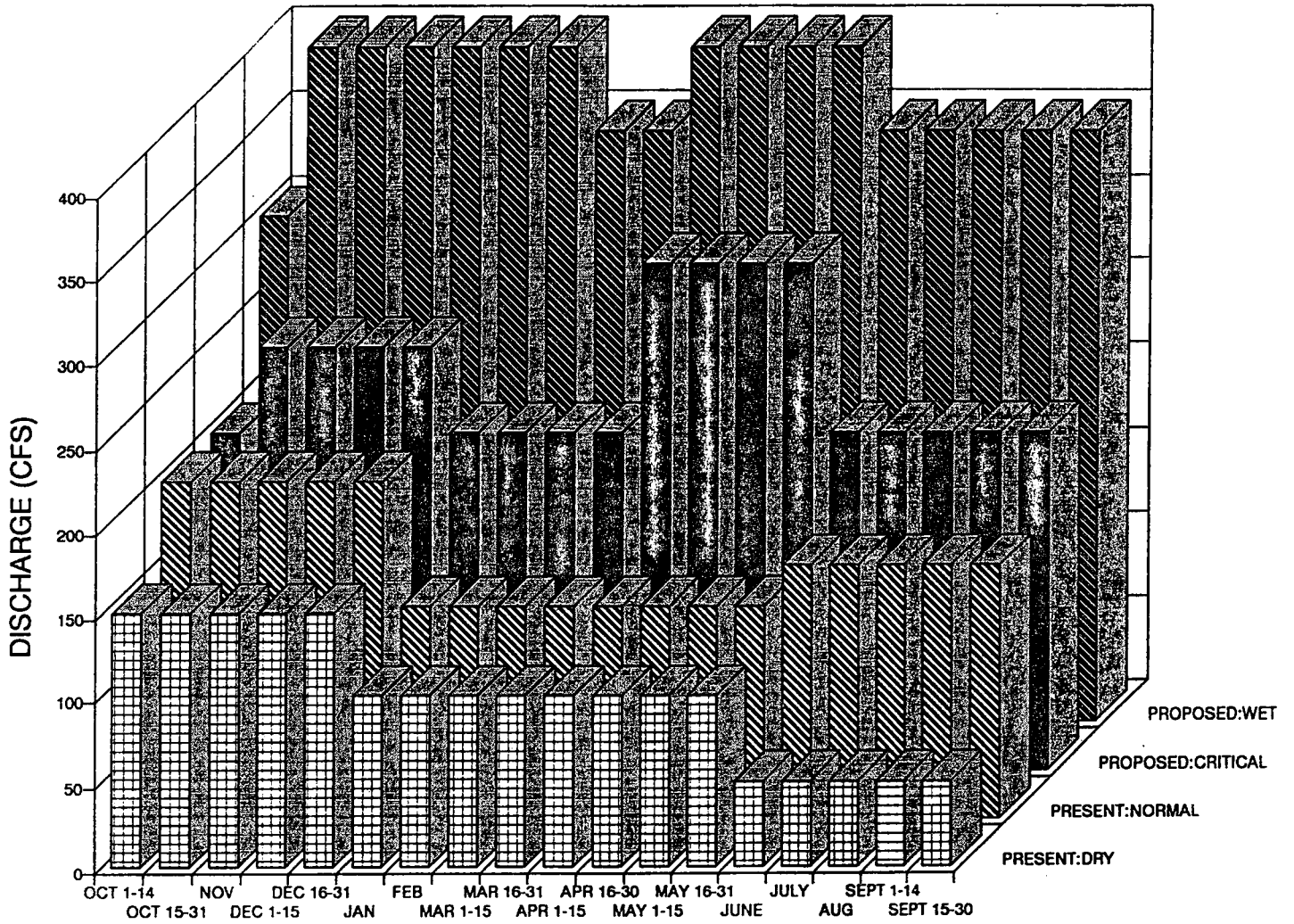
# MOKELUMNE RIVER AT WOODBRIDGE



Present Flow Regime is From 1961 Agreement

Proposed Flow Regime is From 1991 Lower Mokelumne River Management Plan

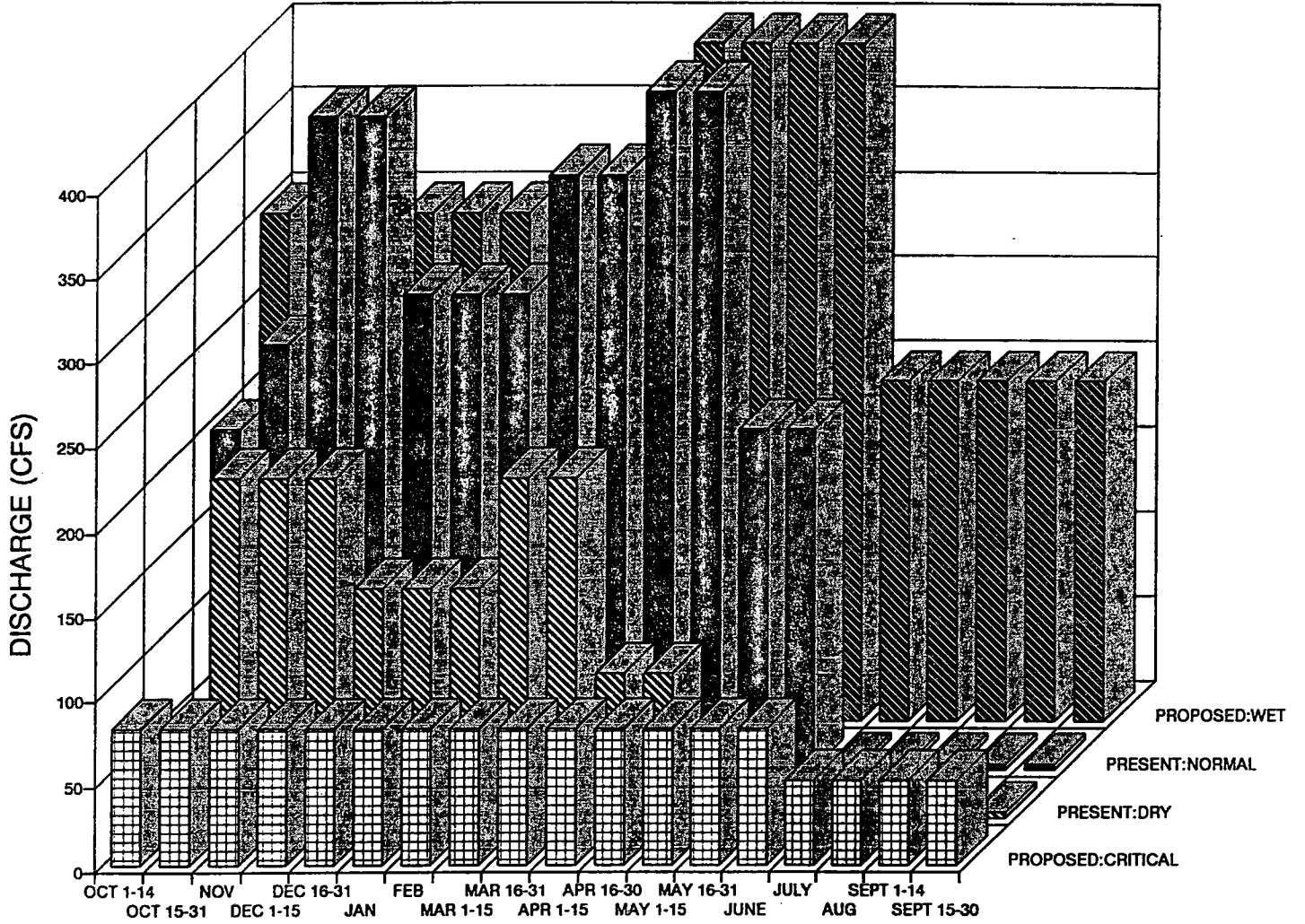
## STANISLAUS RIVER AT GOODWIN DAM



Present Flow Regime is From 1987 Agreement

Proposed Flow Regime is From 1992 DFG Letter to USBR and DWR

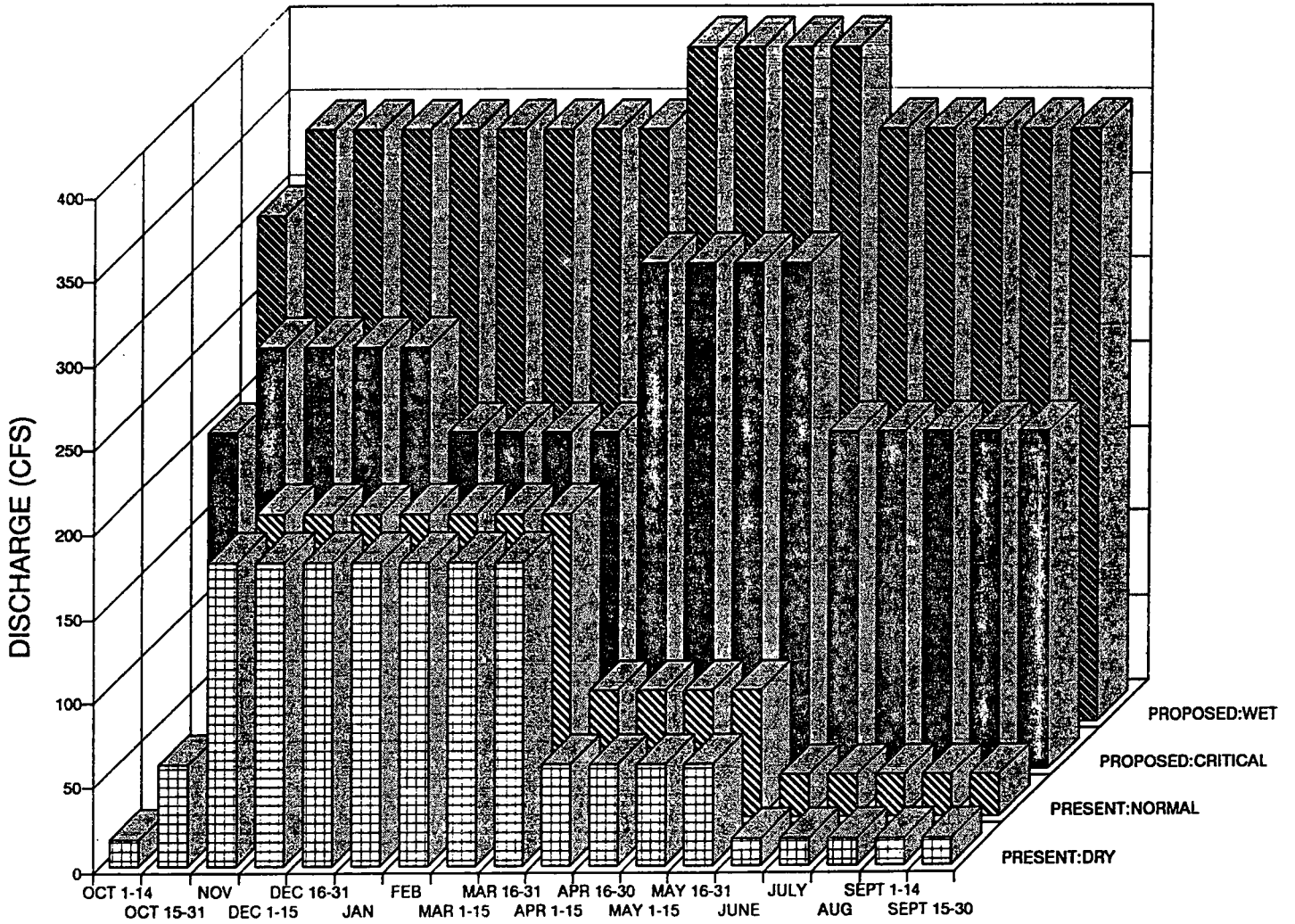
## TUOLUMNE RIVER AT NEW DON PEDRO DAM



Present Flow Regime is From FERC License

Proposed Flows Regime is From 1992 Agreement

# MERCED RIVER AT SHAFFER BRIDGE



Present Flow Regime is From FERC License and Davis Grunsky Contract

Proposed Flow Regime is From Action Plan

## ISSUE 4: STATUS AND TRENDS OF BIOLOGICAL RESOURCES OF THE SACRAMENTO-SAN JOAQUIN ESTUARY

### Introduction

The ability of the Sacramento-San Joaquin Estuary to maintain consistent levels of abundant species has been altered over the years. Striped bass, delta smelt, and some runs of chinook salmon have declined 70-90% from their historical levels. Winter-run chinook salmon and delta smelt are already listed under State and Federal endangered species acts and Sacramento splittail is being considered for Federal listing as a threatened species. The depleted status of spring-run chinook salmon, longfin smelt, and green sturgeon make them potential future candidates for listing.

The abundance of many species in the estuary also has been depleted by the recent drought. The low flows which have occurred in 7 of the 9 last years are unprecedented in the historical record. It remains to be seen what the long-term consequences of the drought are for those species.

### Phytoplankton

Phytoplankton abundance is estimated by direct counts or by measuring the pigment chlorophyll produced by these tiny plants. In general, chlorophyll levels (i.e. phytoplankton) have declined in Suisun Bay since the mid-1970's (Figure 1). Extremely low phytoplankton levels were observed in San Pablo and Suisun bays during 1976-1977 while, at the same time, the highest levels were observed entering the delta with Sacramento and San Joaquin river inflow. Since 1978, however, such high in-flowing levels of phytoplankton have not been observed. Further, since the mid-1970's, a previously less common phytoplankton species, *Melosira granulata*, has dominated most phytoplankton blooms. This change in species composition is significant since *Melosira* is not a preferred food source of zooplankton.

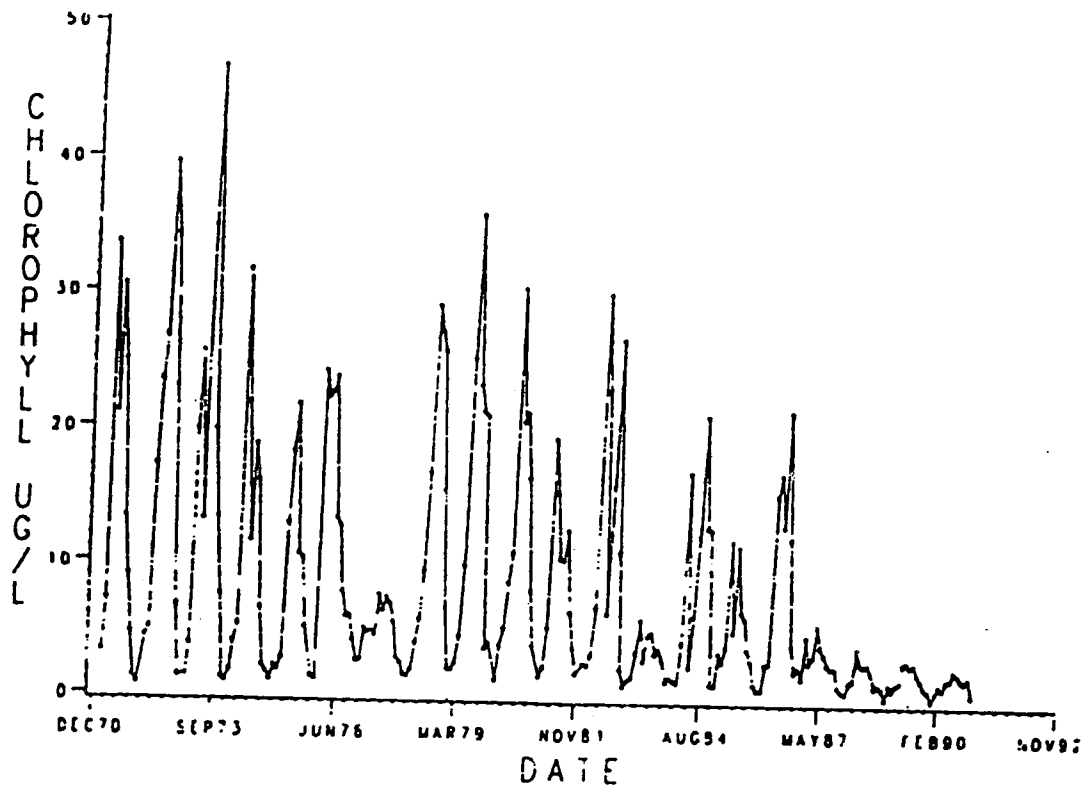


Figure 1. Chlorophyll concentration in Suisun Bay from 1971 to 1990. (Figure from DWR report to the State Water Resources Control Board)

### Zooplankton

Three important zooplankton groups are rotifers, cladocerans, and copepods. Since the early 1970's, rotifer populations have declined sharply throughout the delta (Figure 2). Average abundance of cladocerans has shown a long-term decline, but at more gradual rate than for rotifers (Figure 3). Native copepods have suffered large declines in abundance while non-native species have increased in abundance, generally with the net result that copepods have been at least as abundant since the late 1970s as previously (Figure 4). During most of the 1980s the *Neomysis mercedis* population varied considerably, but at a lower level than existed in the early 1970s (Figure 5). *Neomysis* abundance fell dramatically after 1986 and remained at very low levels from 1990 to 1993.

### Benthos

In the northern reach of the estuary, the abundance and distribution of benthic species is greatly affected by salinity variation. During high outflow years, some brackish water species decline; during low flow years, species that like more saline water move back in. In 1987, however, something changed this pattern. Following several years of very low flow and high salinity, the expected colonization of Suisun Bay by the more marine species did not occur. Instead, the newly introduced clam *Potamocorbula amurensis* increased remarkably in abundance (Figure 6). The impact of this filter feeding organism on phytoplankton has been dramatic and the fate of this invader when freshwater flows return to the system remains to be seen.

### White Catfish

We have more information on white catfish trends than for other freshwater resident fishes. Therefore, it will be discussed here as a representative of freshwater species in the delta.

Based on estimates from a tagging study in 1978 to 1980, the abundance of white catfish  $\geq 7$  inches was 3-8 million fish. Anglers harvested about 18% of those fish annually.



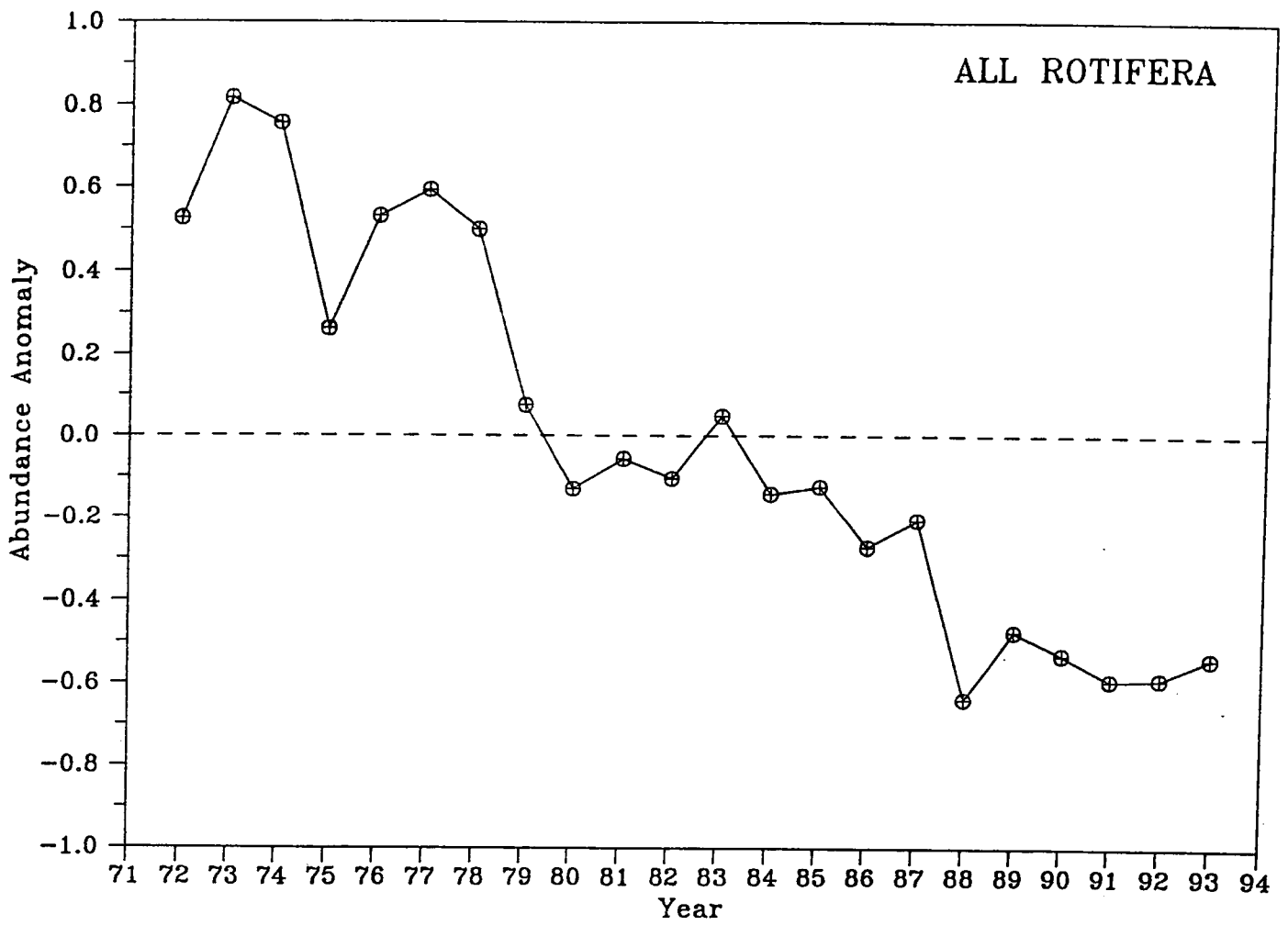


Figure 2. Trend in rotifer abundance in the Sacramento-San Joaquin Estuary, 1972-1993.

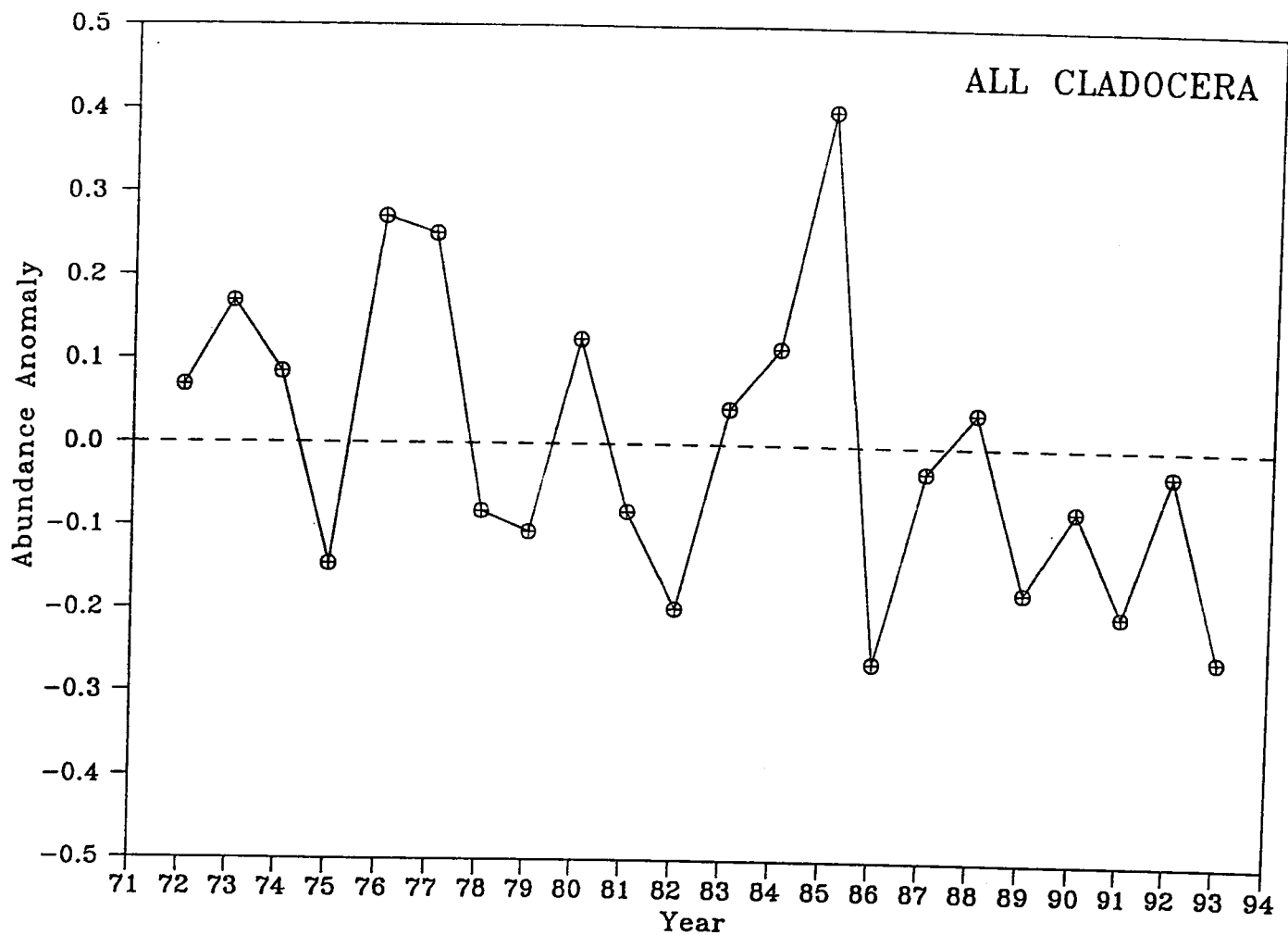


Figure 3. Trend in cladocera abundance in the Sacramento-San Joaquin Estuary, 1972-1993.

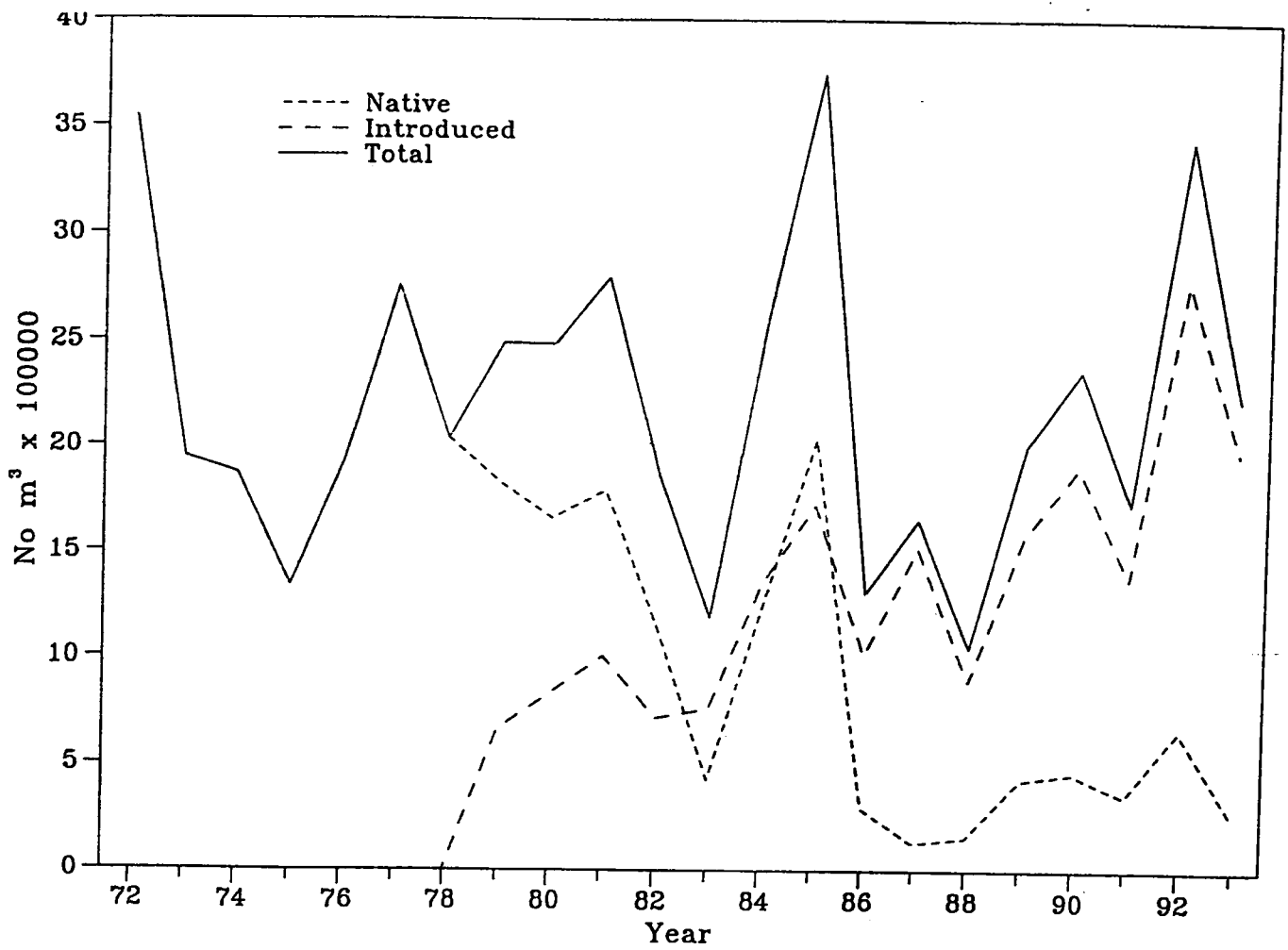


Figure 4. Trend in native and introduced copepod abundance in the Sacramento-San Joaquin Estuary, 1972-1993.

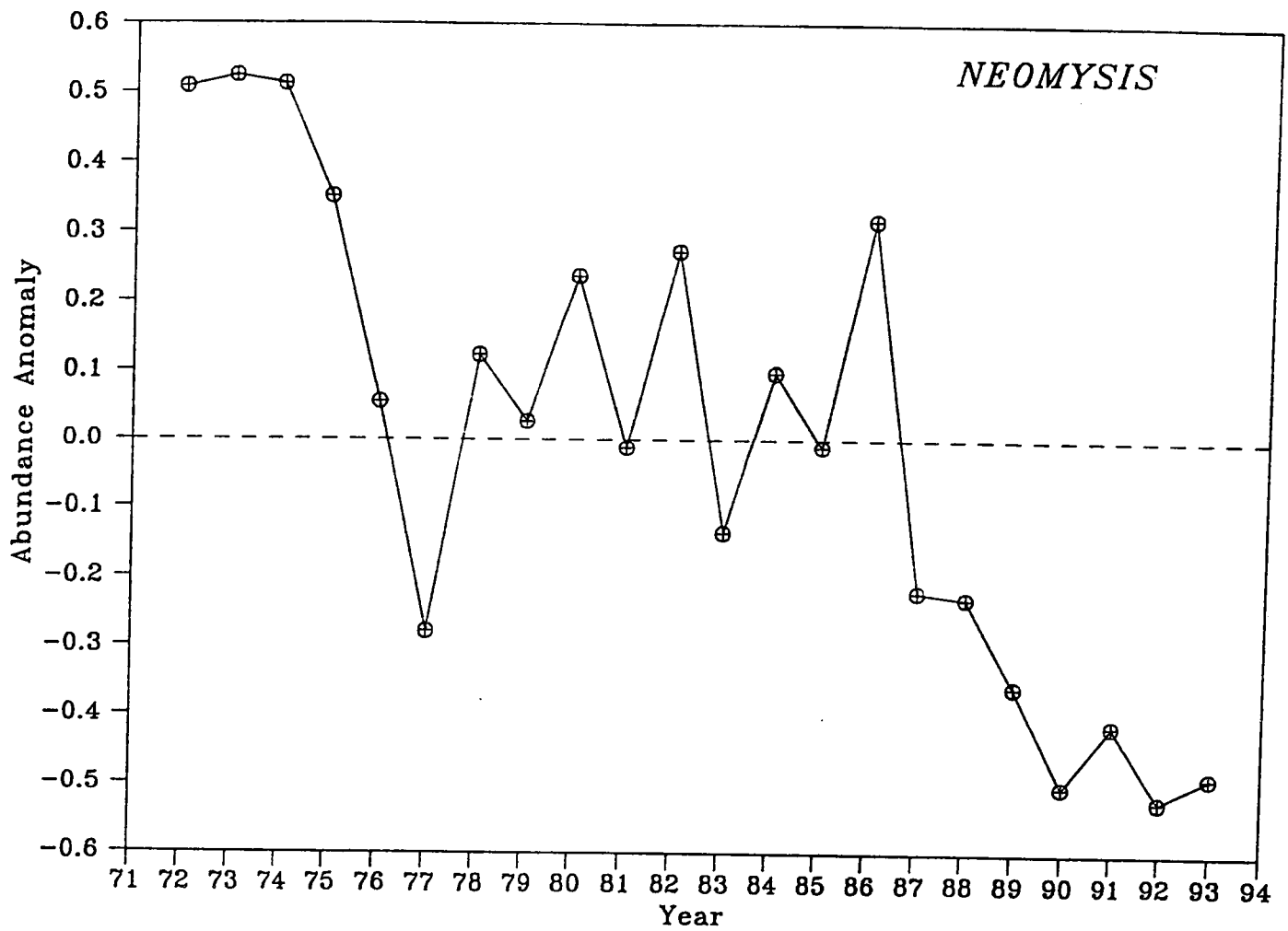


Figure 5. Trend in *Neomysis* abundance in the Sacramento-San Joaquin Estuary, 1972-1993.

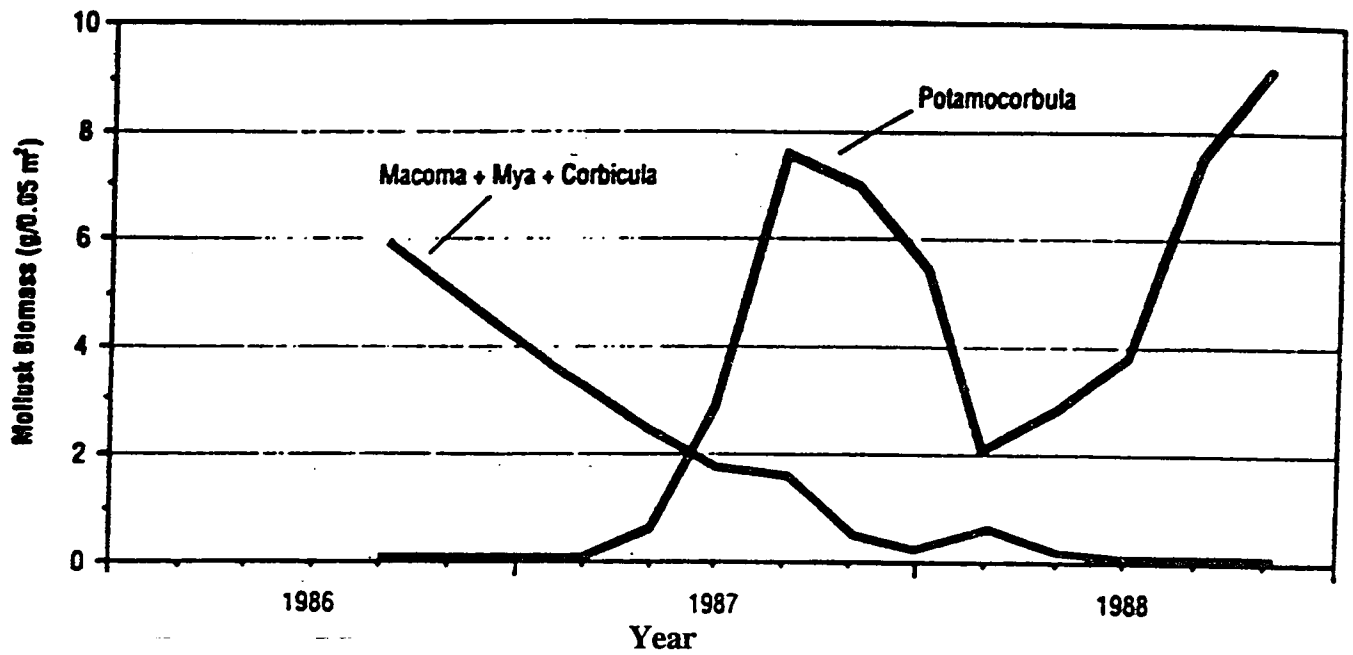


Figure 6. Biomass of *Potamocorbula* and other mollusks in Grizzly Bay, 1986-1988.

Population estimates of adult white catfish have not been made since this 1978-1980 tagging study. However, data from three additional sources indicate that abundance of whitecatfish has declined severely since the mid-1970's. The first evidence of decline comes from incidental catches of young ( $\leq 4.5$  inches) white catfish in the summer tow-net survey designed to sample young-of-the-year (YOY) striped bass. Abundance of white catfish in this survey fluctuated from about one to more than four fish per tow from 1968 to 1975 (Figure 7). Since 1975, the catch has never exceeded one fish per tow and in several years the catfish catch has been less than 0.06 per tow.

More evidence of white catfish decline comes from the fall mid-water trawl survey. The mid-water trawl index of white catfish abundance ranged from about 250 to 850 in all but 1 year from 1967-1973 (Figure 8). After 1975, this index fluctuated downward, and was particularly low in 1982, 1987, and 1990 before rebounding in 1992.

A third estimate of catfish abundance is obtained from salvage information at the State and Federal water project fish screens. At these facilities the number of fish salvaged per acre-foot of water diverted is recorded. Data are available for the Federal Central Valley Project (CVP) screens since 1957 and for the State Water Project (SWP) screens since 1967. Numbers of white catfish salvaged per acre-foot of water diverted has declined dramatically since salvage peaks in the later 1960's (Figure 9). In terms of total fish salvaged, only 33,000 catfish were caught in 1990 at the SWP. This is near a record low. At the CVP only 203,000 fish were salvaged in 1990. This compares to about 8 million fish in 1967.

### Delta Smelt

Various surveys have charted the abundance of delta smelt since about 1959, and information from seven of these independent data sets has demonstrated a dramatic decline of the delta smelt population and particularly low levels since 1983 (see DFG testimony at the May 16, 1994 SWRCB workshop). Alarm over the observed decline of delta smelt led to its listing as a threatened species under both the Federal and State Endangered Species acts. A

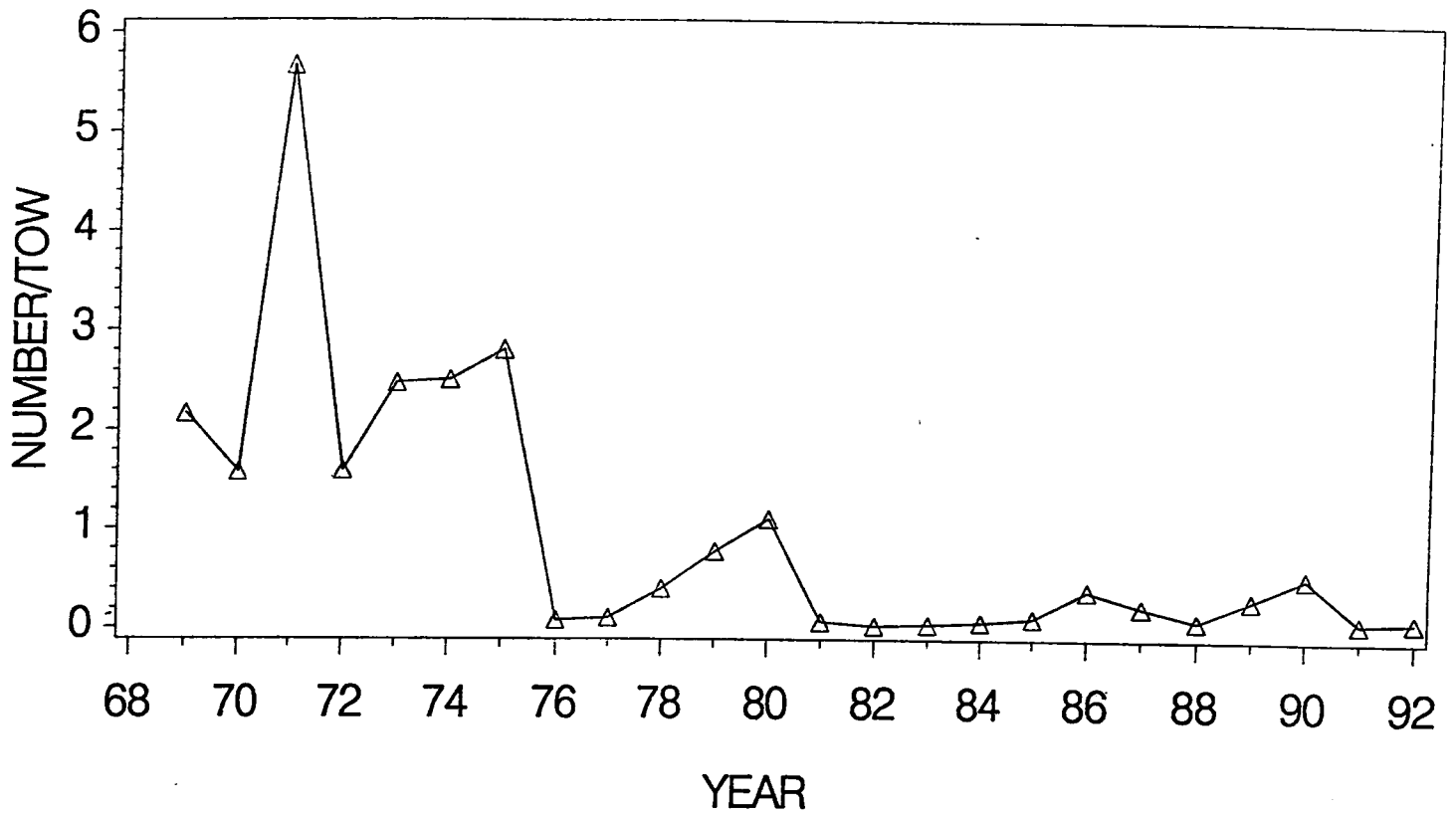


Figure 7. Mean white catfish catch per tow in the mid-summer tow-net survey. Data before 1968 is omitted because species identification is questionable.

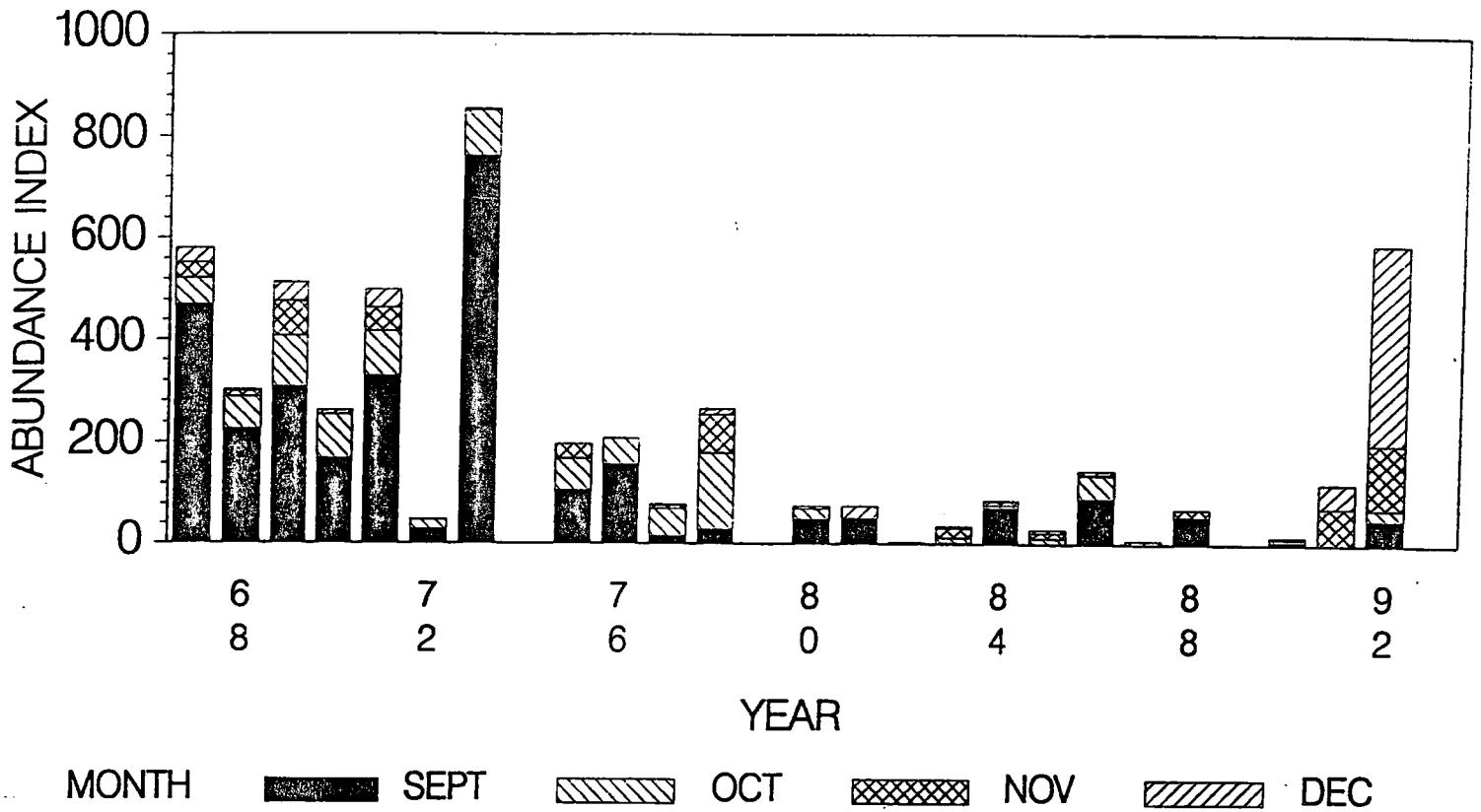


Figure 8. Abundance index of white catfish in the fall mid-water trawl survey. No surveys were conducted in 1974 and 1979.



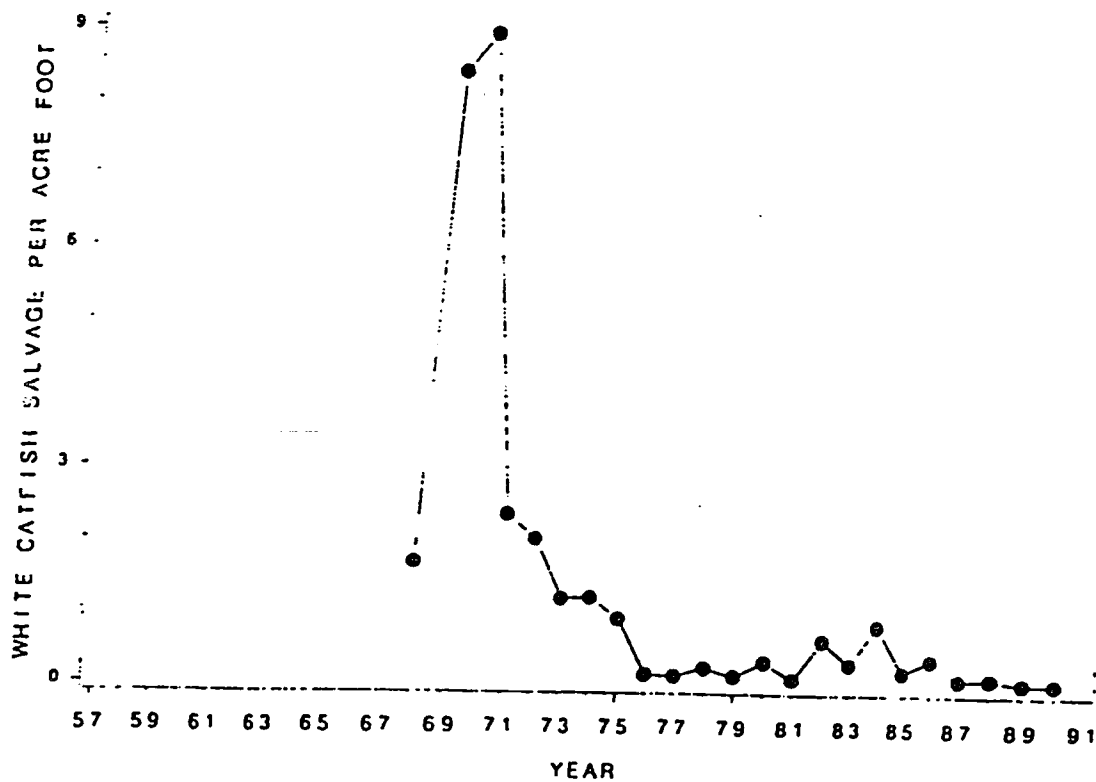
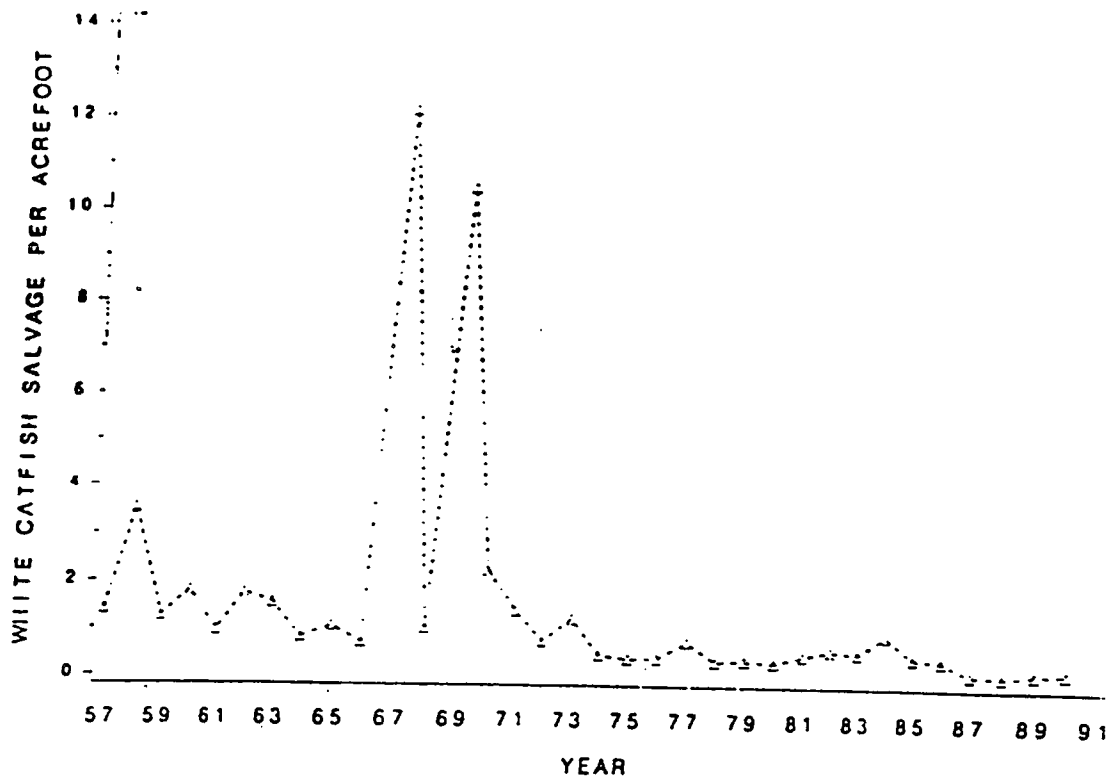


Figure 9. White catfish salvaged per acre-foot of water exported during June-September at the (a) CVP and (b) SWP fish facilities.

more detailed account of trends and status of the delta smelt population has previously been presented to the Board (WRINT-DFG-Exhibit 9).

### **Longfin Smelt**

The longest index of longfin smelt abundance in the estuary comes from the fall mid-water trawl sampling program which began in 1967. The longfin smelt from this survey are not separated into year classes, so the index from each year represents at least two year classes; however, young-of-the-year usually predominant in the fall catch.

Since 1967, the longfin smelt abundance index has fluctuated widely from year to year (Figure 10). Since 1982, when the index was 63,000, values have dropped precipitously until the 1992 level of approximately 14 was reached.

The San Francisco Bay Outflow Study mid-water and otter trawl sampling effort (begun in 1980) that concentrates on the estuary downstream from Antioch substantiates the decline detected by the fall mid-water trawl program (Figure 11). Bay Study YOY longfin smelt abundance indices were strongly correlated with the fall mid-water trawl longfin smelt index ( $r=0.988$  and  $r=0.992$  for mid-water and otter trawl indices, respectively) and show that young-of-the-year longfin smelt were generally much more abundant during the early and mid-1980s than from 1987 to 1993.

The dramatic decline in longfin smelt abundance prompted a petition to the U.S. Fish and Wildlife Service to list this fish as a threatened species in California. This petition was recently denied.

### **Sacramento Splittail**

The splittail is a large minnow endemic to the estuary. Although it is considered a freshwater species, adults and sub-adults have an unusually high salt tolerance for members of the minnow family. Historically, splittail occurred throughout low elevation waters of the Central Valley from Redding to Fresno. Currently, they are restricted to the lower reaches of

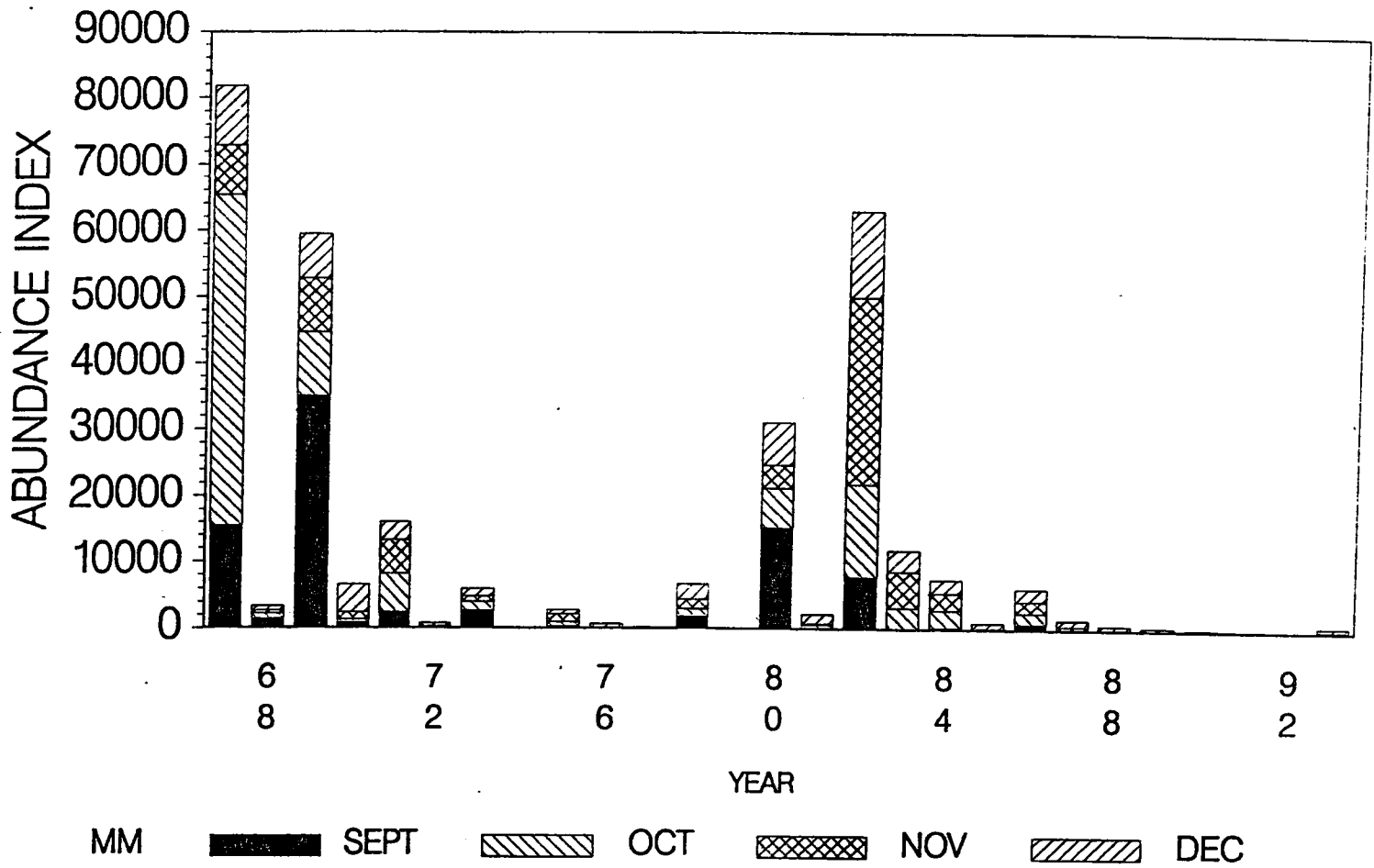


Figure 10. Abundance index of longfin smelt in the fall mid-water trawl survey. No surveys were conducted in 1974 and 1979.

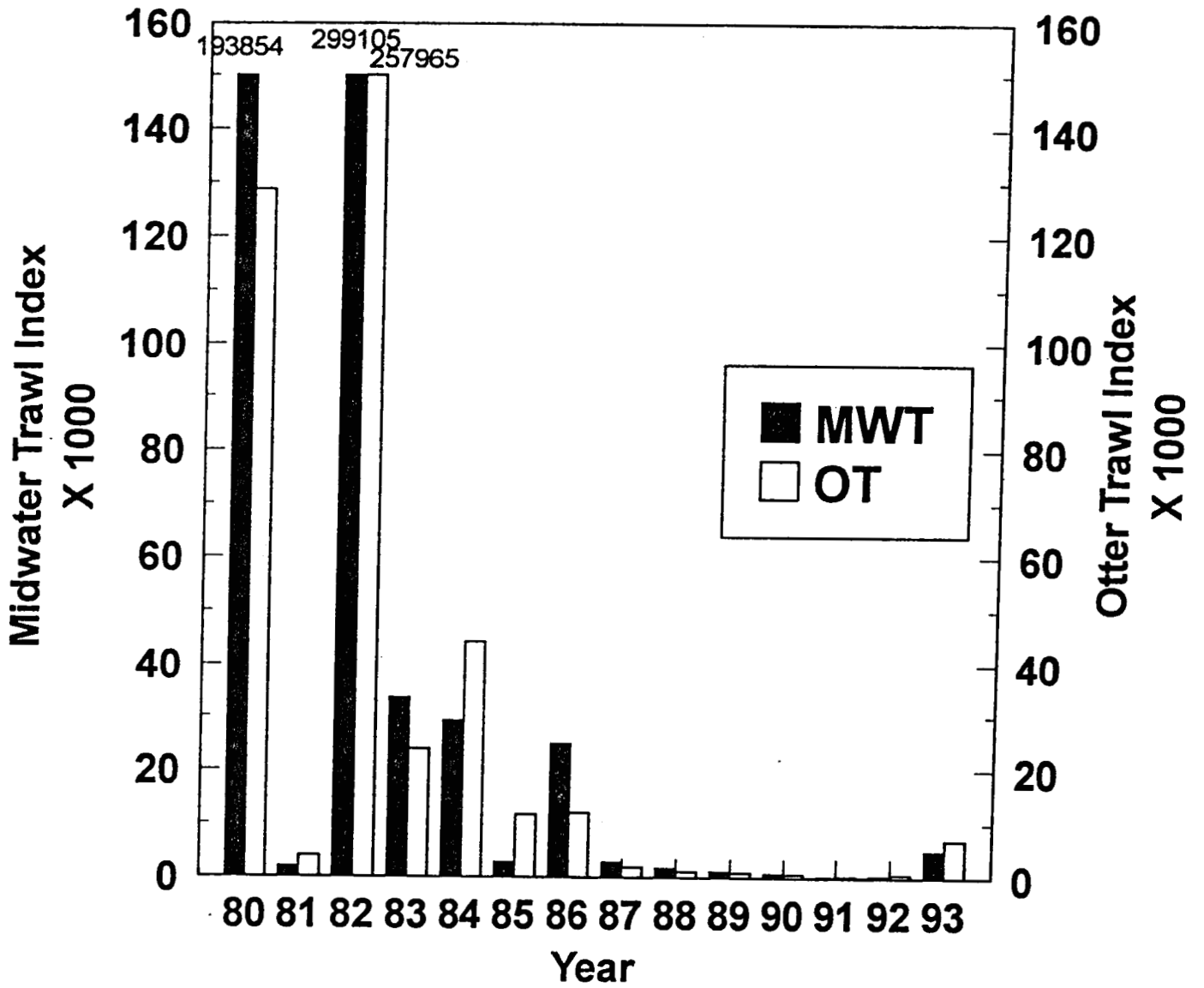


Figure 11. Young-of-the-year longfin smelt abundance indices from mid-water and otter trawl sampling by the San Francisco Bay Outflow Study.

the Sacramento and San Joaquin rivers, the delta, Suisun and Napa marshes, and tributaries of north San Pablo Bay.

Abundance indices of splittail based on fall mid-water trawl catches have varied over the years (Figure 12). They were relatively high in the late 1960's (i.e. 66.3 in 1967) and then declined severely until 1977. From 1977, abundances increased until an all time high of 153.2 in 1983. After that period the indices again decreased to 3.6 in 1992.

Sacramento splittail abundance indices from the San Francisco Bay Outflow Study sampling were calculated for ages 0, 1, and 2 based on length-frequency analysis and length-at-age data from the literature. Like fall mid-water trawl indices, Bay Study indices were highly variable, reaching maximums for the 1982, 1983, and 1986 year classes (Table 1). Indices declined through the late 1980s, then increased somewhat during the early 1990s.

Because of the reduced abundance and distribution of Sacramento splittail, it is considered a species of special concern by the Department of Fish and Game and its listing as a threatened species under the Federal Endangered Species Act is being contemplated by the USFWS.

### Sturgeon

Mark-recapture population estimates for white sturgeon  $\geq 40$  inches are available from intermittent tagging between 1967 and 1991. Estimated abundance was high in 1967 (114,700 fish), decreased to 20,700 in 1974, then increased to another peak of 117,700 in 1984 (Table 2). Since 1984, because of low recruitment between 1975 and 1982 and high harvest rate in the mid- to late 1980s, the estimated population has decreased again to 26,800 in 1990. Due to concerns about population status, angling regulation changes were initiated in 1990 to increase the minimum size limit from 40 to 46 inches and impose a maximum size limit of 72 inches. These new restrictions have reduced harvest rate to about one-third of the late 1980s level.

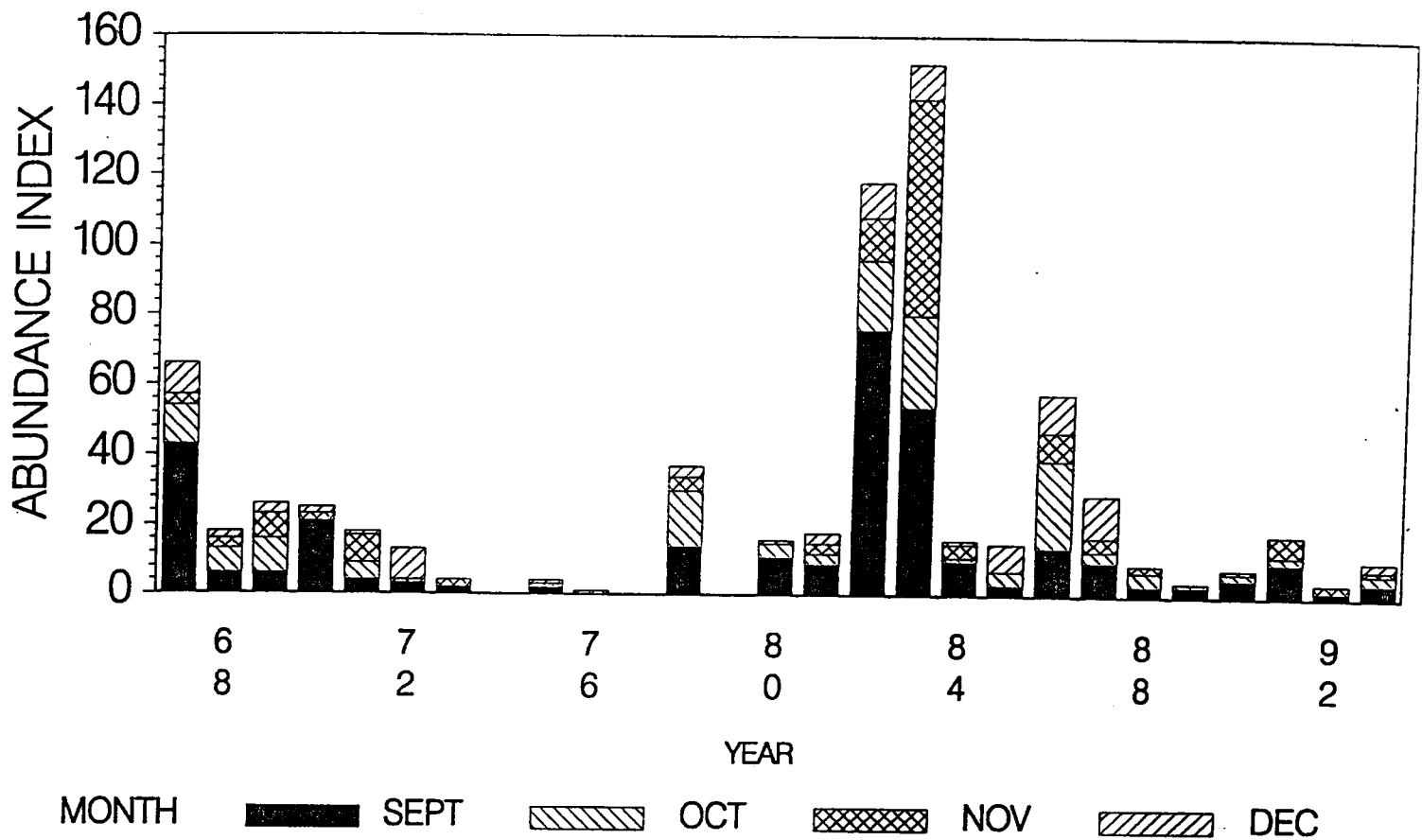


Figure 12. Abundance indices for Sacramento splittail in the fall mid-water trawl survey. No surveys were conducted in 1974 and 1979.

Table 1. Abundance of Sacramento splittail by year of sampling and age for San Francisco Bay Outflow Study mid-water and otter trawl catches combined. Splittail  $\geq$  age 3 were caught but were not included with these indices. Year class strength can be followed by reading diagonally upper left to lower right.

| Age   | Sampling Year |     |     |     |     |     |     |     |    |    |    |     |     |     |
|-------|---------------|-----|-----|-----|-----|-----|-----|-----|----|----|----|-----|-----|-----|
|       | 80            | 81  | 82  | 83  | 84  | 85  | 86  | 87  | 88 | 89 | 90 | 91  | 92  | 93  |
| 0     | 9             | 15  | 671 | 364 | 28  | 10  | 663 | 18  | 20 | 0  | 12 | 71  | 0   | 68  |
| 1     | 56            | 43  | 0   | 211 | 273 | 13  | 58  | 241 | 0  | 10 | 46 | 50  | 110 | 64  |
| 2     | 39            | 59  | 26  | 8   | 139 | 159 | 26  | 16  | 68 | 0  | 0  | 28  | 0   | 108 |
| Total | 104           | 127 | 697 | 583 | 440 | 182 | 747 | 275 | 88 | 10 | 58 | 149 | 110 | 240 |

Table 2. Abundance Estimates of White and Green Sturgeon Greater than 40 Inches Total Length.

| Year | White   | White: Green Ratio During Tagging | Green |
|------|---------|-----------------------------------|-------|
| 1954 | 11,200  | 56.5                              | 200   |
| 1967 | 114,700 | 62.0                              | 1,850 |
| 1968 | 40,000  | 38.6                              | 1,040 |
| 1974 | 20,700  | 101.9                             | 200   |
| 1979 | 74,500  | 52.6                              | 1,420 |
| 1984 | 117,700 | 106.3                             | 1,210 |
| 1985 | 107,700 | 127.3                             | 760   |
| 1987 | 86,000  | 163.7                             | 510   |
| 1990 | 26,800  | 49.7                              | 540   |



Green sturgeon are much less common in the estuary than white sturgeon (Table 2). The ratio of white:green sturgeon in tagging catches can be used along with white sturgeon population estimates to estimate abundance of green sturgeon in the estuary in the fall when tagging occurs. Abundance estimates of green sturgeon have ranged from about 200 fish in 1954 and 1974 to 1,850 in 1967. Abundance has steadily decreased since 1979.

### **Marine and Estuarine Dependent Species**

Since 1980, we have sampled numerous marine and estuarine species, but trends are not evident for many of these species. Some species that show general trends are discussed here.

Pacific Herring - Pacific herring use the bay as a nursery area for approximately 6-8 months before migrating to the ocean; they return to the bay as 2- and 3-year-olds.

YOY Pacific herring abundance is estimated from the San Francisco Bay Outflow Study mid-water trawling, which began in 1980. YOY herring were abundant in the bay in 1980, declined through the *El Niño* year 1983, then increased to high abundance in 1986, only to decrease again through the early 1990s (Figure 13). YOY abundance was particularly low in 1990.

Information regarding abundance of adult Pacific herring in San Francisco Bay comes from the estimated spawning biomass (Table 3). The spawning population has been relatively stable, but with two obvious anomalies. The first was the very low spawning biomass in 1977-78 associated with an *El Niño* condition. The second unusually low abundance level occurred in 1992-1993 and reflected poor recruitment from the 1990 and 1991 year classes.

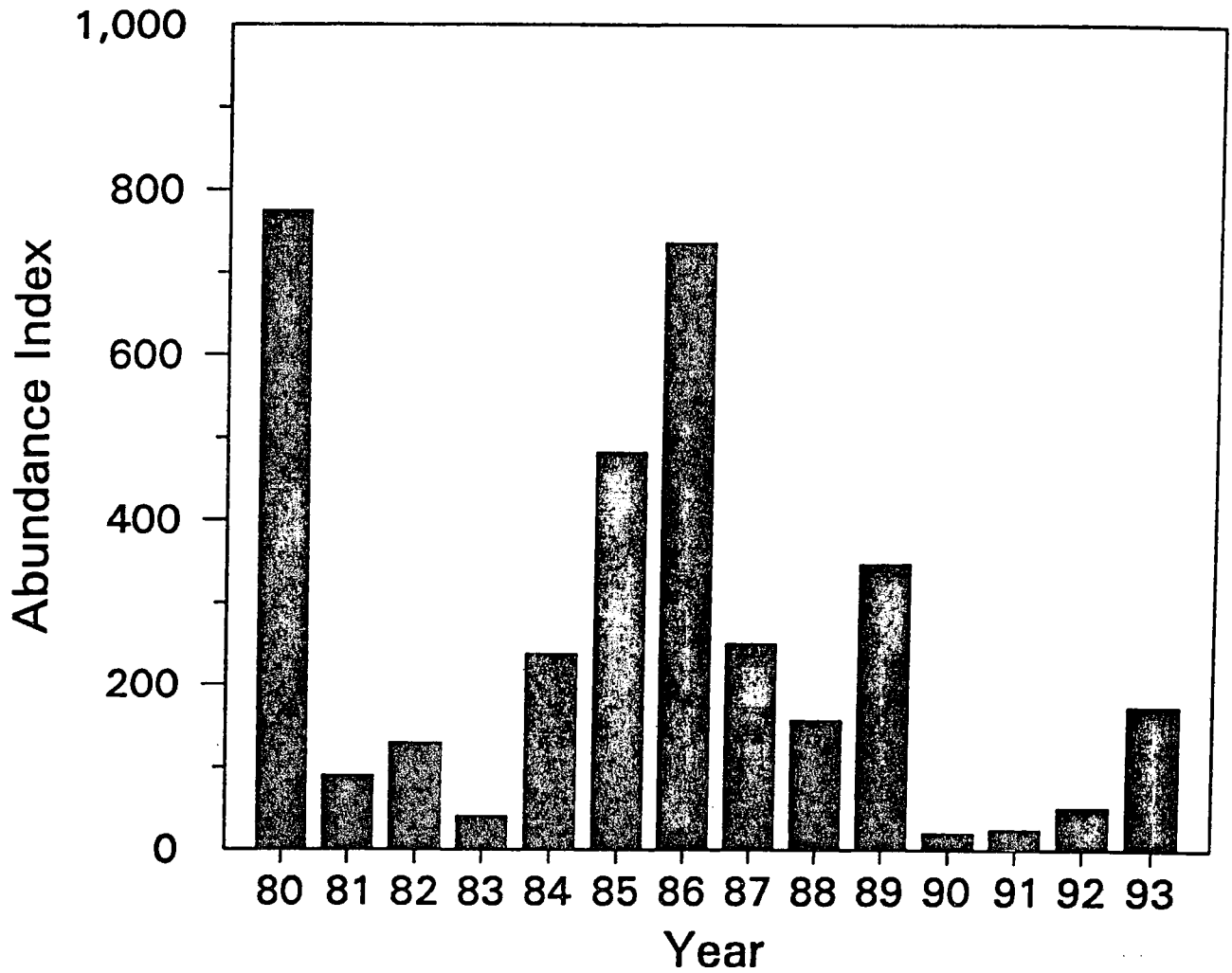


Figure 13. Young-of-the-year Pacific herring abundance indices from April-September mid-water trawl catches by the San Francisco Bay Outflow Study.

Table 3. Spawning Biomass of Pacific Herring in San Francisco Bay.

| <u>YEAR</u> | <u>Spawning Biomass</u><br><u>(Tons)</u> |
|-------------|--|
| 1974-75     | 27,200                                   |
| 1975-76     | 27,100                                   |
| 1976-77     | 26,900                                   |
| 1977-78     | 8,700                                    |
| 1978-79     | 36,700                                   |
| 1979-80     | 53,000                                   |
| 1980-81     | 65,400                                   |
| 1981-82     | 99,600                                   |
| 1982-83     | 59,200                                   |
| 1983-84     | 40,800                                   |
| 1984-85     | 46,900                                   |
| 1985-86     | 49,100                                   |
| 1986-87     | 56,800                                   |
| 1987-88     | 68,900                                   |
| 1988-89     | 66,000                                   |
| 1989-90     | 64,500                                   |
| 1990-91     | 51,000                                   |
| 1991-92     | 46,600                                   |
| 1992-93     | 21,500                                   |
| 1993-94     | 39,900                                   |

Starry Flounder - Starry flounder adults inhabit shallow coastal marine water, whereas juveniles seek out fresh to brackish water areas of bays and estuaries for nursery areas. Juvenile starry flounder appear to be estuarine-dependent, and so by virtue of its size, San Francisco Bay should be the most important nursery area for starry flounder in California.

The longest historical record of starry flounder numbers in San Francisco Bay comes from charter boat logs. Most of the estuary's starry flounder catch has occurred in San Pablo and Suisun bays; only catch data for San Pablo Bay is provided here. In general, catch per angler-hour and total catch increased between 1964 and 1971 (Figure 14) and decreased to 1964 levels by 1976. In 1976, the total starry flounder catch and catch per hour dropped rapidly and except for a brief period in the mid-1980's has not recovered to anywhere near previous levels. This information indicates that numbers of starry flounder vulnerable to this fishery have declined substantially in the estuary since the early to mid-1970s.

A shorter data base, from the San Francisco Bay Outflow Study otter trawling, demonstrates a dramatic decline in starry flounder abundance since sampling started in 1980, culminating in the complete absence of the 1992 year class in the samples at both age 0 and age 1 (Figure 15).

Caridean Shrimp - Five species of Caridean shrimp are relatively abundant in the bay: *Crangon franciscorum*, *C. nigricauda*, *C. nigromaculata*, *Heptacarpus stimpsoni*, and *Palaemon macrodactylus*. *Heptacarpus* and the three species of *Crangon* are native while *Palaemon* was accidentally introduced to the bay from the Orient in the 1950s.

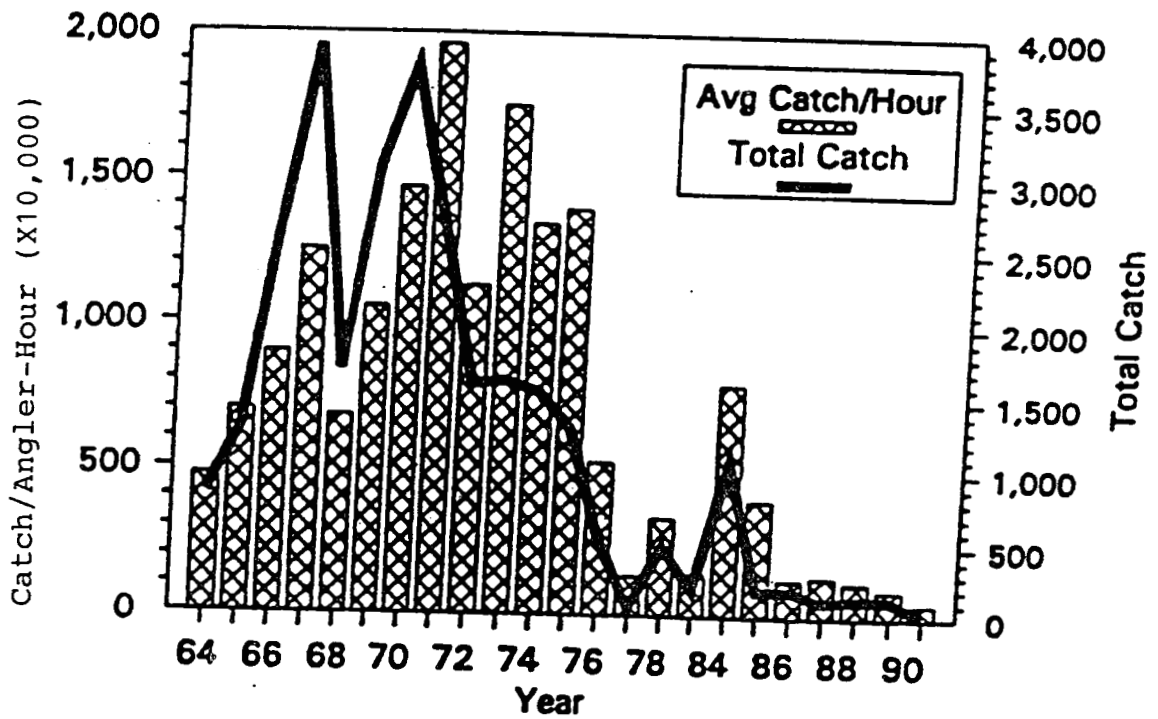


Figure 14. Starry flounder catch and catch per angler-hour in San Pablo Bay from January to May as reported by charter boat operators. Data for 1979 and 1981-1983 were not available.

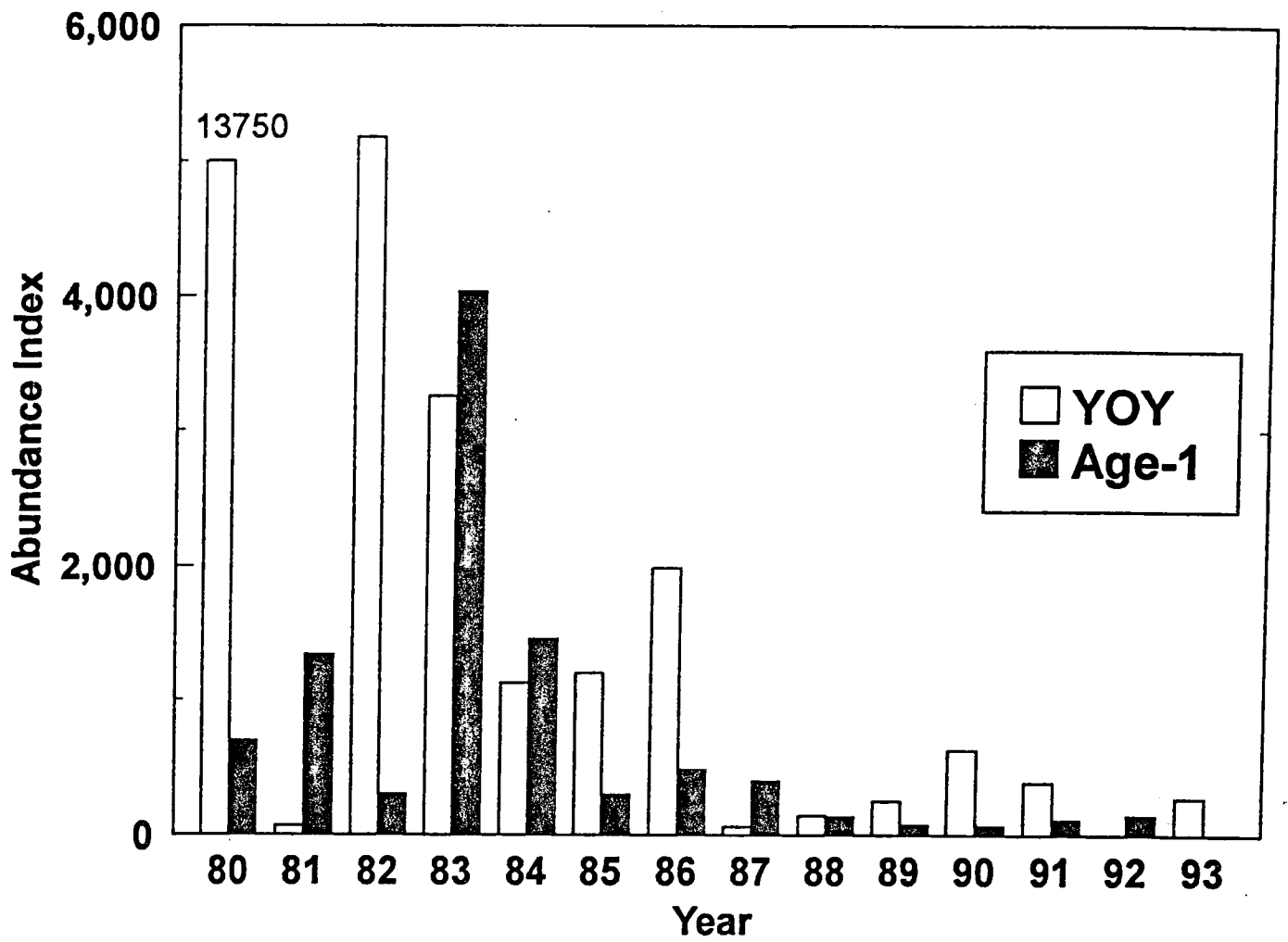


Figure 15. Young-of-the-year and age 1 starry flounder abundance indices from otter trawl catches by the San Francisco Bay Outflow Study.

*Crangon spp.* and *Palaemon* are fished commercially by trawl fishermen and are primarily sold as bait for sport fishermen. Earlier in this century, when there was a large market for dried shrimp, over three million pounds per year were landed (Figure 16). Since 1980 this fishery has landed between 100,000 and 200,000 pounds of shrimp annually. During the recent drought the fishery was concentrated in the Alviso Slough and Redwood Creek areas of South San Francisco Bay. Since 1985 shrimp fishermen have been prohibited from fishing in the area upstream of Carquinez Strait to protect juvenile striped bass. Occasionally commercial fishermen are not able to meet demand because of a scarcity of large shrimp suitable for bait.

Each of these shrimp species use the bay as a nursery area to a varying degree. Timing of larval hatching and juvenile recruitment to the bay is slightly different for each species. *C. franciscorum* is estuary dependent and its juveniles are found in brackish, relatively warm water. *C. nigricauda* is found in higher salinity and cooler water than *C. franciscorum*. *C. nigromaculata* is primarily a coastal shallow water species and is the most common crangonid in the nearshore ocean area adjacent to San Francisco Bay. *Heptacarpus stimpsoni* is found in high salinity, cool water, very similar to *C. nigromaculata*. This genus is considered to be coastal, although *H. stimpsoni* is locally abundant in the bay. *Palaemon macrodactylus* is an estuarine species that remains in the bay throughout its life cycle. No life stages are known to occur in the ocean. Adults are most common in Suisun Bay, the west delta, and areas adjacent to freshwater sources such as the mouths of creeks in South San Francisco and San Pablo bays.

Aside from the commercial catch data mentioned above, dependable abundance indices for shrimp are only available since 1980 (Figure 17). Although annual abundance indices were relatively high during the recent drought, species composition changed. In the early 1980s *C. franciscorum* dominated the catches, but in the late 1980s and early 1990s

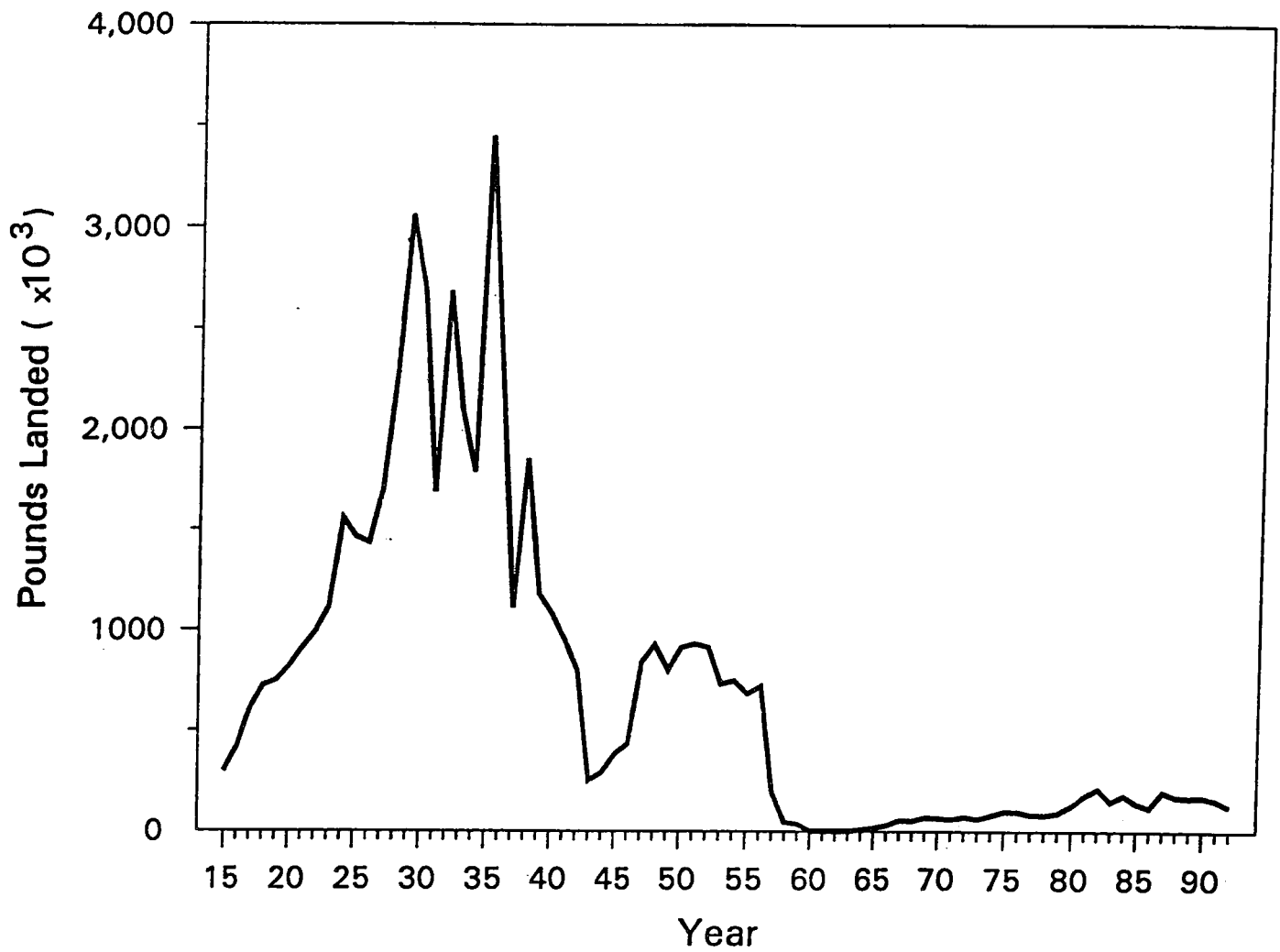


Figure 16. Trend in commercial landings of caridean shrimp in the Sacramento-San Joaquin Estuary from 1915 to 1992.



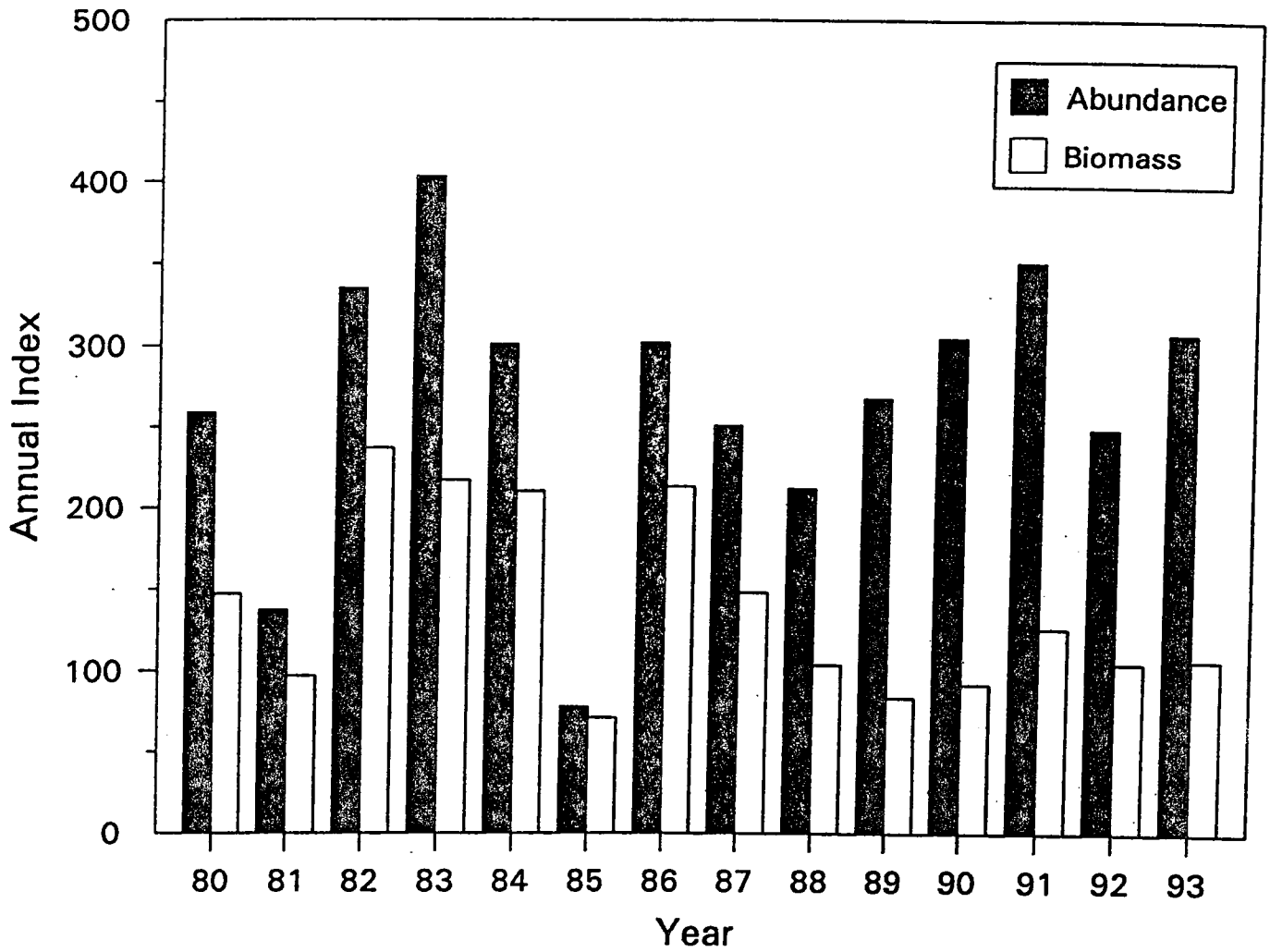


Figure 17. Annual abundance and biomass indices of caridean shrimp in the Sacramento-San Joaquin Estuary based on otter trawl catches by the San Francisco Bay Outflow Study.

*C. nigricauda* dominated and the abundance of *C. nigromaculata* and *Heptacarpus* increased (Table 4). This change was caused in part by the relatively stable, high salinities associated with the drought, resulting in increased habitat for species that prefer higher salinities, but decreased habitat for *C. franciscorum*, which prefers lower salinities.

Reflecting this change in species composition, the contribution of San Pablo and Suisun bays to the total abundance index declined while the contribution of Central San Francisco Bay increased (Table 5). In 1992, the Suisun Bay index decreased to a study period low, and contributed only 3% of the total index.

Biomass indices, a relative measure of the weight of shrimp available as a food source, have declined since 1986 (Figure 17). The divergence between the abundance and biomass indices during the recent drought is due to an increase in abundance of juveniles and species that do not grow as large as *C. franciscorum*.

The fall mid-water trawl survey and the San Francisco Bay Outflow Study otter trawling provide contradictory evidence concerning the present status of the introduced brackish water shrimp *Palaemon macrodactylus*. Fall mid-water trawl catches suggest a steady decline in *Palaemon* abundance since the early 1970s (except for 1986) with particularly low abundance since 1988 (Figure 18). Bay Study catches do not show a decline in this species (Table 4). Probably neither survey method adequately samples *Palaemon*.

Miscellaneous Marine and Estuarine Species - Among other species sampled by the San Francisco Bay Outflow Study, two temporal patterns of abundance are worth noting: 1) trends over the period of record starting in 1980 and 2) anomalous abundance in recent years. Examples of species exhibiting declining trends with low abundance in the late 1980s and early 1990s are Dungeness crab, most species of surfperch (some have completely disappeared from Bay Study catches), jacksmelt, and topsmelt. Species showing increasing trends include white

Table 4. Annual abundance indices (thousands) for the six most abundant species of caridean shrimp collected in otter trawls by the San Francisco Bay Outflow Study. Data are for all months sampled: January-December, 1980-1989; January-August, 1989; and February-October, 1990-1993.

| Year | <i>Crangon franciscorum</i> | <i>Crangon nigricauda</i> | <i>Crangon nigromaculata</i> | <i>Palaemon macrodactylus</i> | <i>Heptacarpus stimpsoni</i> | <i>Lissocrangon stylirostris</i> | Total |
|------|-----------------------------|---------------------------|------------------------------|-------------------------------|------------------------------|----------------------------------|-------|
| 1980 | 202.8                       | 47.1                      | 2.3                          | 4.1                           | 2.7                          | 0.0                              | 259   |
| 1981 | 104.8                       | 25.6                      | 0.8                          | 4.3                           | 1.4                          | 0.0                              | 137   |
| 1982 | 310.5                       | 18.4                      | 1.4                          | 2.7                           | 1.9                          | <0.1                             | 335   |
| 1983 | 343.6                       | 38.9                      | 16.1                         | 1.5                           | 2.4                          | <0.1                             | 403   |
| 1984 | 268.7                       | 14.2                      | 6.5                          | 5.9                           | 2.5                          | 2.8                              | 301   |
| 1985 | 50.0                        | 17.7                      | 2.8                          | 3.5                           | 3.3                          | 0.8                              | 78    |
| 1986 | 225.6                       | 55.4                      | 8.1                          | 4.7                           | 3.3                          | 4.9                              | 302   |
| 1987 | 126.0                       | 97.3                      | 14.1                         | 2.2                           | 10.5                         | 2.0                              | 252   |
| 1988 | 81.5                        | 105.8                     | 12.9                         | 1.5                           | 9.8                          | 0.2                              | 212   |
| 1989 | 100.6                       | 120.9                     | 16.4                         | 4.6                           | 24.9                         | 0.1                              | 267   |
| 1990 | 67.3                        | 168.5                     | 44.8                         | 3.5                           | 19.9                         | 0.6                              | 304   |
| 1991 | 51.4                        | 190.3                     | 63.0                         | 4.7                           | 41.1                         | 0.3                              | 350   |
| 1992 | 24.8                        | 134.6                     | 66.5                         | 4.6                           | 18.5                         | 0.1                              | 249   |
| 1993 | 70.5                        | 128.0                     | 78.6                         | 4.0                           | 25.4                         | 1.7                              | 308   |

Table 5. Annual abundance indices (thousands) and percentages, by embayment, for the six most abundant species of caridean shrimp collected in otter trawls by the San Francisco Bay Outflow Study. Data for years with less than year-round sampling (1989-1993) were derived by expanding catches from shorter sampling periods (January-August, 1989; February-October, 1990-1993).

| Year | South Bay |      | Central Bay |      | San Pablo Bay |      | Suisun Bay |      | West Delta |     | Total |
|------|-----------|------|-------------|------|---------------|------|------------|------|------------|-----|-------|
|      | Index     | %    | Index       | %    | Index         | %    | Index      | %    | Index      | %   |       |
| 1980 | 41        | 15.8 | 17          | 6.6  | 147           | 56.9 | 49         | 18.9 | 4          | 1.7 | 259   |
| 1981 | 55        | 40.1 | 5           | 3.9  | 28            | 20.2 | 38         | 28.0 | 11         | 7.9 | 137   |
| 1982 | 44        | 13.0 | 15          | 4.4  | 190           | 56.7 | 87         | 25.9 | 0          | 0.0 | 335   |
| 1983 | 78        | 19.3 | 69          | 17.2 | 218           | 54.2 | 37         | 9.3  | 0          | 0.0 | 403   |
| 1984 | 78        | 25.8 | 43          | 14.4 | 96            | 31.9 | 80         | 26.6 | 4          | 1.4 | 301   |
| 1985 | 20        | 25.8 | 20          | 25.1 | 13            | 16.1 | 20         | 26.0 | 5          | 6.9 | 78    |
| 1986 | 73        | 24.3 | 40          | 13.1 | 109           | 36.2 | 77         | 25.4 | 3          | 1.1 | 302   |
| 1987 | 64        | 25.7 | 70          | 27.7 | 41            | 16.5 | 65         | 26.0 | 10         | 4.2 | 252   |
| 1988 | 65        | 30.7 | 49          | 23.0 | 61            | 28.7 | 21         | 9.8  | 17         | 7.8 | 212   |
| 1989 | 54        | 20.3 | 63          | 23.5 | 46            | 17.2 | 29         | 10.8 | 8          | 3.2 | 200   |
| 1990 | 80        | 26.2 | 114         | 37.3 | 54            | 17.7 | 18         | 5.8  | 14         | 4.6 | 280   |
| 1991 | 84        | 24.0 | 145         | 41.4 | 65            | 18.6 | 21         | 5.9  | 7          | 1.9 | 322   |
| 1992 | 55        | 22.2 | 120         | 48.3 | 38            | 15.3 | 8          | 3.3  | 5          | 1.8 | 226   |
| 1993 | 56        | 18.0 | 143         | 46.3 | 60            | 19.4 | 32         | 10.4 | 2          | 0.7 | 293   |

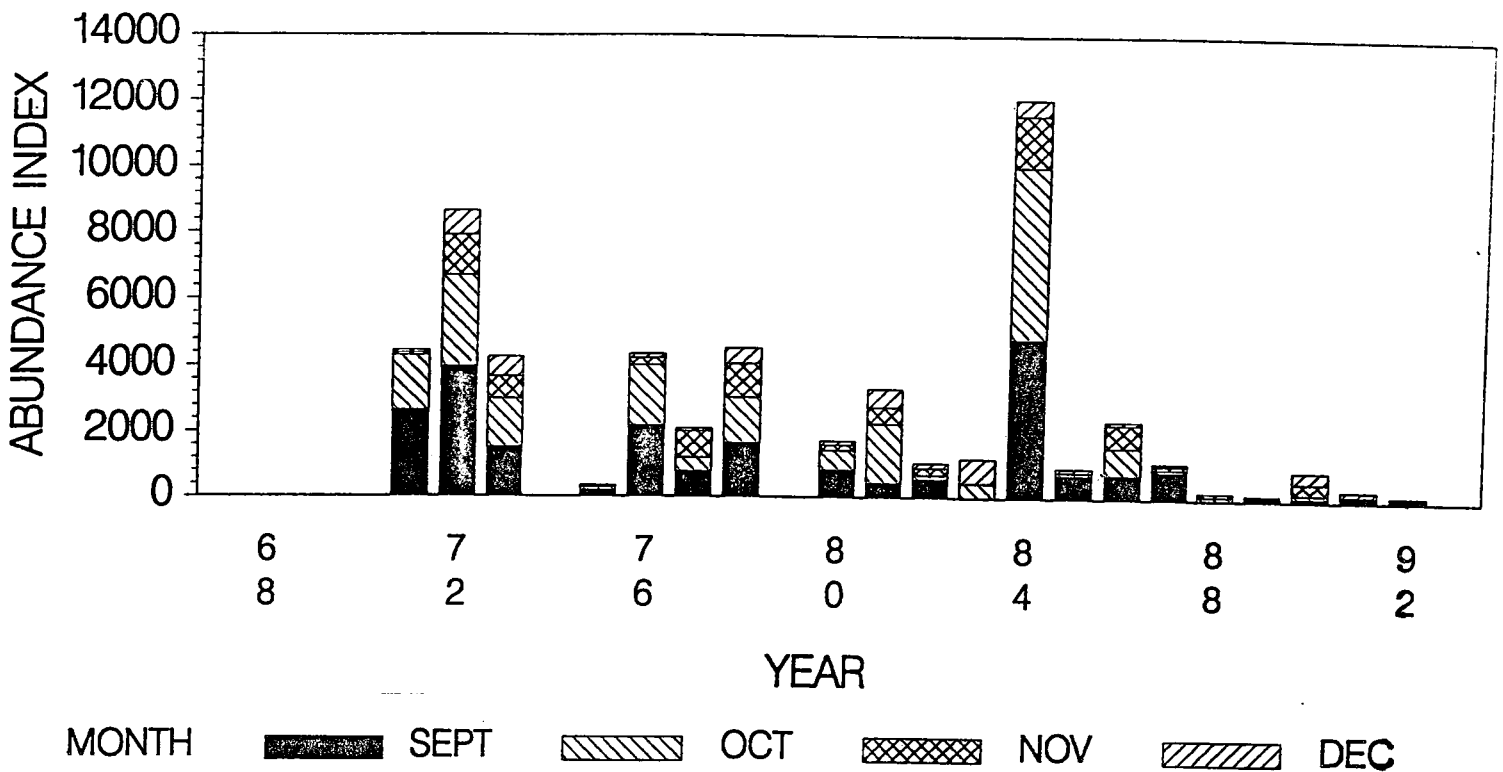


Figure 18. Abundance index of *Palaemon macrodactylus* in the mid-water trawl survey. No surveys were conducted in 1974 and 1979 and shrimp were not counted prior to 1971.

croaker, California halibut, and chameleon goby. The chameleon goby may actually be two species: *Tridentiger trignocephalus*, which is marine, and *T. bifasciatus*, a freshwater species. The former has existed in San Francisco Bay for many years while the latter has recently colonized the delta and upper bay and undoubtedly was introduced with ship ballast water.

Species with unusually high abundance in 1993 were sardines, northern anchovy, English sole, speckled sanddab, and California tonguefish. Catches of all sharks, skates, and rays were unusually low in 1992 and 1993.

### Striped Bass

Based on Petersen mark-recapture population estimates, the number of legal-sized adult striped bass fell to a record lows of 624,000 fish in 1992 (Figure 19). Excluding hatchery fish, the 1992 abundance estimate for naturally-produced fish is only about 533,000. As discussed in WRINT-DFG-Exhibits 2 and 3, current estimates of the adult striped bass population represent a decline from about 1 million fish in the 1980s and 1.7 million fish in the late-1960s and early 1970s when the mark-recapture estimates were initiated. Comparison of charter boat catches since 1969, when population estimates have been available, with catches in previous years suggests that the population was about 3 million fish in the early-1960s.

The adult striped bass population decline primarily reflects reduced recruitment. Estimates of the abundance of legal-sized 3-year-old fish, which are the youngest and most numerous component of the adult population, declined and have been at record lows since 1988 (Figure 20). This decline in recruitment has resulted primarily from the irregular but steady decline in production of young striped bass that extends back to the mid-1960's (Figure 21). As measured by the DFG's annual summer tow-net survey, which was initiated in 1959, the peak abundance of young bass occurred in 1965 when the index was 117.2. The four lowest indices of record occurred from 1988 to 1991, when the average index was 4.9. Since

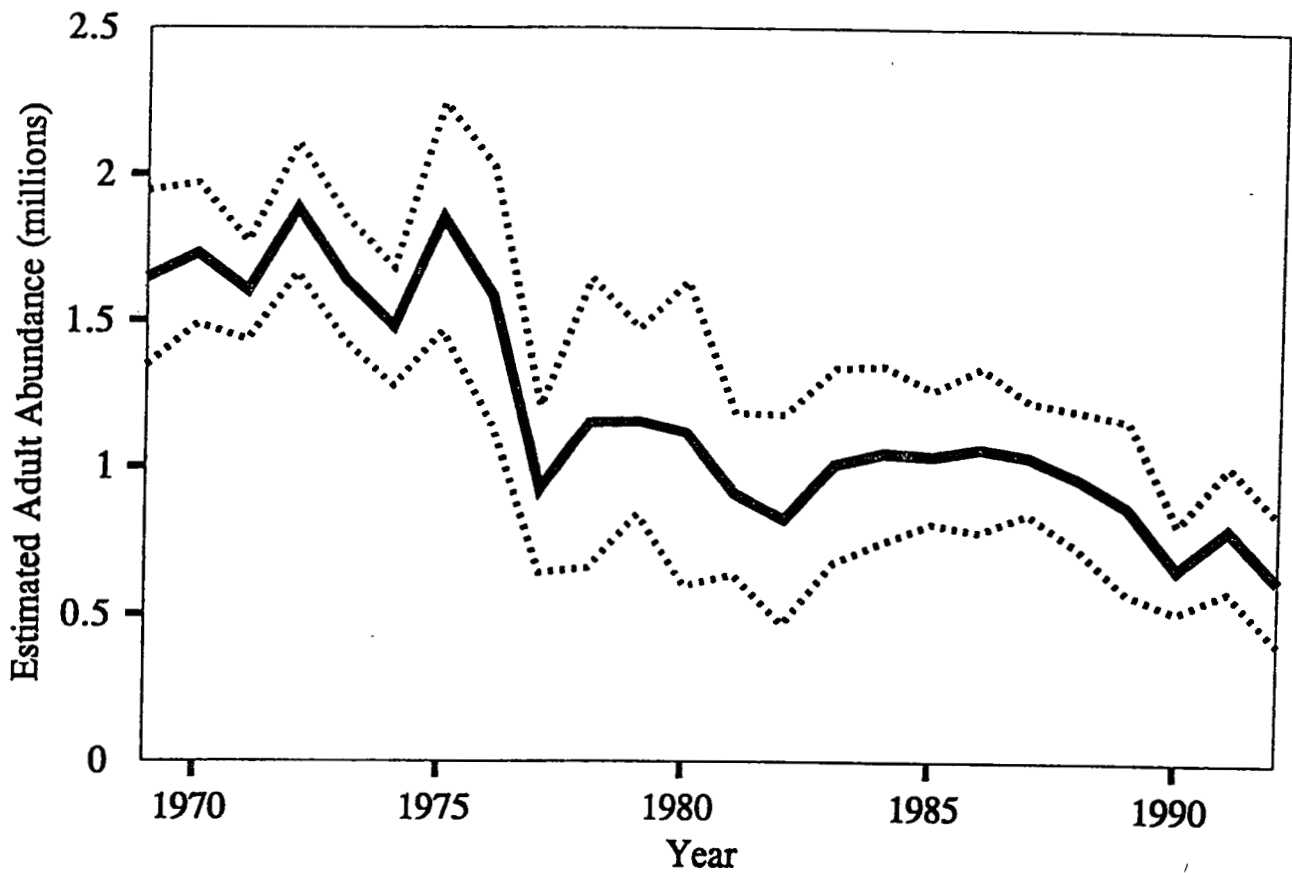


Figure 19. Trend in adult striped bass abundance in the Sacramento-San Joaquin Estuary, based on mark-recapture population estimates. Dashed lines are the 95% confidence limits about the estimates.

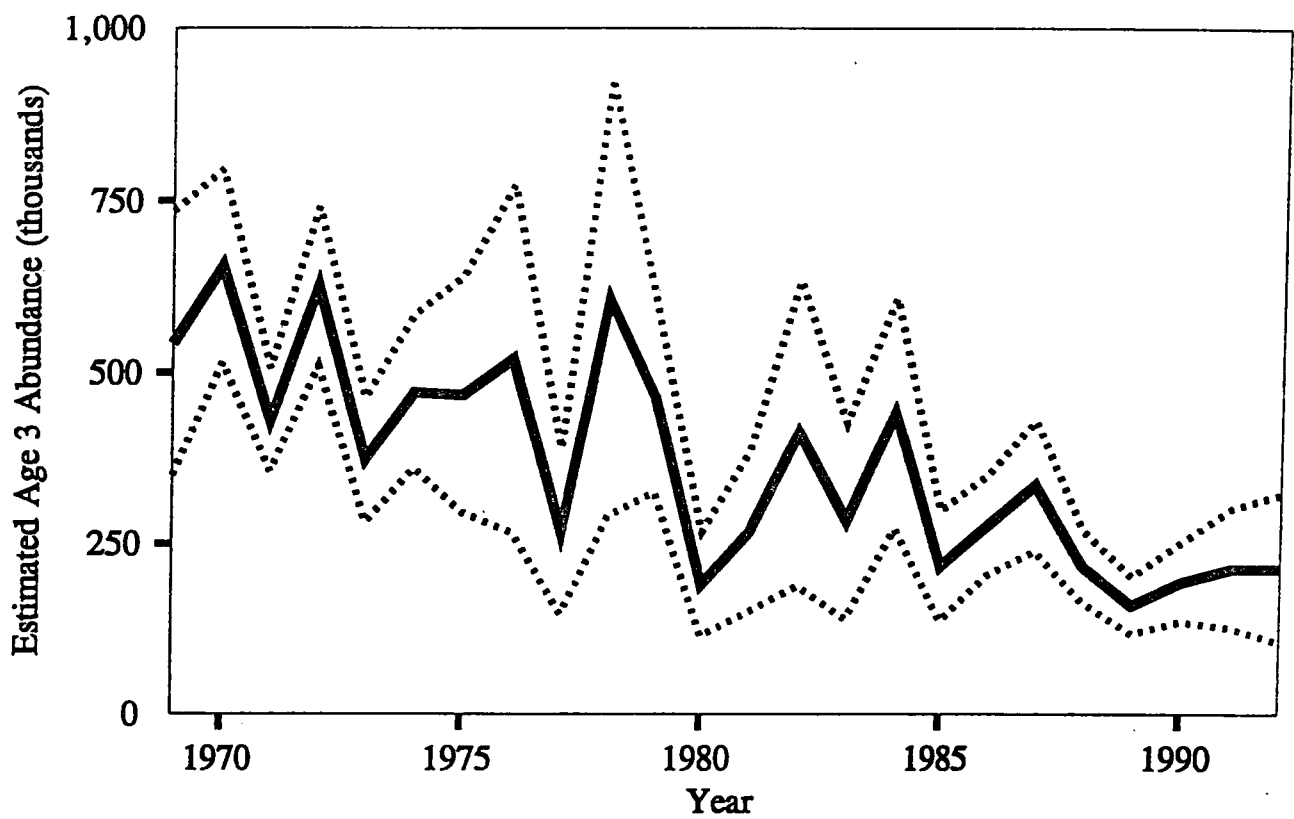


Figure 20. Trend in age 3 striped bass abundance in the Sacramento-San Joaquin Estuary, based on mark-recapture population estimates. Dashed lines are the 95% confidence limits about the estimates.



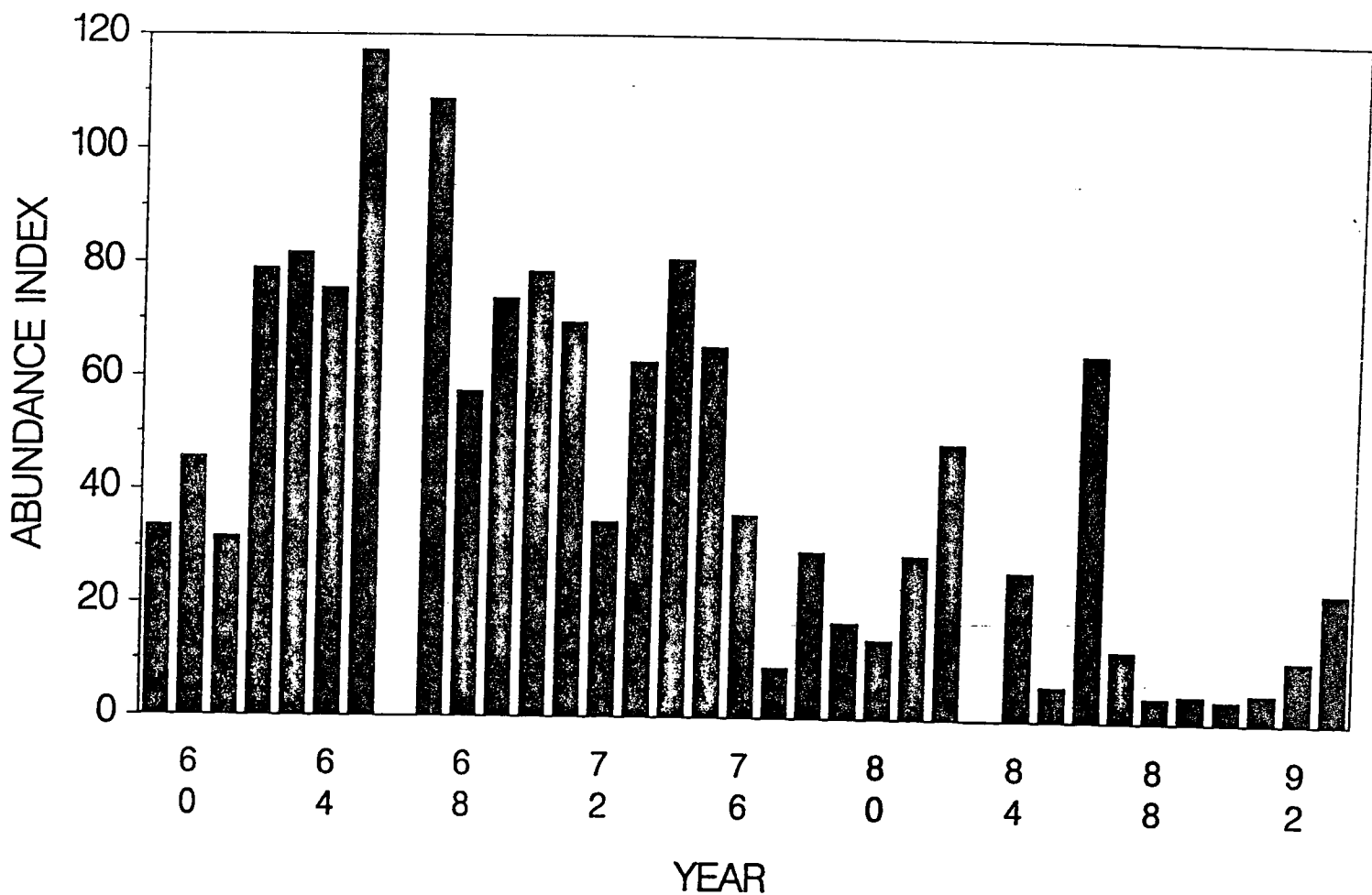


Figure 21. Annual abundance indices of young-of-the-year striped bass in mid-summer when mean size is 38 mm. No sampling was conducted in 1966 and no valid index could be calculated for 1983.

1977, the average abundance index for young bass has been 19.4. From 1959 to 1976, the average was 66.6.

For a detailed discussion of causes of this major population erosion, see WRINT-DFG-Exhibits 2 and 3.

### **Chinook Salmon**

There are four distinct salmon runs in the Sacramento system that are named for the season of their upstream migration: spring, fall, late fall, and winter. Today, the fall run is the most abundant run found in the Sacramento River and the only one found in the San Joaquin drainage. About 90% of the Central Valley chinook of all four runs are produced in the Sacramento River basin. Typically, about 80% of all Central Valley spawners are fall run fish.

Naturally produced salmon populations in the Central Valley are augmented by hatchery production. The release of most hatchery fish in the lower estuary, rather than in the rivers, has substantially increased survival and enabled a relatively intense ocean fishery to continue even with reduced natural salmon populations. The success of the hatchery program, however, increases the risk of over-harvesting natural stocks.

Monitoring data for chinook salmon in the estuary are subdivided into various geographic regions: the main stem Sacramento River, Sacramento tributary streams, eastside delta tributary streams, the San Joaquin basin, and the delta. Since 1953, DFG has made annual estimates of spawning fish in each of the major river systems. These are estimates of spawning "escapement" since they describe the numbers of chinook salmon that have escaped the ocean fisheries and returned to spawn.

Spawning runs of chinook salmon from all areas, since the regular counts started in 1953, have fluctuated greatly. Total runs plummeted from over 600,000 in 1953 to 120,000

in 1957 and then back up to almost 500,000 by 1960. From 1967 to 1991, the total has tended to be lower, averaging 247,100 natural spawners and 28,500 hatchery spawners.

The remainder of this section of the report will discuss population trends of the various races in two management basins, the Sacramento River Basin and the San Joaquin Basin.

Sacramento River Basin - An estimated 147,500 adult fall-run chinook salmon returned to the Sacramento River basin in 1993 and an estimated 107,300 returned in 1992. These recent escapement estimates are only 73% and 53%, respectively, of the average 201,100 fall chinook salmon that returned during the 1967-1991 period. The precipitous declines in salmon numbers in the Sacramento system are even more apparent when compared to prosperous years such as 1985 and 1986, when spawning escapement estimates were 295,200 and 274,000 fish, respectively.

DFG estimated that about 10,400 late fall-run chinook salmon returned to the upper Sacramento River in 1992, while the 1991 estimate was 8,600. Recent escapements are below the average 14,100 escapement of late-fall run chinook during 1967-1991. Late-fall run chinook salmon estimates will not be generated after 1992. Recent and anticipated future operation of the Red Bluff Diversion Dam resulting from the National Marine Fisheries Service Biological Opinion regarding the effect of the operation of the State and Federal water projects on winter-run chinook salmon will prevent the estimation of late-fall run chinook salmon escapement until new estimation methodology is implemented and verified.

In 1992, fewer than 1,200 spring-run chinook salmon used the Sacramento River basin, including the main stem, Mill Creek, Deer Creek, and Butte Creek. The 1993 estimate was 1,400 spring chinook. These escapements are well below the 1967-1991 average of 13,000.

Winter-run chinook salmon enumeration started when Red Bluff Diversion Dam was completed in 1967, and numbers have steadily declined from about 118,000 fish in 1969 to an

estimated 1,200 fish that returned in 1992 and 300 fish that returned in 1993. These recent escapements are well below the 1967-1991 average return of 23,100 fish. Even though the 1992 estimate suggested resurgence of the population, winter-run returns are expected to remain low for the next few years. As a result of these low winter-run chinook numbers, both the State Fish and Game Commission and the National Marine Fisheries Service have listed this race as endangered, which has mandated significant restoration efforts aimed at allowing levels to be returned to more acceptable numbers.

San Joaquin Basin - Annual population surveys have been conducted in the San Joaquin Basin since the early 1950s. During that time, the annual populations of salmon have experienced wide fluctuations. Populations were highest during the 1950s, 1967-1972, and 1981-1988; they were lowest during 1961-1966, 1973-1980, and 1989 to the present. The 1991 estimate of 900 fall-run chinook salmon was the lowest escapement ever observed in the San Joaquin Basin. The 1992 and 1993 escapements were estimated to be about 2,000 and 3,200 fish, respectively. These recent returns are much lower than the 1967-1991 average of 20,700.

Salmon Summary - Traditional indices of salmon abundance indicate that most runs of chinook salmon in the estuary and its tributary rivers and streams have been severely reduced compared to the 1967-1991 average. There is little likelihood that sport and commercial fisheries or spawner escapement will increase soon. A few stream systems, such as the Feather and the American rivers, which are supported by effective hatchery programs, have maintained adequate populations. Of greatest concern at this time are winter-run, spring-run, and San Joaquin fall-run. The concern arises from chronically low escapements and low future population projections based on recent trend data. As all chinook salmon pass through or reside in the delta at different stages in their life history, improving delta conditions is a critical element in rebuilding all runs of chinook salmon in the Central Valley.