BAY-DELTA OVERSIGHT COUNCIL

DRAFT

BRIEFING PAPER ON BIOLOGICAL RESOURCES OF THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Bay-Delta Oversight Council

September 1993

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Bay-Delta Oversight Council

September 1993

State of California | The Resources Agency

Memorandum

Date : September 30, 1993

To : BDOC Members

From : Steve Yaeger, Deputy Executive Officer
Bay Delta Oversight Council

Subject: Briefing Packet on Biological Resources

This section of the two part Draft Briefing Packet on Biological Resources is being provided to the Council for your advance review while the remainder of the packet is still in preparation. This specific section deals with Aquatic Resources. The second section, dealing with Wildlife and Plant Resources is currently being reviewed by the Peer Groups and we expect to provide those papers to you prior to the briefing on that subject -- tentatively scheduled for the November BDOC meeting.

The perspectives papers of the Aquatic Resources section are still in progress despite our best efforts to solicit them from a wide spectrum of biological experts. We will provide these issue papers as soon as they are available. In any event, several of the biological experts will present their perspectives orally at the meeting and be available to answer your questions. We will make written copies of their presentations available for your future use.

SURNAME				

DWR 155 (Rev. 2/86)

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LISTING OF BRIEFING ITEMS
BDOC BRIEFING ON BIOLOGICAL RESOURCES OF THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

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      2. Factors Controlling the Abundance of Aquatic Resources prepared by Department of Fish and Game

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   C. Perspectives and Issues of Concern to Agencies and Public Interest Groups (Issue papers prepared by the Agencies and Groups)

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IV. Estuary Wildlife and Plant Resources

   A. Status, Trends and Factors Controlling the Estuaries Wildlife and Plant Resources

      1. Status and Trends
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   B. Perspectives of State and Federal Agencies

      1. U.S. Fish and Wildlife Service
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   C. Perspectives and Issues of Concern to Agencies and Public Interest Groups (Issue Papers Prepared by the Agencies and Groups)

      1. Fishery Groups
      2. Public Interest Groups
      3. Others

INTRODUCTION

INTRODUCTION

Briefing Materials on Biological Resources of the

San Francisco Bay/Sacramento-San Joaquin Delta Estuary

This briefing package is meant to provide basic information on Estuary Biological Resources. Its two components deal separately with aquatic resources and wildlife and plant resources.

Also to be provided at a future date, are representative spectrum regarding these topics submitted by various affected agencies, and experts in the Estuaries biological resources. Time constraints did not allow for canvassing all agencies and concerned public groups, however, we believe that the coverage provided will encompass a fairly comprehensive identification of the major issues.

The Executive Summary seeks to provide an overview of the material contained herein. It deserves emphasis, however, that the Summary should not be considered a substitute for the full text of the issue papers. Rather, it is meant to provide merely a snapshot of the major points raised since the characterization and flavor of the entire prepared pieces simply cannot be replicated in the Summary.

The first section of the package covers the aquatic resources of the Estuary, and begins with a background paper on the status of the resources. This status paper is followed by a paper which discusses the factors which affect the abundance of aquatic species. These papers are intended to present as objective an overview as possible.

Following the discussion papers, prepared comments will be included, representing particular perspectives and concerns relating to the estuaries aquatic resources as submitted by affected State and Federal agencies, as well as a cross-section of other experts in the field.

The discussion of Wildlife and Plant Resources of the Estuary is similarly organized. Background papers presenting an overview of the status of the resource and factors affecting the abundance of the resource will be followed by papers presenting various perspectives of State and federal resource agencies and other experts in the field.

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

STATUS AND TRENDS OF ESTUARY AQUATIC RESOURCES

■ GENERAL

Highly dynamic and complex environmental conditions exist in the Estuary, which have historically supported a diverse and productive ecosystem.

Over 200 species of fish, shrimp, and crabs are known to inhabit the Estuary. Throughout the food chain, many aquatic species representing varying needs and methods of utilizing the Estuary as a habitat, are in decline, suggesting that the Estuary's ability to maintain aquatic species has decreased.

Many aquatic species living in the Estuary have experienced serious population declines in recent years. While the condition of all species is important in the discussion of the resource, several species are generally recognized as indicator species representing broader groups, and therefore are discussed here, including white catfish, Delta smelt, longfin smelt, Sacramento splittail, sturgeon, Pacific herring, starry flounder, Caridean shrimp, striped bass and chinook salmon.

The Estuary's biological resources have undergone a significant transformation over the last century and a half. Many species of non-native aquatic invertebrates and more than 50 species of non-native fish species have been introduced.

Estuarine species spawn in salinities ranging from ocean concentrations to freshwater, depending on the species. Brackish water habitats typically provide critical nursery areas. As their classifications suggests, freshwater and marine species spend most of their lives in freshwater and salt water habitats respectively.

It is important to note that the observed declines of most, if not all, species under consideration here, were undoubtedly intensified by the recent, historically unprecedented drought. Long-term biological consequences of the drought will require additional study in order to specifically address such effects.

■ PHYTOPLANKTON AND ZOOPLANKTON

- Phytoplankton abundance has declined in the last 20 years in Suisun Bay. Moreover, over the same period, a previously less common species of phytoplankton, which is not a preferred food source for zooplankton, has

- Historically, the Delta smelt was widely distributed throughout the Estuary. Recently, they have become heavily concentrated in the lower Sacramento River, between Collinsville and Rio Vista.

- Abundance indicies for the Delta smelt have declined from the 1,000 -- 1,500 range in the early 1970's, to the 300 -- 400 range in the late 1980's and early 1990's. The 1992 index (157) was one of the lowest on record.

- The U.S. Fish and Wildlife Service added the Delta smelt to the Threatened and Endangered Species list in March of 1993. This species has also been listed as Threatened under the California Endangered Species Act.

■ Longfin Smelt --

- Longfin smelt are found in fresh, brackish, and marine waters from San Francisco Bay to Alaska.

- The Longfin smelt spawn in the lower Sacramento and San Joaquin Rivers, the Delta and the freshwater portions of Suisun Bay. The second year of the life cycle of the longfin smelt, an important component of the estuarine food chain, is normally spent in the Bay.

- Fluctuations in abundance are closely correlated to freshwater flows between February and May. No such similar relationship exists for Delta smelt.

- There are petitions presently pending to place the longfin smelt on the federal endangered species list.

■ Sacramento Splittail

- The Sacramento 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.

- Spawning and nursery habitat have been significantly reduced through land reclamation. The splittail's range has historically covered the Central Valley, from Redding to Fresno. Today, however, they are only found in the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun and Napa marshes, and tributaries north of San Pablo Bay.

- These shrimp support a fishery and are primarily sold as bait.

- Each species utilizes the Bay as nursery area to a varying degree. While one species' abundance is strongly related to freshwater outflow in the spring, the other species do better in drier, low flow years. There has appeared to be both a shift in relative abundances of the five species and an overall decline of total biomass during the 1988-90 period.

- Striped Bass

  - Striped bass were introduced as a sport and commercial fish in the late 1800's. By the turn of the century the commercial catch was over a million pounds annually. However, by 1935 commercial fishing for striped bass was prohibited in order to enhance the sport fishery.

  - Striped bass begin spawning in the spring, usually from April to mid-June. They spawn in freshwater, with moderate to swift current, and water temperatures in the range of 61 F to 69 F. Important spawning grounds include the San Joaquin River between Antioch Bridge and the mouth of Middle River, and the Sacramento River between Sacramento and Colusa. About 1/2 to 2/3 of total striped bass eggs are spawned in the Sacramento River. In wet years, some spawning occurs in the San Joaquin River above the Delta.

  - Striped bass are very prolific. A five-pound female may spawn 180,000 eggs in a season, while a 15 pound fish can produce over a million eggs. Even so, population levels have declined substantially since the 1960's. 1990 estimates were at a record low of approximately 590,000 naturally produced adult fish.

- Chinook Salmon

  - Chinook, or "King," salmon spawn in freshwater but spend most of their adult lives in the ocean. Chinook salmon and steelhead rainbow trout are the principal salmonids in the Estuary.

  - There are four distinct salmon runs in the Estuary system; named for the season of their upstream migration. They are the spring, fall, late fall, and winter.

- San Joaquin Basin

Salmon populations in the San Joaquin have fluctuated widely since the early 1950's when counts were begun.

1991 counts of fall-run chinook salmon produced an estimate of 1,100, well below the 76,100 that returned in 1985.

Traditional indices of salmon populations suggest that most runs of chinook salmon in the Estuary and its watershed have declined significantly in recent years, with little evidence suggesting near-term improvement.

FACTORS AFFECTING THE AQUATIC RESOURCES OF THE ESTUARY

- **THE INFLUENCE OF DELTA INFLOW ON AQUATIC RESOURCES**

  - Freshwater flows into the Delta affect biological resources both in the rivers above the Estuary and in the Estuary proper. Specific examples of this effect include:

    - Striped bass eggs and larvae experience increased survival rates during periods of higher spring flow rates;

    - Minimum flow rates are needed in the Sacramento River system during various time frames to protect salmon in upstream spawning and rearing areas. Many believe flows impact outmigrating salmon in the Delta. A USFWS model, however, identified water temperature and diversion, rather than flow, as the principal controlling factors in the success of outmigrating salmon.

    - It is important to note that needs of the various salmon runs may differ and caution is warranted in making management decisions based on limited observations of particular runs.

    - A strong statistical correlation exists between spring flows of the Tuolumne and Stanislaus rivers and returning runs of adult salmon to those rivers 2 1/2 years later;

    - USFWS, NMFS and DFG advocate minimum spring flows in the San Joaquin River to improve salmon survival in the Delta;

- Entrained fish are trucked to the western Delta for release. However, a small to large proportion of these fish die as a result of associated stress and predation at the point of release. (However, this loss is almost 100% for some species.)

- Predation, particular of salmon by striped bass, in Clifton Court Forebay is of significant concern. A major program to remove striped bass from the Forebay is planned for this fall.

- Two major disadvantages of having large water diversions from the south Delta are:

  - No flow can bypass the intake, so all fish must be captured and transported to another location for release, suffering associated stress mortality; and,

  - Since water is being withdrawn from a large "pool" which is a major nursery for some fish and a permanent residence for others, the capacity of the "pool" to support these populations is diminished through effects on the fish and their food supply.

- All fish species are not equally vulnerable to being drawn to the pumps. Migrating fish which follow the downstream flow are more vulnerable than resident fish that reside near the shore.

- High flows may make some vulnerable species less vulnerable by quickly carrying fish downstream.

- Striped bass (before 20 mm stage) losses through entrainment at the project pumps have been estimated by DFG to be more than 70% in dry years and 32% in wet ones.

- There are approximately 20 to 50 million salmon smolt migrating through the Delta which are susceptible to various negative impacts as a consequence of project operations:

  - Losses at project diversions in the south Delta have been estimated to be between 400,000 and 800,000 in recent years, assuming an estimated mortality of 75% in the Clifton Court Forebay.

  - About 2% of spring outmigrants from the Sacramento River are entrained at the project screens, while as many as 20% to 70% of the San Joaquin outmigrants are captured.

- Physics of Outflow:

  - Freshwater flowing out of the Estuary overrides salt water intrusion caused by tidal action. This results on fresher water near the surface and more saline bottom currents.

  - The entrapment zone (an accumulation of suspended particles) occurs near the location of the upper end of the salinity gradient and is an important fishery nursery area. Production tends to increase when outflows are maintained at a moderate level.

- Bay Fishes and Invertebrates:

  - The magnitude of Delta outflow strongly influences the *distribution* of almost all estuarine fishes and invertebrates, but the relationship of flows to *abundance* for most species is not as well documented. Still, for several species, there is a strong positive relationship between outflows and abundance.

  - Storage and diversion of water during the winter and spring has decreased outflow, probably contributed to the long-term decline of shrimp, starry flounder and longfin smelt populations by decreasing upstream transport to nursery areas.

  - High flows increase survival of longfin smelt by spreading them over a larger area and increasing their food supply.

- Striped Bass:

  - Survival of young striped bass increases in proportion to Delta outflow during April through July.

  - First year conditions appear to determine subsequent abundance of adults.

- Chinook Salmon:

  - Salmon smolts migrate through the lower Estuary faster than net flow would transport them, thus their survival is apparently not related to outflows.

- Toxicant effects are potentially confounded by flow effects because the magnitude of flow dilutes concentrations of toxicants, particularly in the upper portion of the Estuary.

- THE INFLUENCES OF LEGAL HARVEST

  - The issue is whether harvest are sufficient to inhibit the population's ability to maintain itself or to be responsible for observed changes in abundance. To date, there has been no evidence correlating declines to harvests.

- THE INFLUENCES OF ILLEGAL HARVEST

  - Illegal harvest is more difficult to estimate by its very nature.

  - DFG believes illegal salmon take in the Estuary has no significant impact on the resources, including harvests by foreign fisheries.

  - It is unlikely that the harvest of sub-legal bass is the dominant factor causing the decline in adult bass abundance since 1970.

- IMPACTS OF LAND RECLAMATION

  - Historical land reclamation destroyed most of the tidal marshes in the Estuary and seasonally flooded wetland upstream from the Estuary and probably caused the extinction of some species and the decline of the Sacramento splittail.

- IN-DELTA DIVERSIONS

  - Diversions onto Delta agricultural lands are made through many small unscreened intakes. These diversions can add up to approximately the same magnitude as the amount of water diverted into the Tracy Pumping Plant .

  - Fish losses occur at cooling water intakes for power plants as well as at the irrigation diversions.

  - Evaluation of fish losses and potential screening methods is underway.

BIOLOGICAL RESOURCES OF THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

AQUATIC RESOURCES

PAST TRENDS AND PRESENT STATUS OF SELECTED FISH AND INVERTEBRATE SPECIES OF THE SAN FRANCISCO BAY/SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

PAST TRENDS AND PRESENT STATUS OF SELECTED FISH AND INVERTEBRATE SPECIES OF THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

Prepared for the

Bay-Delta Oversight Council

by

CALIFORNIA DEPARTMENT OF FISH AND GAME

BAY-DELTA AND SPECIAL WATER PROJECTS DIVISION

STOCKTON, CALIFORNIA

September 1993

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Figures

SUMMARY AND CONCLUSION

This report presents evidence that many aquatic species living in the San Francisco Bay/Sacramento-San Joaquin Delta Estuary have recently experienced serious population declines. Data and trends for phytoplankton, zooplankton, white catfish, Delta smelt, longfin smelt, Sacramento splittail, sturgeon, starry flounder, shrimp, striped bass, and chinook salmon are included, as they are generally recognized indicator species representing broader trends mirrored in other Estuary status reports. Three figures from the report "Status and Trends Report on Aquatic Resources in the San Francisco Estuary" by Bruce Herbold, Alan Jasby and Peter Moyle, vividly illustrate these declines (Figures 1, 2 and 3).

INTRODUCTION

The San Francisco Bay/Sacramento-San Joaquin Delta Estuary (hereinafter "Estuary") is the largest estuary on the west coasts of North and South America. Freshwater runoff from 40 percent of California's land area mixes with Pacific Ocean water in the Estuary, creating highly dynamic and complex environmental conditions which have historically supported a diverse and productive ecosystem.

The upper part of the Estuary, known as the Sacramento-San Joaquin Delta, is comprised of 1,153 square miles of waterways, marshes, farm, and urban land, while the downstream portion is made up of the 478 square mile San Francisco Bay. The Estuary supports many important economic activities; including sport and commercial fishing (including the commercial bait fishery and the party boat recreational fishery), tourism, recreation, shipping, industry and agriculture.

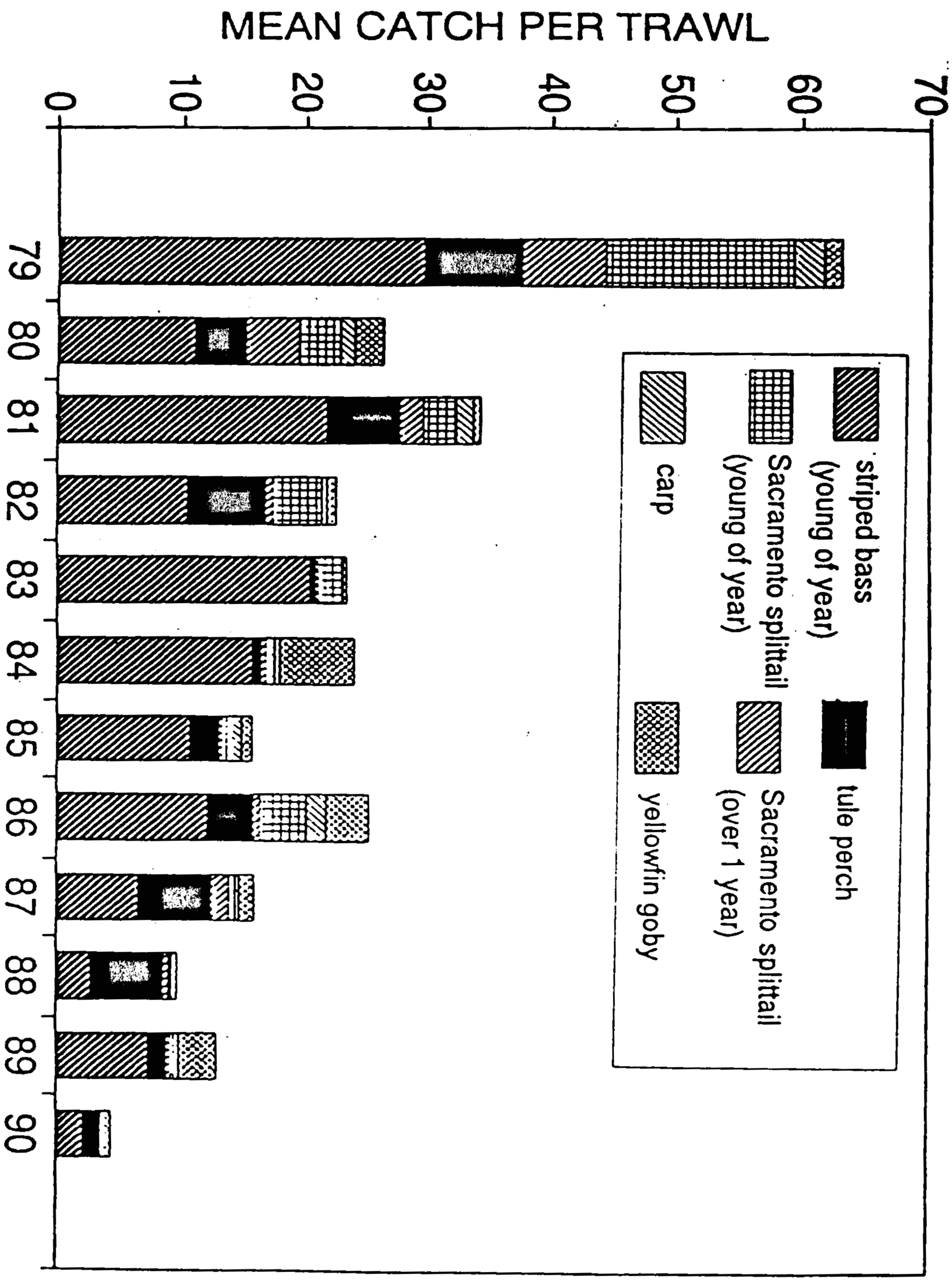


Figure 2 Abundance of six most frequently captured species collected by otter trawl sampling program by UCD in Suisun Marsh.

(Figure from Herbold et al, 1992)

The Estuary was essentially undisturbed by man until the mid-1800's, when human impact and development began to intensify. Gold Rush-related activities initiated physical, chemical, and biological changes in the estuarine system that would eventually lead to it being highly modified by human activity.

The Estuary's biological resources, particularly, have experienced a major transformation over the last century and a half. Aquatic communities; including phytoplankton (small, floating plants which transform sunlight to food), zooplankton (small animals that feed on phytoplankton and detritus), bottom-dwellers (benthos), and fish have undergone extensive change. Many species of non-native aquatic invertebrates; including clams, oysters, and worms have been introduced into the Estuary in the past century. In addition, more than 50 fish species that occupy the Delta are not indigenous.

The Estuary's ability to maintain consistent levels of abundant species has also been altered over the years. Since the early 1970's, and especially since the 1976-1977 drought, zooplankton and phytoplankton abundance have generally declined in San Pablo and Suisun Bays. Many fish species dependent on the Estuary for food, nursery habitat, and as a migration corridor are in decline too: the spring-run chinook is down 80 percent, while fall-run is down 50 percent; the striped bass population has declined by 70%; starry flounder and Bay shrimp populations have declined; listings under endangered species laws for the spring-run salmon and green sturgeon are actively being considered, and petitions for longfin smelt and Sacramento splittail have recently been filed. In the past, species such as the thicktail chub have become extinct in the system.

It should be recognized that the depleted abundance of most, if not all, of these organisms mentioned above were undoubtedly intensified by the recent drought. The drought also restricted the geographic distribution of some species in the estuary. The low flows which occurred in the last 5 or 6 years are unprecedented in the historical record. Still, it remains to be seen what the long-term, biological consequences of the drought will be.

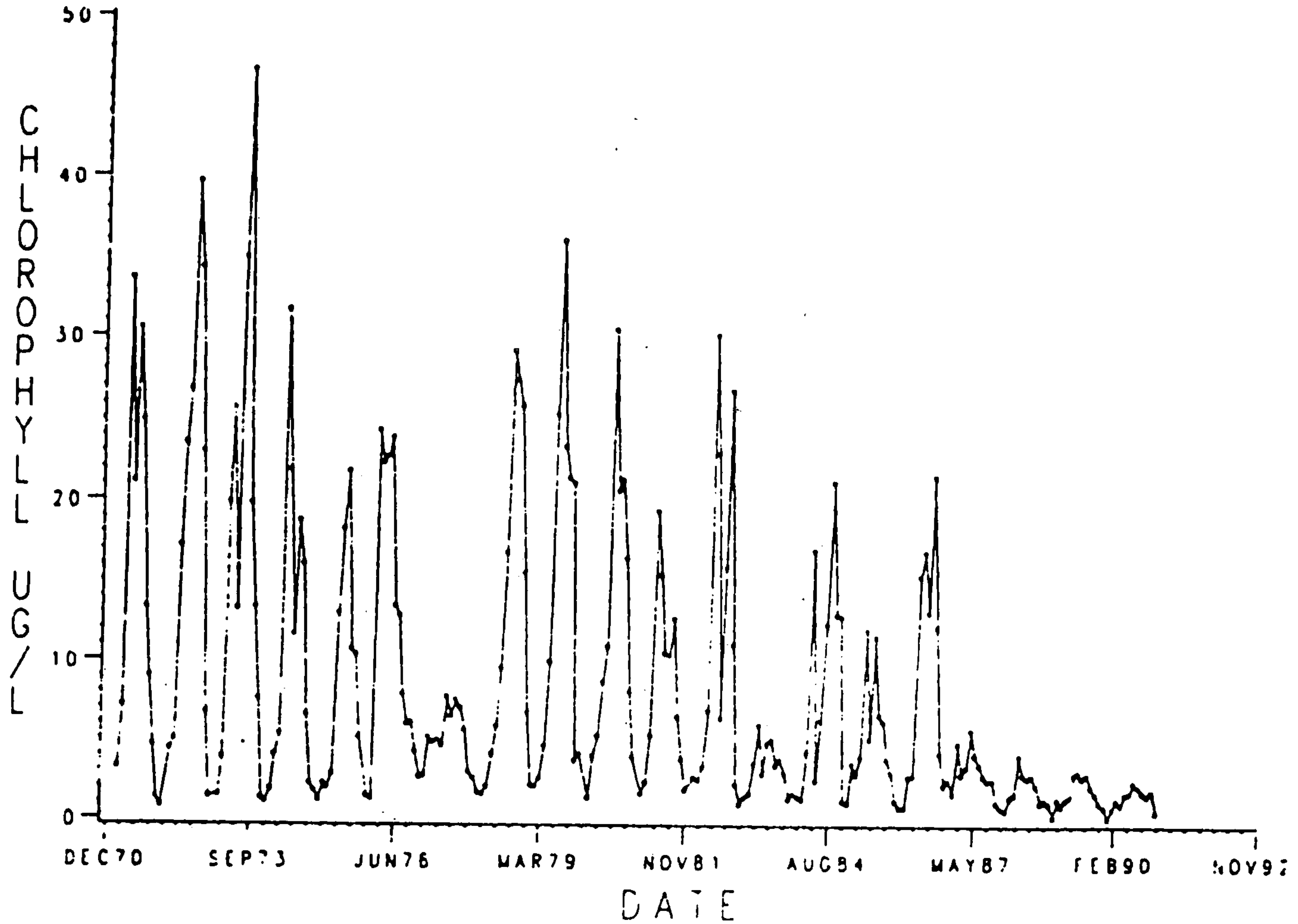


Figure 4. Chlorophyll Concentration in Suisun Bay, 1971-1990
(Figure from DWR report to State Water Resources Control Board)

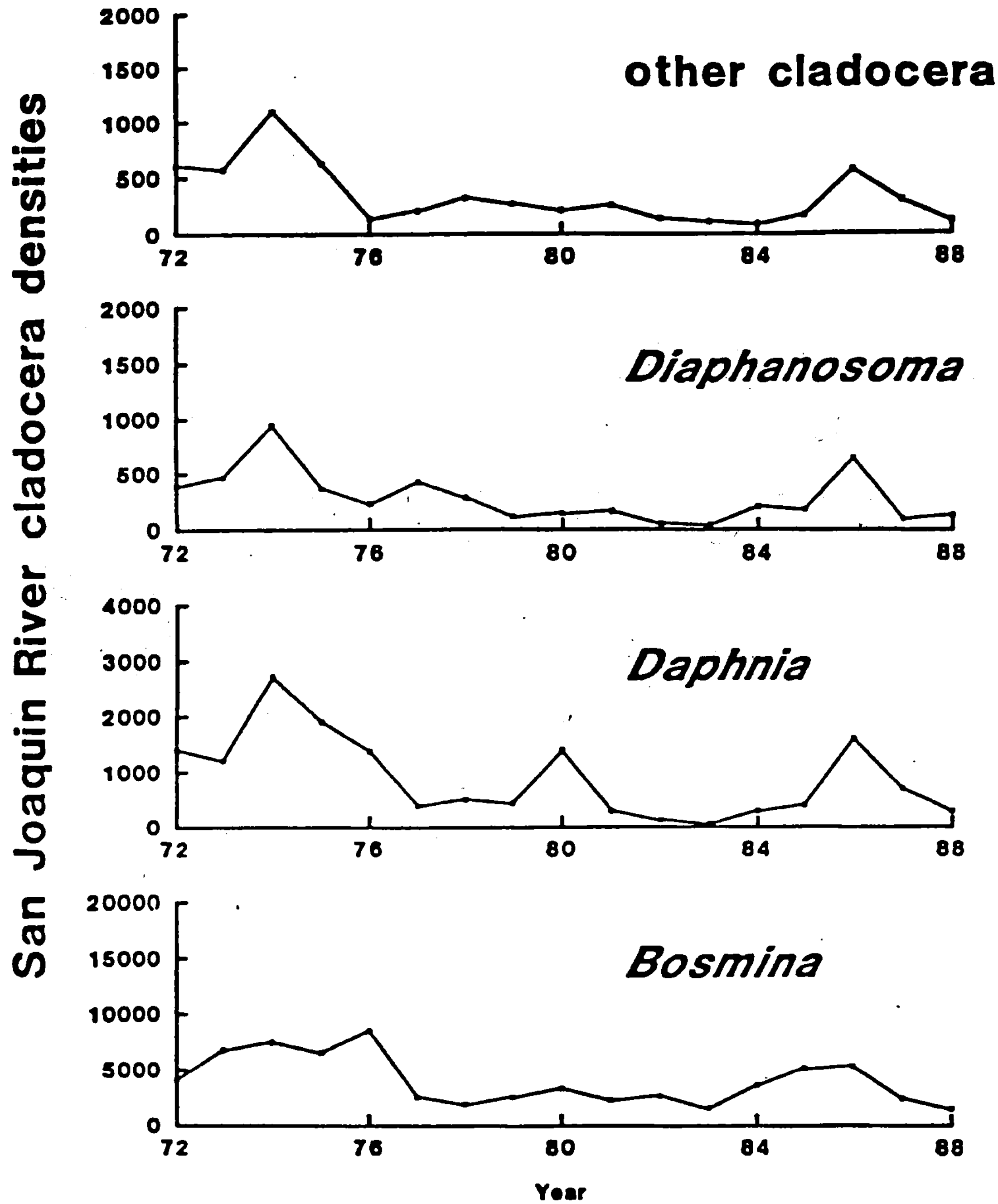


Figure 6 Mean densities of the three most abundant species of cladocerans in the San Joaquin River (no./ per cubic meter).
(Figure from Herbold et al, 1992)

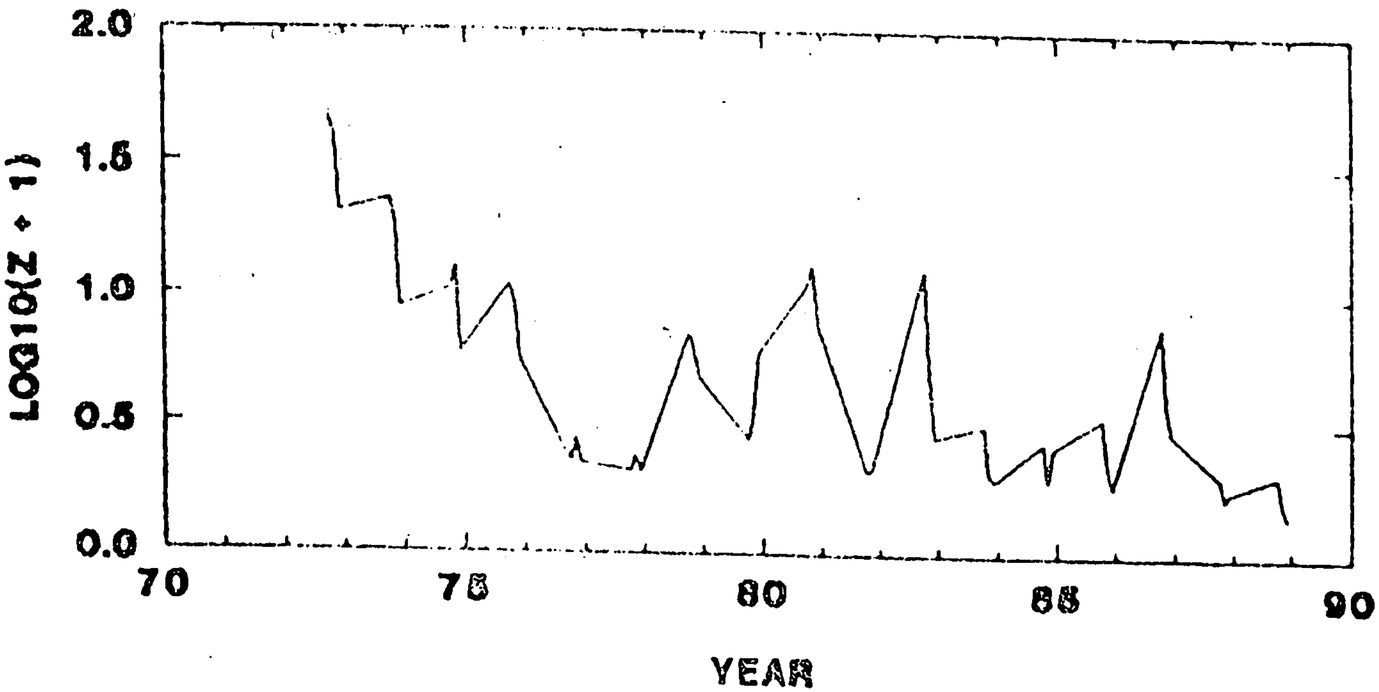
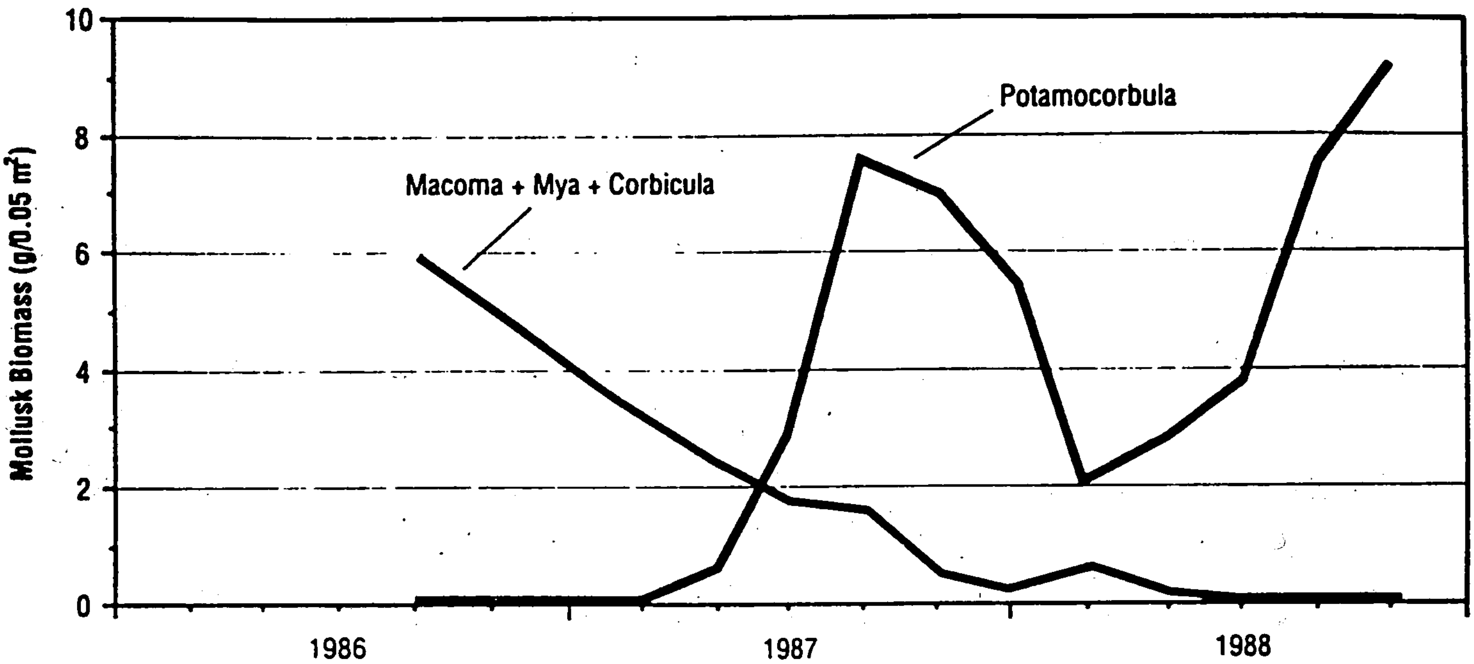


Figure 8. Neomysis Abundance (Figure from Obrebski et al, 1992)

Figure 9. (From Monroe and Kelly, 1992)

Biomass of Potamocorbula *and Other Mollusks in Grizzly Bay, 1986-1988*



Population estimates of adult white catfish have not been made since a 1978-1980 study. However, data from three independent sources (sampling during striped bass surveys, fall surveys and salvage at the State and Federal fish screens) indicate that abundance of white catfish has declined severely since the mid-1970's (Figure 10). Available evidence indicates catfish reproduction has been concentrated in the south and east Delta, and that this source of recruitment of new fish to the overall catfish population has greatly diminished since the early 1970's.

2. Delta Smelt

The delta smelt is a small, slender-bodied fish, with a typical adult size of 2-3 inches, although some may reach lengths of up to 5 inches. They are fast growing, short-lived, and feed entirely upon zooplankton. Food studies indicate that the diet of smelt larvae (just hatched fish) consists of small copepods and, as they grow, larger copepods. Delta smelt spawn in freshwater or in slightly brackish water.

Delta smelt are only found in this Estuary, and have been collected as far up the Sacramento River as the mouth of the American River, and at Mossdale on the San Joaquin River. Their normal downstream limit appears to be western Suisun Bay, although during episodes of high Delta outflow they can be washed into San Pablo and San Francisco Bays.

Various types of 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, with particularly low levels recorded since 1983 (Figure 11).

Notably, the abundance index based on fall sampling, which provides the best measure of population trends, has declined from values between 1,000 to 1,500 between 1970 and 1974 to values in the 300-400 range in the late 1980's and early 1990's. The other indices used to measure abundance remained consistently low during this entire period as well.

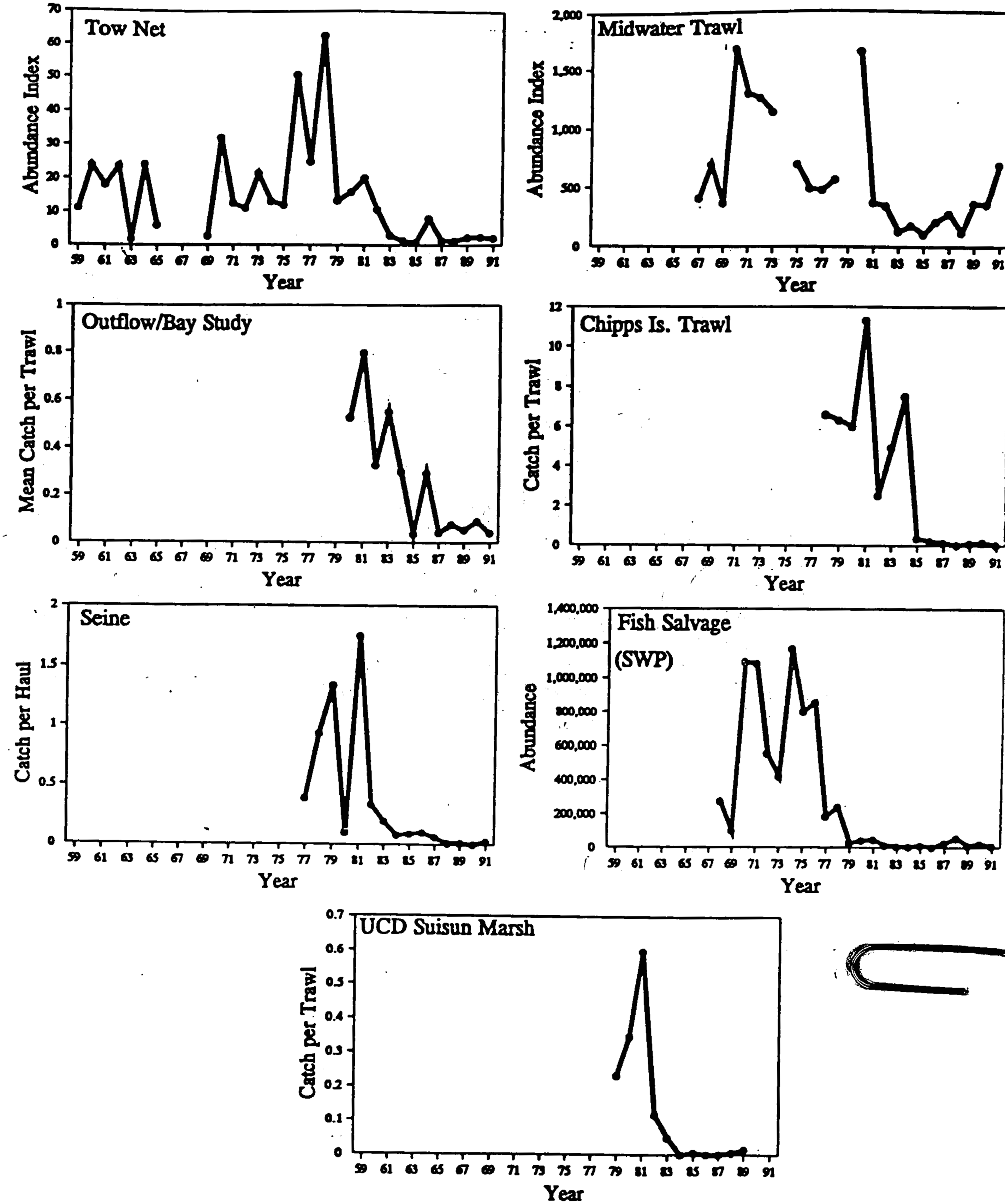


Figure 11. Trends in delta smelt as indexed by seven independent surveys (updated from Stevens, et.al., 1990, Figure 4).

The most accurate index of longfin smelt abundance in the Estuary comes from a fall sampling program which began in 1967. Since 1967, the longfin smelt abundance index has fluctuated widely from year to year (Figure 12). Since 1982, when the index was 62,929, values have dropped precipitously until the 1992 level of approximately 73 was reached. A characteristic of the fluctuations in longfin smelt abundance is that they are closely correlated with freshwater flows between February and May. No similar relationship exists for Delta smelt.

The reduction in longfin smelt abundance has prompted parties to petition the U.S.F.W.S. to list this fish under the Endangered Species Act as well.

4. Sacramento Splittail

The splittail is a large minnow endemic to the Estuary. They are relatively long lived fish, reaching over 14 inches in length by their fifth year. Although considered a freshwater species, adults and sub-adults have an unusually high salt tolerance.

The loss of spawning and nursery habitat as a result of reclamation activities has significantly impacted the splittail population. Historically, the splittail could be found in low elevation waters of the Central Valley, from Redding to Fresno. Currently, their abundance and distribution is much more limited. They are now only found in the lower reaches of the Sacramento and San Joaquin Rivers, the Delta, Suisun and Napa marshes, and tributaries of north San Pablo Bay.

Abundance indices of splittail have varied over the years. They were relatively high in the late 1960's and then declined severely until 1977. From 1977, abundances increased until an all time high was reached in 1983. After that period the indices again decreased to 3.6 in 1992. (Table 1)

Table 1. Splittail Indices of Abundances for 1967 to 1992 Based on Midwater Trawl Catches.

Year	Index	Year	Index	Year	Index
1967	66.3	1977	0.0	1987	28.6
1968	18.1	1978	37.2	1988	9.0
1969	19.4	1979		1989	4.1
1970	25.4	1980	17.0	1990	9.0
1971	17.4	1981	18.3	1991	17.9
1972	12.5	1982	118.6	1992	3.6
1973	4.4	1983	153.2		
1974		1984	16.2		
1975	3.6	1985	14.9		
1976	0.7	1986	57.7		

Table 2. Abundance Estimates of White and Green Sturgeon Greater than 102 cm in Length.

Year	White	White:Green	Green
1954	11,200	56.5	198
1967	114,700	62.0	1,850
1968	40,000	38.6	1,036
1974	20,700	101.9	203
1979	74,500	52.6	1,416
1984	128,300	106.3	1,207
1985	96,200	127.3	756
1987	84,000	163.7	513
1990	26,800	49.7	539

TABLE 3 - Annual Spawning Biomass of Pacific Herring from the Period 1974-1990

YEAR	Metric Tons
1974-75	27
1975-76	25
1976-77	22
1977-78	4
1978-79	33
1979-80	46
1980-81	65
1981-82	99
1982-83	59
1983-84	41
1984-85	47
1985-86	49
1986-87	57
1987-88	69
1988-89	66
1989-90	71

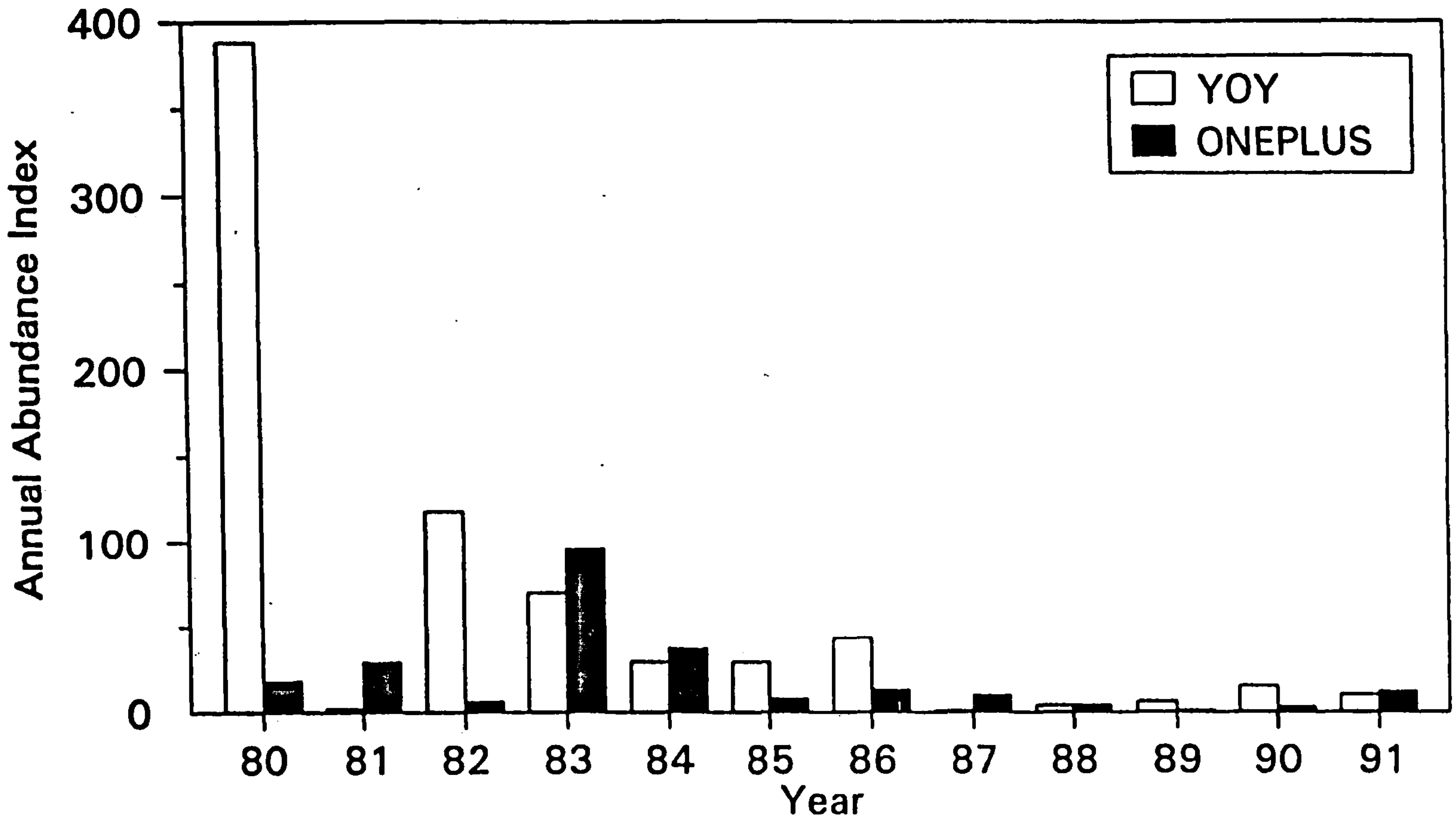


Figure 14. CDFG Bay Study starry flounder young of the year (YOY) and one year old (ONEPLUS) annual indices based upon otter trawl sampling from May through October and February through October for YOY and ONEPLUS fish, respectively. Data for 1989 represent sampling through August only for each age group. Data for 1991 are preliminary.

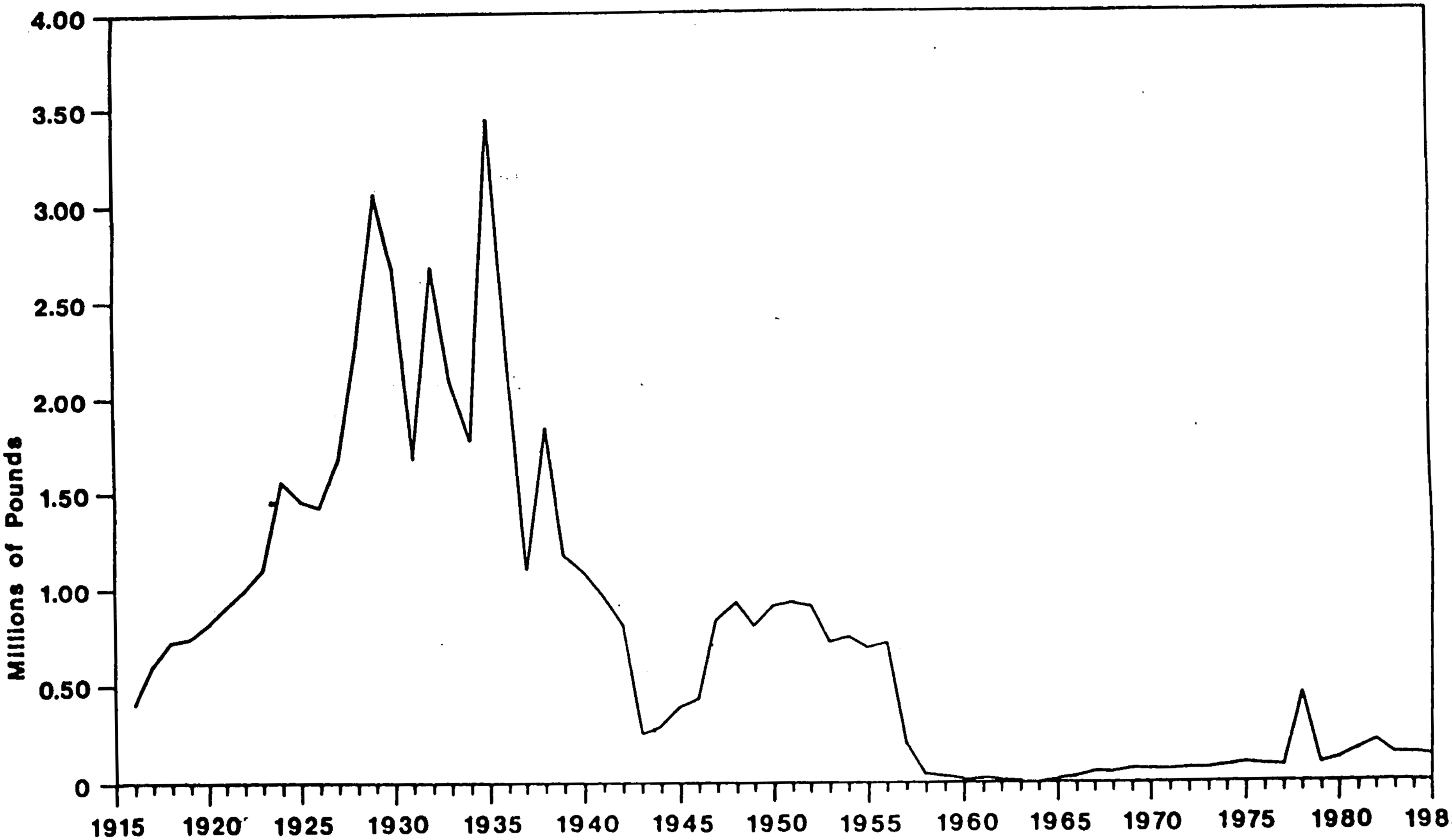


Figure 15. Commercial catch of bay shrimp in San Francisco Bay, 1916-1985.

In the early 1980's Crangon franciscorum dominated the catches, while in the late 80's and early 90's C. nigricauda, C. nigromaculata and Heptocarpus dominated. This change was caused by the differences in salinity preferences of the shrimp species and a series of dry, low outflow years. C. franciscorum is strongly related to the amount of freshwater outflow in the spring, while the other species do better in drier, low flow years.

Further information exists on the total biomass (weight of shrimp available for food sources in the ecosystem) during the 1980-1991 period. This information shows that the shrimp biomass during the 1988-1990 period was 20 percent less than the average biomass in 1981 and 1985 and 55 percent less than the average index for the remaining years. This is because most of the increase in numerical abundance in recent years was composed of smaller, immature C. nigricauda and C. nigromaculata rather than larger individuals.

9. Striped Bass

Striped bass are non-indigenous to the Bay-Delta. One hundred and thirty two small bass were introduced in 1879. Soon thereafter, striped bass were being caught in such large numbers that by 1889 they were being sold in San Francisco markets. In another 10 years the commercial net catch, alone, was averaging well over a million pounds annually. In 1935, however, all commercial fishing for striped bass was stopped in order to enhance the sport fishery.

Striped bass begin spawning in the spring when water temperatures reaches about 60 F. Most spawning occurs between 61 and 69 F and the spawning period usually extends from April to mid-June. "Stripers" spawn in freshwater where there is moderate to swift current.

The section of the San Joaquin River between Antioch Bridge and the mouth of Middle River, and two other channels in the same area, are important spawning grounds. The Sacramento River, between Sacramento and Colusa, is another important spawning area.

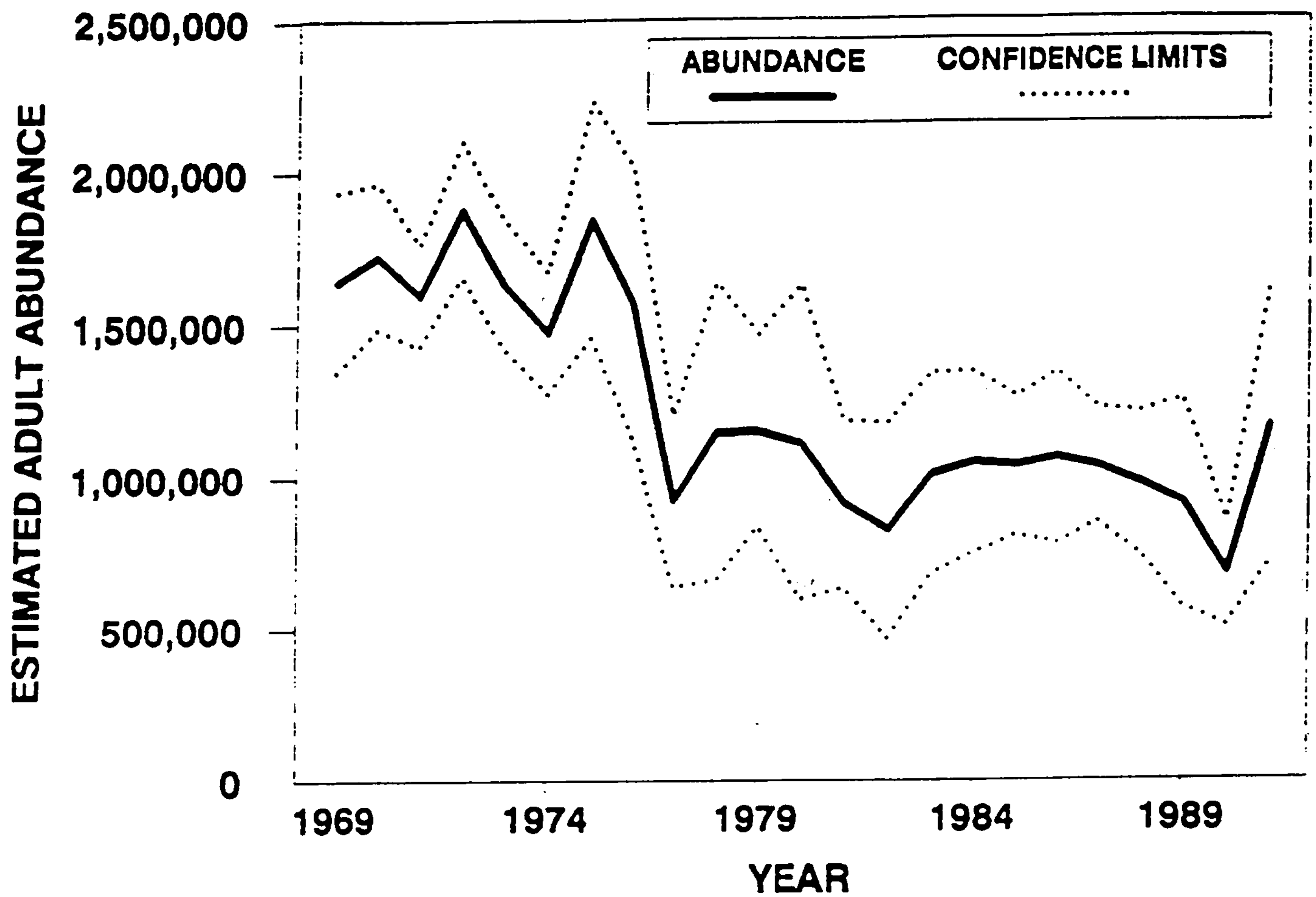


Figure 17. Trend in mark-recapture estimates of adult striped bass abundance in the Sacramento-San Joaquin Estuary, 1969-1991.

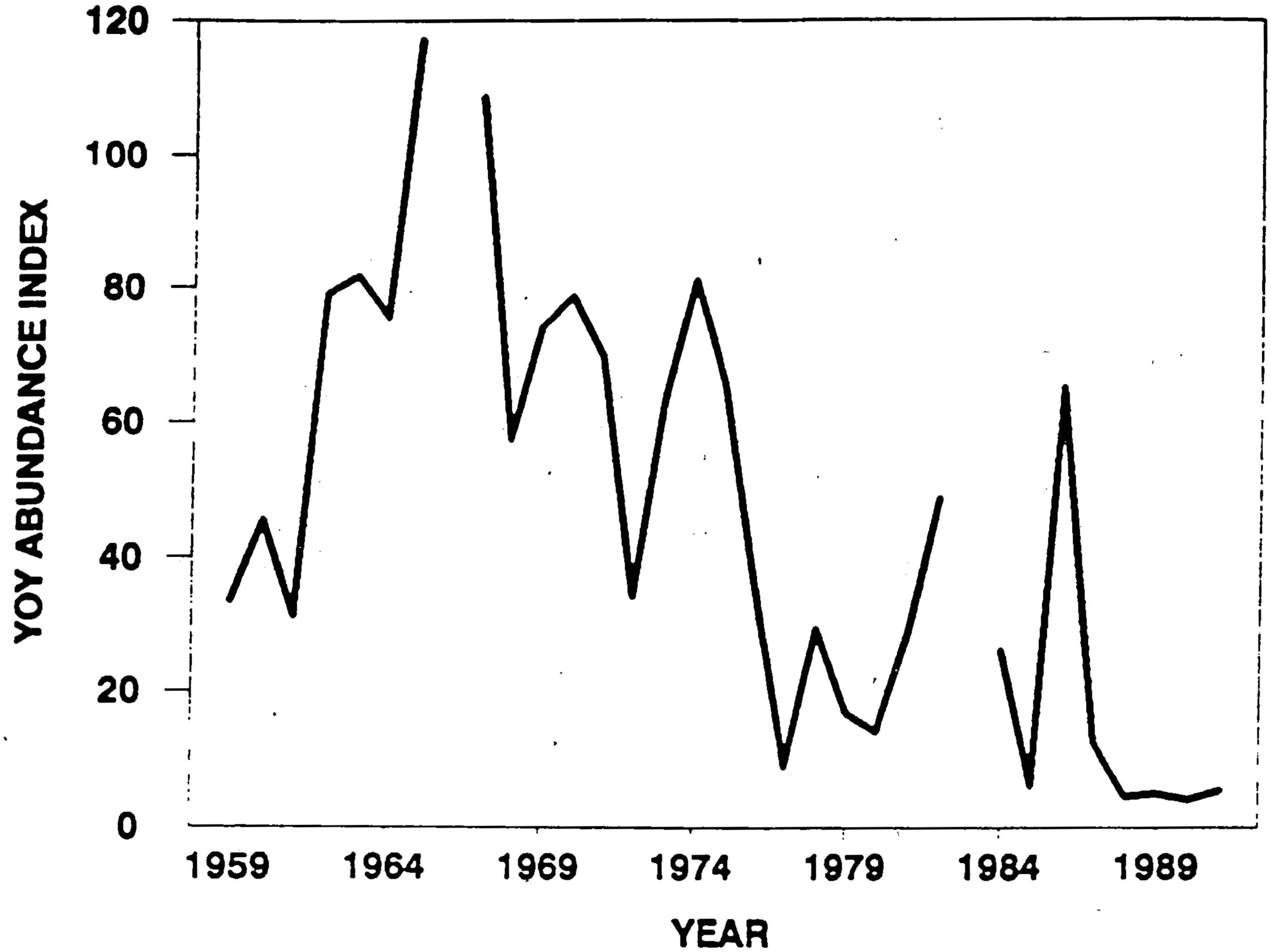


Figure 18. Trend in young striped bass abundance in the Sacramento-San Joaquin Estuary when mean length is 38 mm. Abundance index is based on catches of young bass during an annual tow net survey from 1959-1991.

DFG, the USFWS, the U. S. Bureau of Reclamation (USBR) have all, over the years, counted salmon at various times and places in these basins. Some counts were made as early as 1937. Since 1953, DFG has made annual estimates of spawning fish on each of the major river systems. The counts include both young adult and adult fish from both natural and hatchery production. They are usually referred to as estimates of spawning "escapement" since they describe the numbers of chinook that have escaped the ocean fishery and returned to spawn.

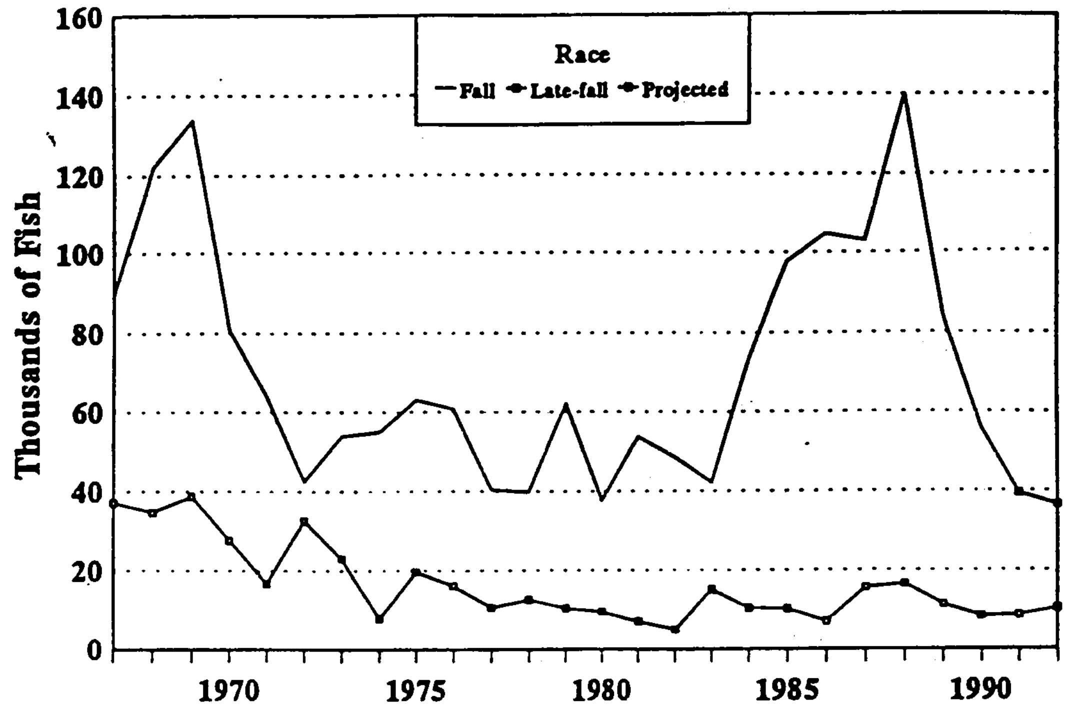
Spawning runs of chinook salmon from all areas, since the regular counts started in 1953, have fluctuated greatly (Figure 19). In the last 20 years, the total runs have been averaging about 250,000 to 300,000 fish.

The remainder of this section will discuss population trends of the various salmon runs in the Sacramento and San Joaquin River Basins.

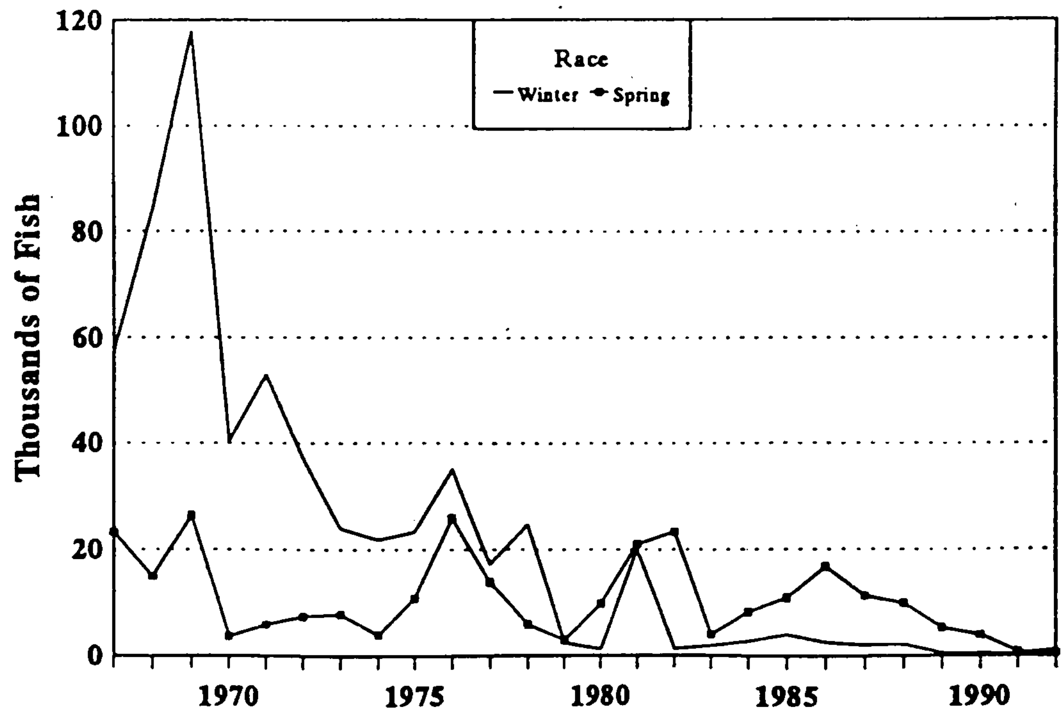
Sacramento River Basin:

An estimated 116,900 adult fall-run chinook salmon returned to the Sacramento River basin in 1991, about equal to the 1990 estimate of 107,300 fish, but 36 percent below the 10-year average of 171,500. 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 the spawning escapement estimates were 230,800 and 235,000 adults, respectively. Fewer than 40,000 fall-run fish were projected to make the run in 1992 (84 percent of 1991 and 45 percent of the 1982-91 average) (Figure 20). In 1992, DFG estimated that about 10,400 late fall-run salmon were present in the upper Sacramento River. The 1991 estimate for late fall-run was 8,600 (Figure 20).

FIGURE 20 RED BLUFF DIVERSION DAM FISH COUNTS
1967 through 1992
Fall and Late-fall Races



RED BLUFF DIVERSION DAM FISH COUNTS
1967 through 1992
Winter-run and Spring-run Races



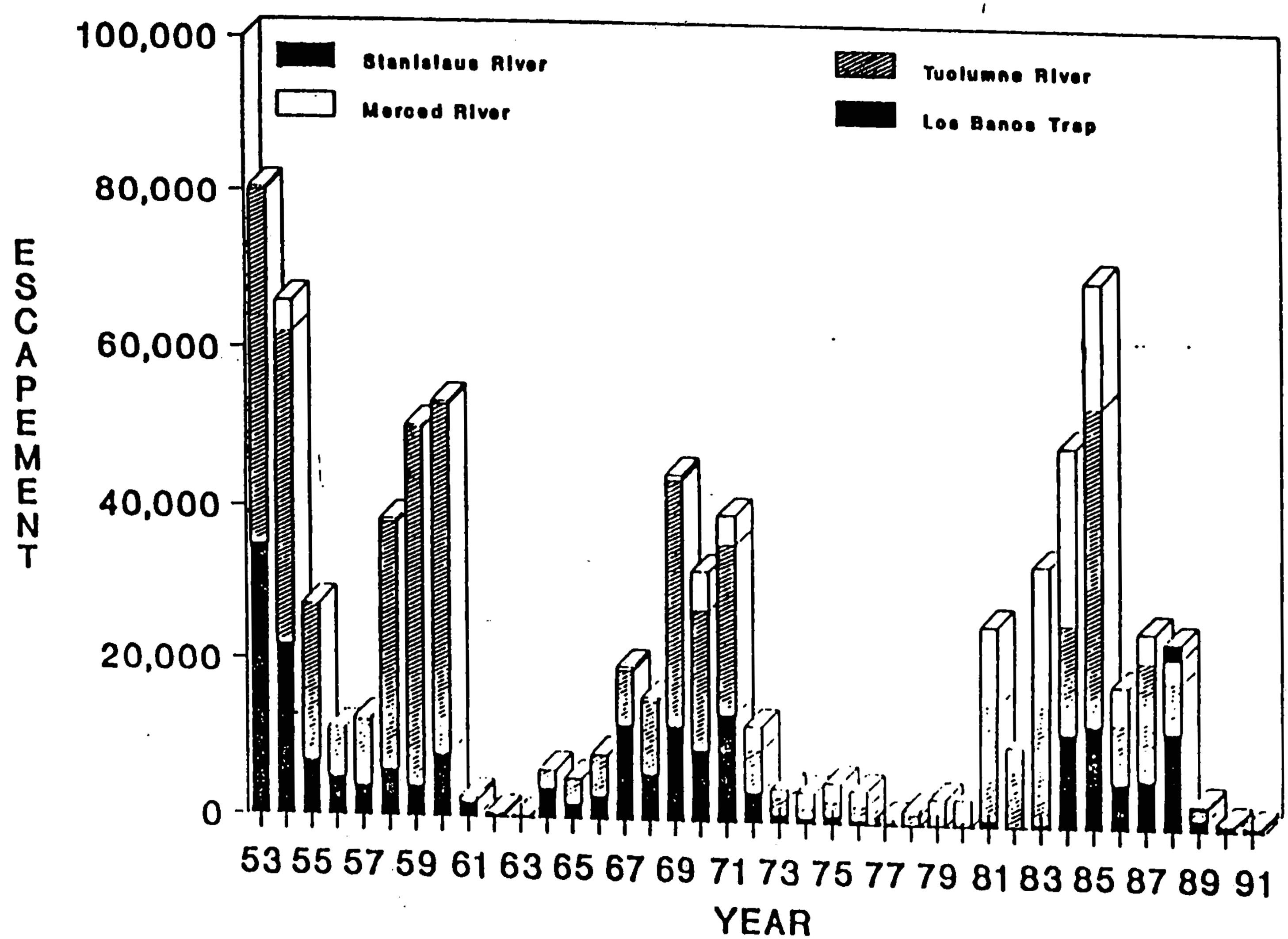


Figure 21. Recent Fall-Run Chinook Salmon Escapement in the San Joaquin Drainage

FACTORS CONTROLLING THE ABUNDANCE OF AQUATIC RESOURCES IN THE SAN FRANCISCO BAY/ SACRAMENTO-SAN JOAQUIN DELTA ESTUARY

FACTORS CONTROLLING THE ABUNDANCE OF AQUATIC RESOURCES IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

BY

Pete Chadwick
California Department of Fish and Game

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INTRODUCTION

The purpose of this paper is to summarize current understanding of the factors controlling the abundance of fishery resources and the food chain that supports them in the Sacramento-San Joaquin Estuary.

This is only one element in a series which needs to be considered by the Bay-Delta Oversight Council (BDOC) in formulating a plan which considers fishery resources adequately. To place it in perspective, a logical progression of planning elements is:

1. Define the status of aquatic resources--a report on this subject accompanies this report.

2. Establish objectives for resource management. An early responsibility of BDOC is to recommend such objectives.

3. Identify factors controlling resources. This is the purpose of this report.

4. Use the knowledge of controlling factors to select and evaluate alternatives to accomplish the objectives identified during Step 2. This and the next step will be a subsequent assignment of BDOC.

These descriptions of consequences will provide a basis for judging generally how a set of measures will affect a given species, thus providing the initial basis for selecting sets of measures in Element 4. During that evaluation, the overall benefit of all measures included in the alternative would be estimated for each species and the measures would be modified as appropriate to attain objectives.

The comprehensive program initiated by the Governor focuses on water management actions necessary to satisfy various needs. Certain factors controlling fishery resources are related directly to those water management measures and are so identified in this paper. Some of these directly related factors suggest a need for water project operating criteria while others suggest a need for changes in the design of water delivery facilities.

BDOC also needs to consider other controlling factors in its planning process to identify measures desirable to complement water management measures and be confident that some non water management factors will not prevent realization of expected benefits from water management.

This paper makes a case for certain factors related to water projects being the principal factors currently controlling the abundance of specific fisheries. Certainly, those are not the only controlling factors, and the paper goes on to provide a

FACTORS RELATED TO CONSTRUCTION AND OPERATION OF WATER PROJECTS

Delta Inflow

The magnitude of flow coming down the rivers into the Estuary affects biological resources both in the rivers above the Estuary and in the Estuary. The principal identified effects within the Estuary are:

1. Striped bass eggs and larvae drifting down the Sacramento River are more likely to survive if flow rates sufficient to transport larvae to the Delta occur when the larvae are old enough to start eating. Limited evidence of poor survival of these early stages during low flows led the Department of Fish and Game (DFG) to propose a minimum flow of 13,000 cfs at Sacramento during the spring.

2. Various minimum flows for Chinook salmon in the Sacramento River system have been identified to protect salmon in the upstream spawning and rearing areas. While many biologists believe that flows in the Delta portion of the Sacramento River are also important to the survival of outmigrating salmon, a statistical model of salmon survival prepared by the U.S. Fish and Wildlife Service (USFWS) identified water temperature

prevent runs from attaining historic levels. It seems likely that flow improves habitat quality both in and upstream from the Delta, but the relative importance of habitat quality in these two regions has not been quantified. USFWS, NMFS and DFG have advocated minimum flows in the San Joaquin River at Vernalis during the spring outmigration based on evidence that such flows would improve salmon survival in the Delta, but the benefit can not be quantified precisely.

4. The number of young American shad migrating seaward through the Estuary in the fall is strongly and positively related to the magnitude of flow in the previous spring. This likely indicates that increasing flow improves conditions in the rivers and upper Estuary for shad survival in the spring and summer.

5. The best year classes of white sturgeon tend to be produced in years when Sacramento River flows are high in the late winter and spring.

from diversion out of the Sacramento River. Survival of salmon migrating earlier has not been evaluated.

Some upstream salmon migrants have always used the lower San Joaquin River-Mokelumne River-Georgiana Slough route on their way to the Sacramento system spawning grounds, and there is some indication that the proportion doing so increases in proportion to the amount of Sacramento River water following that route. This is believed to cause no harm so long as the channels are not blocked, including the present normal operating mode for closing the Delta Cross Channel.

Young of several other species, including striped bass, American shad, and Delta smelt, are also diverted from the Sacramento River during their downstream migration and are likely adversely affected. However, effects on their survival have never been measured as they have for salmon. One indication of such effects is the annual occurrence of hundreds of thousands to several million American shad, most of which come from the Sacramento system, in SWP/CVP salvage operations at fish screens in the South Delta.

The effect of diversion through Three Mile Slough has not been directly evaluated for fish; however, studies by the Contra Costa Water District suggest Three Mile Slough is a major transport route to the interior delta for ocean salts that enter to ascertain net flows. In such cases estimates of net flow are derived from mathematical models.

The potential significance of reverse flow is that it tends to move fish and their food supply towards the export pumps rather than towards the ocean. One would expect this effect to be most significant where net flows are relatively large in relation to tidal flow, such as in Old and Middle rivers near the pumps. In fact it is questionable whether effects of modest reverse flows are significantly more detrimental than small positive flows to fish in areas such as the lower San Joaquin River, where net flows are so small in relation to tidal flow that net flows can't be measured by the best scientific instruments. While that is a legitimate question, some animals have characteristics which may override such logic. For example, opossum shrimp, a major animal in the food chain, move farther off the bottom during flood tides than during ebb tides. Since velocities near the bottom are less than those at mid-depth, the shrimp's migration pattern subjects them to being transported by flow more on flood tide than ebb tide. The sensory mechanism they use to do this is unknown, but it seems to be an obvious adaptive strategy to maintain their location in an estuary with a predominance of downstream flow. It would make them more vulnerable to upstream transport than suggested by the relative magnitude of net flows and tidal flows. We do not know whether any other species, including fish, behave similarly.

Salmon smolts must use factors other than net velocity to help guide them through the Estuary, as their migration rate is considerably faster than the net velocity. Nevertheless, reverse flows may impede migration and have been investigated as a cause of mortality. Some quantitative support for adverse effects is provided from outmigrant studies in the San Joaquin River. In two experiments in 1989 and 1990 survival of salmon was 9 and 75 percent greater when flows were positive than when negative. Those results, in combination with releases made in 1991, produced a positive relationship between net flow and survival. There is also a positive correlation between survival of salmon released at Ryde on the Sacramento River and reverse flow on the lower San Joaquin River. That correlation suggests that reverse flow adversely affects salmon migrations through Three Mile Slough. Neither study is definitive due to variability in results and the small number of observations.

Losses in Water Project Diversions

Most evaluations of the factors affecting salmon survival in the Delta pertain to smolts migrating in the spring. Particularly in wet years a portion of both the fall- and winter-run enters the Delta as fry and rear there until they smolt and migrate to the ocean. Marked hatchery reared fry released in the Delta generally survive better than those released in the Sacramento River upstream from the Delta. That is the reverse of release them into the western Delta. Losses vary markedly for different species and sizes of fish, operating conditions and water temperatures.

A particularly significant issue concerns mortality in Clifton Court Forebay at the intake to Banks Pumping Plant. For example, approximately half to 95% of young hatchery-reared salmon released at the intake to the Forebay disappear before reaching the fish screens. The principal cause of this disappearance is probably predation by striped bass that has been enhanced by the Forebay design and operation. Studies are underway to define the problem better and to reduce losses. A major program is being planned for 1994 to remove striped bass from the Forebay and return them to the Estuary.

While certain improvements in the present screening system can and are being made, diversions from the south Delta present two inevitable problems. First, no flow can bypass the intake. Thus all fish must be captured and transported to another location for release. Substantial losses are inevitable in the process, especially for species or life stages which are easily stressed.

The more fundamental problem is that water is being withdrawn from a large "pool", albeit one which is sloshing back and forth with the tide, which is a major nursery for some fish considerable uncertainty exists as to minimum outflow needs even in the absence of diversions from the present location.

The remainder of this section will describe effects of losses in the SWP\CVP diversions for a few species.

Striped bass from egg stage through the first year of life and beyond are lost in diversions. Historical annual loss estimates of bass longer than 20 mm for the combined SWP\CVP diversions range from less than 1 million in two very wet years when exports were low and most bass were farther downstream to more than 113 million in 1974 when striped bass were more abundant than now and average combined SWP\CVP diversions exceeded 9,800 cfs for June through August. Estimated annual losses of smaller bass and eggs have ranged up to about 793 million since they were first measured in 1985. To provide some perspective on potential impacts on the bass population, DFG biologists estimated that losses of bass entrained by the SWP\CVP reduced the population before the 20 mm stage by more than 70% in three dry years and 32 percent in a wet year. DFG analyses also indicate that losses in SWP\CVP diversions throughout the first year of life are largely responsible for the adult population declining from about 1.7 million fish in 1970 to only about 700,000 fish in 1991. While there is not a consensus on the specifics of the DFG analyses among biologists, no biologist testifying during the recent Bay-Delta hearings before the State from the Sacramento system as few shad spawn in the San Joaquin. Also, the percentage lost at the screens is greater, because shad are difficult to handle. Observations indicate that about 70 percent of the shad die in the handling process subsequent to their being "saved" by the screens while comparable losses of salmon are on the order of 5 percent.

Secondly, Delta smelt is another species which is vulnerable to being drawn to the export pumps. Typically, the largest numbers are captured in May, June, and July during and shortly after spawning. In some years, the pattern of Delta smelt occurrence deviates from this "norm". For example, during 1977 virtually no pumping occurred from May through November due to a drought. Pumping commenced in December when large storms broke the drought and the numbers of smelt captured increased rapidly. In fact, in January 1978, 134,000 Delta smelt were captured at the SWP screens. That almost equaled the number captured in all of 1977 and exceeds the annual total for all subsequent years. In effect 1977 was an unintended experiment in curtailing diversions much more than has ever been considered practical from a regulatory standpoint. It appeared to increase survival of smelt and several other fishes in the Delta temporarily, only to destroy the fish when pumping resumed. It provides dramatic evidence of the virtual impossibility of protecting those resident fish species which are easily transported by flow by

While this temperature need is included in this section describing factors of direct concern to BDOC, it might be more appropriate to include it in the next section on indirect concerns. Water operations definitely exert a major control over water temperature in upstream areas, but the Delta is so far from reservoirs that water temperature has largely come into equilibrium with air temperature. Analyses indicate that it is not feasible to influence water temperature in the Delta by manipulating reservoir releases in most, if not all, cases.

Delta Outflow

Outflow vs. Salinity Controversy

Delta outflow is the amount of water flowing past Chipps Island, at the western edge of the Delta, into San Francisco Bay. The magnitude of Delta outflow largely controls the intrusion of salt water from the ocean into the Estuary. Hence, Delta outflow and salinity intrusion are highly correlated.

Historically, the Department of Fish and Game and the U.S. Fish and Wildlife Service have described fishery protection measures for the western Estuary in terms of Delta outflow. Recently, a group of scientists convened by the Environmental Protection Agency proposed salinity standards be used in conjunction with and in preference to flow standards. Arguments

Physics of Outflow

Freshwater flowing out of the Estuary tends to override salt water transported into the Estuary from the ocean by tidal action. This phenomenon results in a surface current of fresh water flowing towards the ocean, and a bottom salty current flowing inland on a tidally averaged basis. In many estuaries this results in a sharp vertical gradient between fresh and salt water. In the Sacramento-San Joaquin Estuary, however, tidal mixing forces are relatively large so the vertical gradient is relatively small except during very high outflows. In fact, the gradient almost disappears at low flow. It is still great enough, however, to have considerable ecological significance.

One consequence is that near the upper end of the salinity gradient suspended particles carried downstream by freshwater settle towards the bottom and get transported upstream by the flow along the bottom. This phenomenon affects both nonliving particles and small living organisms, such as phytoplankton, zooplankton and fish larvae. The net effect is an accumulation of suspended particles near the upper end of the salinity gradient, and hence the name entrapment zone for that segment of estuaries.

The entrapment zone tends to be an important fish nursery area in all estuaries due to the accumulation of biological upstream. The strengthening of the bottom current by increasing outflow is probably responsible for starry flounder and a species of bay shrimp (Crangon franciscorum) being much more abundant when flows are high than when they are low.

The second process is the downstream transport of young by freshwater flow. The prime example is longfin smelt. They spawn in the Delta and their young are transported downstream to nursery areas mostly in Suisun and San Pablo bays. High flows increase their survival probably by a combination of spreading them over a larger area of the estuary and increasing their food supply as discussed in the previous section. No similar relationship has been identified for Delta smelt.

Longfin smelt, bay shrimp and starry flounder spawn in the winter and early spring and their abundance is positively related to outflow during the same period. In each case, the relationship exhibits substantial variability so benefits would be obvious only for fairly large incremental differences in outflow.

Commercial and angler records, however, indicate long-term declines in shrimp and starry flounder abundance. Also, during the recent drought longfin smelt have become so scarce that they have been proposed for listing as an endangered species and no young flounder were captured during DFG's 1992 survey. Thus it

Chinook salmon -

Three years of sampling for salmon at the Golden Gate, indicates salmon smolts migrate through the lower estuary faster than net flow would transport them. In those three years, their survival rate in that reach was not related to the magnitude of Delta outflow.

SALINITY

The only fishery regulatory standard now in place which reflects a need clearly dependent on salinity is striped bass spawning objective in the San Joaquin River. Bass spawn in the freshest reach of the river. Typically, that reach is between the upper limit of ocean derived salinity near Antioch and increase salinities near Stockton resulting from land derived salts entering the Delta from the San Joaquin River. This reach of very freshwater is created by Sacramento River water flowing into the central Delta through the connecting channels as described earlier.

Bass generally spawn where salinity, expressed as electrical conductivity (EC), is less than 300 microsiemens and do not continue mitigating up the San Joaquin River past ECs greater than 550.

and decreases in the number of species of fish and fish abundance.

An exception was the gradual increase in the abundance of a more salt tolerant shrimp, Crangon nigricauda, in San Francisco Bay during the drought. While it became more abundant than the normally dominant bay shrimp, the total biomass of shrimp declined because C. nigricauda is smaller than bay shrimp.

Another interesting aspect of the change is C. nigricauda doesn't invade the Bay in large numbers in single drought years. Rather it seems to respond over several years to stable saline conditions. Thus, this species apparently is not well adapted to the dramatic salinity fluctuations which are typical of estuaries.

FACTORS UNRELATED TO WATER PROJECTS

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

Estuary. The perch is a "primitive" member of the bass family and probably could not compete with the several members of the family introduced from the East.

Introductions Since 1950

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 exchange of ballast water by ships.

Among fishes, threadfin shad, introduced deliberately as a forage fish in the early 1960s; inland silversides, introduced illegally apparently in an attempt to control gnats in Clear Lake; 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 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 and a newly introduced amphipod, *Gammarus daiberi*, has become a major food of young striped bass.

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.

The trends in the abundance of various fish species have also 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 sufficiently for the introduced species to be the likely cause of observed declines.

A recent question has been raised about that conclusion in regard to Delta smelt and inland silversides. It has recently been hypothesized that the measures of silversides abundance are poor, because little sampling is done along the shoreline where most occur. Hence predation and competition with silversides may have been more significant for Delta smelt than previously recognized.

The best summary of the effects of introduced species is that introductions have caused major changes in fish fauna in the estuary, particularly in fresh waters. The most obvious effects

As discussed in the previous section on introductions, food supply probably does influence the survival of bass, but the available evidence does not provide any clear evidence that food limitations have contributed significantly to the decline in bass abundance.

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 involving toxics 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 regulation of pesticides in 1991 and 1992 indicates that the correlation probably does not reflect a cause and effect relationship.

For apparently healthy adult striped bass, studies initiated by NMFS and followed up on by DFG found body burdens of various hydrocarbons and heavy metals, including mercury concentrations 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 were found during the eleven years.

Another avenue of exploration concerns a fish die off which has occurred each spring or 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

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 twice as old as bass. In fact, no sturgeon fishing was permitted in California from 1917 until 1954 because sturgeon had become so scarce, probably due to overharvesting by a commercial fishery.

In 1954 a tightly regulated sportfishery was opened--1 fish per day bag limit, with minimum sizes ranging between 40 and 50 inches at various times since 1954.

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 more restrictive size limits (both increased minimum size and a maximum size). Subsequently, harvests have fallen to less than 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 this 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 rear 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 in both the 1959-61 and 1976-77 droughts. Within 2 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.

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 of light concurrent declines in fish species which are not subject to either commercially 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 questions about illegal harvest concern 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 less certain for striped bass. They involve the illegal harvest of both legal and sublegal-sized

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 could account for about 25% of the decline in adult abundance observed since 1970.

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 most unlikely that all of it would be. For example, sea lions eat adult striped bass. Since they have increased their numbers and range with the Estuary, sea lion predation likely has contributed to the increased mortality.

Another perspective on total mortality is provided by experience on the East Coast. Some bass stocks there, including the largest stock which inhabits Chesapeake Bay, were being

Contrasting the estimated illegal catch with the estimated ±400,000 3-year old bass in the population now, it is very likely that the illegal take significantly 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. While actions to reduce take are clearly warranted, 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, it seems unlikely that the harvest of sublegal bass is the dominant factor causing the decline in adult bass abundance since 1970.

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.

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 the purpose of this paper is whether modest rehabilitation of tidal or seasonal wetlands offers some potential. It likely is responsible for the wetland created when the tip of Mandeville Island was severed during construction of the Stockton Deep Water Channel.)

In-Delta Diversions

Diversions onto Delta agricultural lands are made through many small unscreened intakes. During the peak of the irrigation season, the net amount of water diverted approximately equals the amount diverted through the Tracy Pumping Plant of the CVP.

Limited evaluations prior to 1970 documented losses of both salmon and striped bass by these diversions but were insufficient to estimate the overall magnitude of such losses. Losses undoubtedly vary due to the uneven geographic and seasonal distribution of fish, differences in intake design and location and other factors.

A more extensive evaluation of losses and potential screening methods is underway.

The largest other loss at diversions occurs at Pacific Gas and Electric Company's Contra Costa and Pittsburg Powerplants. The principal loss there is eggs and larvae of striped bass entrained in the cooling water for the plants structural and operational changes made in recent years pursuant to permits

SUMMARY

A host of factors must be considered in formulating a fishery restoration plan for the Sacramento-San Joaquin Estuary. Enough is known to make sound judgments about the potential value of various actions, but not enough is known to design definitive restoration plans for the best known species, much less for the whole ecosystem.

Dealing with the effects of water development should be the cornerstone of any restoration plan. This involves providing adequate flows or salinities for various fishery needs, providing better fish screens and making some structural changes in the water distribution system to deal with adverse effects associated with the nature and location of the major water diversions.

Of the nonwater project related factors, control of toxicants and illegal harvest probably offer the greatest potential for assisting restoration. Prevention of further introductions of fish and invertebrates is important to avoiding additional, potentially harmful changes.

BIOLOGICAL RESOURCES OF THE

SAN FRANCISCO BAY/

SACRAMENTO-SAN JOAQUIN

DELTA ESTUARY

AQUATIC RESOURCES

PERSPECTIVES OF STATE AND FEDERAL AGENCIES

STATE OF CALIFORNIA - Environmental Protection Agency PETE WILSON, Governor

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20 August 1993

Mr. Steve Yaeger
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Dear Sir,

Thank-you for allowing me to review the two draft briefing papers on Delta biological resources. All my comments pertain to the paper written by Mr. Peter Chadwick entitled "Factors controlling the abundance of aquatic resources in the Sacramento-San Joaquin Estuary".

I have four comments. First, the factors which control the abundance of aquatic resources in the Estuary are controversial and not well understood. They are a topic about which knowledgeable biologists can and do disagree. It is surprising, therefore, to encounter in the text in place of literature citations, statements like "...most biologists believe..." or "...while no consensus exists as to the model's validity, most, if not all, biologists agree that...". The paper would be much stronger if all statements were backed by literature references.

Second, Mr Chadwick is right that hundreds of millions of dollars have been spent on upgrading Valley sewage treatment plants. However, this does not necessarily mean that water quality for aquatic organisms in the Basin has substantially improved as a result of the expenditures. Only 10 to 15 percent of Valley surface water is derived from municipal/industrial discharge. The remaining 85-90 percent comes from non-point sources--agriculture, mining, and urban runoff. Non-point source regulation has proved difficult and it is the consensus of Regional Board staff that the non-point source programs have not been as successful as the point source ones.

Third, I agree with Mr. Chadwick that the diversion and export of water has been detrimental to the aquatic resources in the Estuary. However, I do not believe there is a clear understanding of how much of the decrease in the population level of any species is attributable to flow and how much can be explained by other factors. Certainly, the biological impact of most of these other factors have not been as well researched as flow has. Absence of information does not necessarily mean that impacts are not occurring. I believe that toxics may be important in controlling the abundance and distribution of some river and estuarine species. For example, in a recently completed two and a half year study, 45 miles of San Joaquin River immediately upstream of the Delta tested toxic about half the time in bioassays with the invertebrate Ceriodaphnia dubia (Foe and Connor, 1991). The cause of toxicity appeared to be insecticides entering the river in tail and stormwater runoff from row and orchard crops. The Ceriodaphnia bioassay test is one of the EPA three species freshwater tests (EPA, 1989). Measurement of toxicity in these bioassays is important as EPA (1991) has demonstrated in other aquatic systems that

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