# Trends in Fish Populations of Suisun Marsh
## January 2002 - December 2002

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**Attention: Heidi Rooks**

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Introduction

Suisun Marsh is the largest brackish water tidal marsh on the West Coast of the United States. It is located in the center of the San Francisco Estuary, adjacent to Suisun Bay (Figure 1.1). Suisun Marsh is important to fish in the estuary because it contains many kilometers of productive tidal sloughs inhabited by numerous estuarine-dependent fish species, both native and alien. The native estuarine species have generally declined, some to the point that they have protection under the U.S. Endangered Species Act of 1973 (Sacramento splittail, delta smelt, and chinook salmon). Numerous factors have contributed to the decline of fish in the estuary including habitat alteration, water diversions and impacts associated with the continued increase in the number and abundance of introduced species. The UC Davis Suisun Marsh fish study was initiated in 1979 by P. B. Moyle as a way to monitor the fish populations, especially in response to modifications being made affecting the way water moves through the marsh. From the beginning, the study has been focused on the entire assemblage of fishes in the marsh examining such factors as changes in species abundance and composition through time, use of the various habitats within the marsh, and association of changes in the fish assemblages with natural and anthropogenic changes. There are currently two major components to the Suisun Marsh fish study, including a juvenile and adult sampling component and a larval fish sampling component. The larval fish sampling component was initiated in 1994 to gain a better understanding of larval fish use of Suisun Marsh. Moyle *et al.* (1986) summarized the first five years of the Suisun Marsh juvenile and adult fish data set and found strong seasonal trends in abundance and occurrence of species as well as co-occurring groups of species. They noticed a downward trend in total catch but considered the results inconclusive due to limited data. Meng *et al.* (1994) summarized the data through 1992 and found the Suisun Marsh fish assemblage to be much less predictable than had been concluded in the 1986 paper. They recorded strong downward trends in most fish populations and discussed the recent invasions of the shimofuri goby and the Asian clam, *Potamocorbula amurenis.* These downward trends continued through 1999, as reported in Matern et al. (2002). Annual reports to the California Department of Water Resources (Matern and Moyle 1994, Matern *et al.* 1995, 1996, 1997, 1998, Schroeter and Moyle 1999) and a recent publication on trends in catch of larval fishes (Meng and Matern 2001) further documented overall declines in juveniles and adults of most fishes and have presented possible factors contributing to successful spawning and rearing of larval fishes within Suisun Marsh. Over its duration, the Suisun Marsh fish project has significantly improved our understanding of species use of brackish water tidal habitat and has contributed to the successful management of protected species in the system by; (1) documenting population fluctuations in association with changing environmental and biotic conditions, (2) improving our understanding of larval, juvenile, and adult fish use patterns, and (3) monitoring species changes over time.

Continued declines in native fish abundance, increases in the number and abundance of introduced species, and a limited understanding of larval fish occurrence and use of Suisun Marsh have prompted further investigation. This report presents the findings from the 2002 fish sampling season. Part 1 of this report summarizes and compares fish catch data from the 2002 juvenile and adult survey with earlier collection data. Part 2 summarizes results from the 2002 larval fish survey with a final wrap up summary for all sampled years including discussion from Meng and Matern (2001) for data up through the 1999 sampling season.

Study area:

Suisun Marsh (Figure 1.1) is a large tidal marsh (approximately 34,000 ha) at the downstream end of the Sacramento-San Joaquin Delta. Approximately one-third of the marsh is tidally influenced and the remainder consists primarily of diked wetlands managed to attract waterfowl. Water inflow to the marsh is provided by a number of sources including tidal inflow through lower Suisun and Montezuma Slough, direct river inflow via the Sacramento and San Joaquin Rivers through upper Montezuma Slough and from a number of local tributaries within the marsh including Green Valley, Suisun, Ledgewood, and Denverton Creek. Flow into the system is highly seasonal and is derived from winter rain pulses and spring and early summer snowmelt from the various mountain regions surrounding the Sacramento-San Joaquin watershed. Water movement through the marsh during some times of the year is regulated by tidal gates located on the Montezuma Slough close to its upstream end on the Sacramento River.

Within Suisun Marsh, fish habitat availability and type changes depending upon the slough location, tide height and freshwater outflow. Sampled sloughs vary in size from 7-10 m wide and 1-2 m deep to 100-150 m wide and 2-6 m deep. Tidal influences on water depth can exceed 1 meter during extreme tidal movements, which can significantly dewater small sloughs. Vegetative cover, bank slope, and slough substrate in addition to biological parameters including temperature and salinity vary depending upon slough size, type and location. Environmental conditions within the marsh vary depending upon freshwater inflow and location of slough. Salinities within the marsh fluctuate by location, with the southwestern corner of the marsh having the highest salinities and southeastern sloughs having the lowest salinities. Salinity within the northern areas of the marsh is generally intermediate and is influenced by local stream inflow. Salinity within Suisun Marsh has ranged from 0 to near 17 ‰ during the course of the study, peaking in the autumn of drought years and falling during periods of high outflow in spring (Meng *et al.* 1994). The proximity of Suisun Marsh to the large upper bay system (Grizzly, Suisun, Honker Bay) and the considerable, but often unpredictable, amount of freshwater inflow from the Sacramento-San Joaquin and numerous local tributaries has influenced the catch of fish within the marsh. Over the course of the study 54 species (Table 1.2) have been captured within Suisun Marsh (29 native species and 25 alien species). Many of the occasional native species inhabitants of the marsh are dependent upon higher salinity conditions (12 species) and as expected their presence corresponds to periods of high salinity. The remainder of the native species are positively influenced by periods of low and intermediate salinity. The majority of alien species captured within the marsh are almost entirely dependent upon freshwater (excluding gobies and striped bass which account for the greatest alien fish abundance) and therefore have been most abundant in the marsh during periods of high freshwater inflow and low salinity (Matern et al. 2002). Additionally, a large number of species are only found in the marsh on a seasonal basis This is most notable for species that spawn in areas upstream or downstream of Suisun Marsh, and that have larvae or juveniles that rear in or pass through Suisun marsh on seaward or freshwater migrations.

Part 1: Suisun Marsh Fish Survey
January 2002 - December 2002

## Introduction

The primary objectives of the Suisun Marsh fish study (juvenile and adult) are: (1) to record long-term changes in fish populations due to environmental fluctuations and species introductions and add to the growing database on environmental changes in the San Francisco Estuary; (2) to monitor the distribution and abundance of native species of the marsh, especially delta smelt, longfin smelt, chinook salmon, and splittail; (3) to track the movement of alien species, especially new invaders such as the shimofuri goby, shokihaze goby and Asian clam; and (4) to study the effects of the Montezuma salinity control gates and other proposed changes in water circulation on fish populations. Original sampling efforts within Suisun Marsh consisted of otter trawling and beach seining and were directed towards the juvenile and adult life history stages of fish. Catches of shrimp and clams have been incidental to the fish catch, but have been consistently recorded throughout the course of the study. Changes in species composition and abundance have occurred over the course of the study and are likely a result of changing environmental conditions and the continued invasion of the marsh by introduced species (Moyle et al. 1986, Menge et al. 1994, Matern, Moyle and Pierce 2002 (see also UC Davis - Trends in Fish Populations of Suisun Marsh, 1994 – 2001). In general, abundance of the various species within the marsh has been declining since the early sampling years (1980 and 1982) with only brief periods of resurgence often associated with wet years. This section of the report (Part 1) presents the findings from the twenty-third year (2002) of the Suisun Marsh juvenile and adult fish survey.

## Methods

Field methods:

Since 1979 monthly fish sampling has been conducted at numerous sites within Suisun Marsh. In the early sampling years (prior to 1994) a total of 12 sloughs and 27 sites were sampled (Table 1.1A, Figure 1.2). A majority of these historic sites were sampled only in the early years of the project (primarily 1980 and 1981) with 17 sites being sampled consistently up until 1994. Currently (after 1994), 21 sites within 9 sloughs are sampled for adult and juvenile fish (Table 1.1B, Figure 1.3). Latitude and longitude coordinates for currently sampled sites were obtained (± 100 m) using a Global Positioning System receiver (adjustments made by Alan Kilgore of the California Department of Fish and Game's Technical Services Branch GIS; Table 1.1B). Data from all historic sampling sites are included in this report because: (1) the entire data set reported here is available on the IEP website (http://www.iep.water.ca.gov); (2) The data are representative samples from within Suisun Marsh; and (3) the data provides a more robust comparison between fish catch in early sampling years and current catch.

Sampled sloughs vary in size and depth. Small sloughs sampled included Peytonia, Boynton, Spring Branch, Cutoff, Goodyear, Denverton, and Nurse (which is wider than the others but of comparable depth). Historically sampled sloughs including Hill, Wells, and Grant Slough, are also small in size. Large sloughs sampled include Suisun and Montezuma.

Trawling was conducted using a four-seam otter trawl with a 1 X 2.5 m opening, a length of 5.3 m, and mesh sizes of 35 mm stretch in the body and 6 mm stretch in the cod end. The trawl was towed at approximately 4 km/hr for 5 minutes in the small sloughs and for 10 minutes (to compensate for small catches) in the large sloughs. In Suisun and Denverton sloughs the monthly sampling was augmented with 10 m beach seines having a stretched mesh size of 6 mm. For each site the tidal stage, temperature (°C), salinity (‰), specific conductance (µS), water transparency (secchi depth in cm), and dissolved oxygen were recorded.

Contents of each trawl or seine were placed into large containers of water. Fishes were identified, measured to the nearest mm standard length, and returned to the site of capture. When possible, sensitive native species were processed first and immediately released. The abundance of several common macroinvertebrates were also recorded including the overbite clam and the shrimps *Crangon franciscorum*, *Palaemon macrodactylus* and the most recent large shrimp to invade the marsh, *Exopalaemon modestus*. *E. modestus* was first positively identified in early 2002 (February), although it was probably present in 2001 and may have composed a large percentage of the 2001 and early 2002 (January and February) *P. macrodactylus* catch. Abundances of *P. macrodactylus* and *E. modestus* are herein reported separately. Mysid shrimps were pooled into one category, "mysids," and given an abundance ranking: 1 = 1-3 shrimp, 2 = 3-50 shrimp, 3 = 51-200 shrimp, 4 = 201-500 shrimp, 5 = >500 shrimp. The index was necessary because most mysids pass through the trawl and those that remain in the net are difficult to accurately count. Chinese mitten crabs (*Eriocheir sinensis*) were sexed and measured to the nearest mm maximum carapace width.

A complete historical list of common and scientific names for all of the fish species captured is presented in Table 1.2 and values used in constructing all charts are listed in the appendix.

## Results and Discussion

<u>Environmental parameters:</u>

### Net Delta Outflow

Net delta outflow, as reported herein, is the measure of water exported through the delta and into the upper San Francisco Estuary. The measure of outflow is influenced by a number of factors including precipitation, reservoir releases and water diversion. The amount of outflow at any given time largely determines the salinity found within the waters of the San Francisco Estuary.

From 1979 until fall of 1983 outflows varied annually and seasonally and salinities, temperatures, and water transparencies reflected the shifting influences of saltwater intrusion and freshwater runoff. During the drought years of 1985-1992 salinities stayed above 2 ‰ for all months except three (February 1986, March 1986 and March 1989). The above normal water year of 1993 resulted in salinities below 2.0 ‰ from February through June (Table 1.3) and a yearly average of 2.4 ‰ (Table 1.4). 1994 was a critical year and the yearly average rose to 4.3

‰ (Table 1.4). Although the years 1995 through 2000 were all classified as being above normal or wet years (DWR DAYFLOW data), they were different in the timing and magnitude of rainfall and environmental conditions, which likely had different ecological effects. Both the 2001 and 2002 water years were classified as dry (DWR DAYFLOW data; Figure 1.4).

**Salinity**

Salinities in Suisun Marsh between 1999 and 2002 returned to a typical pattern following the exceptional year of 1998, throughout which salinity remained below 2 ‰ (Table 1.3). Between 1999 and 2002, salinities were generally low from January through June with a usual large increase in salinity in July and extending through November. December salinities usually drop off considerably especially from the summer and fall months, especially in wet years. In 2002, average salinities in the marsh ranged from 1.2 ‰ in January to 7.3 ‰ in September. Yearly average salinities between 1999 and 2002 were 2.4, 3.1, 4.1 and 4.2, respectively (Table 1.4).

**Temperature and Water Transparency**

Overall, the temperature regimes in Suisun Marsh have shown no easily detectable changes (Table 1.3, Table 1.4). However, in 2002 the average monthly fall (September and October) and early winter (December) water temperatures were considerably warmer than in previous years with the October average (21.9 °C) being the warmest temperature, the September average (21.3 °C) being the third warmest, and the December average temperature being the second warmest since sampling began in 1980.

Water transparency (secchi depth) has historically decreased in response to high outflows and increased during periods of low outflow (Table 1.3, Table 1.4). For example, mean secchi depths were greater in 1996 than in 1995 for every month but February, the only month in which 1996 outflow exceeded that of 1995. Inexplicably, secchi depths in 1998 were higher during the high outflow months of March and April than they were during most low outflow months (Table 1.3). Secchi depths increased in 2001 with the yearly average being the third highest since 1980. The average annual secchi depth in 2002, was the second highest since 1980 with the May, August, and September average monthly secchi depths being the deepest ever recorded.

**Dissolved Oxygen**

Dissolved oxygen monitoring was initiated in the fall of 1999, following a local pond discharge, which discolored water and resulted in a fish kill. In this report we have included the average monthly and yearly dissolved oxygen concentrations for the 2000 - 2002 sampling seasons (see Table 1.3 and Table 1.4). As a cautionary note, as with all environmental parameters, using averages masks potentially relevant biological parameters such as minima and maxima, which are more likely to affect aquatic organisms. Presentation of such data is beyond the scope of this report, thus a more detailed report is planned, which will address the high variability of dissolved oxygen levels observed throughout the marsh on both a spatial and temporal scale. Average dissolved oxygen levels in 2000 and 2001 rarely dropped below 7 mg/l $O_2$, except in the fall of 2001. In the fall of 2001 average dissolved oxygen values of 5.6 and 6.2 mg/l $O_2$ were observed in October and November, respectively. Average monthly dissolved oxygen levels in 2002 were similar to those in 2001, although the summer dissolved oxygen concentrations were lower and the fall levels were somewhat higher (Table 1.3).

General trends in fish abundance:

Throughout the twenty-three years of fish sampling in Suisun Marsh, otter trawl catches of native and alien species have shown considerable population fluctuations (Figure 1.5). The largest fluctuations have occurred in the abundance of alien species with abundance fluctuations as high as 150 % over a 2-3 year period. These extreme fluctuations are largely a result of recruitment of age 0 fish. Understanding factors responsible for successful recruitment of introduced species will provide some insight into these large and periodic (1- 3 years) cycles. Before taking into consideration the 2000 and 2001 fish catch, the general trend in abundance of introduced species over the twenty-two years of sampling in Suisun Marsh has been an overall decline. However, the abundance of alien species in 2000 (average of 27.8 fish / trawl) was the highest since sampling began in 1979. In 2001, the number of alien species remained high, but dropped to the fourth highest catch overall with 23.4 fish caught per trawl. The catch of alien species in 2002 (average of 11.6 fish / trawl) declined significantly from the 2000 and 2001 levels again illustrating how volatile the abundances of alien species have been over the course of our sampling (1980-2002).

The widely fluctuating catch of alien species has been strongly influenced by the changes in abundance of relatively few species, primarily striped bass, yellowfin goby and shimofuri goby. These three species have accounted for, on average, 90% of the annual catch of alien species through 1997 (Figure 1.6 and 1.7, respectively). The abundance of shimofuri goby has declined considerably since 1997 with the alien species catch now being dominated by yellowfin goby and striped bass. In 2001, striped bass dominated the catch (> 50% of total catch) with yellowfin goby declining considerably from 2000 levels and making up only 6.4% of the total catch. In 2002, yellowfin goby were again captured in low abundance making up less than 6% of the introduced species catch. Similar to the 2001 catch, striped bass comprised the largest percentage (52%) of the introduced species catch in 2002, although striped bass abundance in 2002 declined markedly from an 18 year high in 2001. Shimofuri goby comprised a larger percentage (18%) of the total introduced species catch in 2002, due mainly to the decline in striped bass abundance rather than an increase in their own abundance.

Native species abundance has not fluctuated as widely as alien species abundance. Despite a prolonged decline in native species abundance from 1980-1994, there has been a rather dramatic and sustained increase in the abundance of native species from 1995-2002 (Figure 1.5). This increase in native fish abundance is driven primarily by increased catches of Sacramento splittail and more recently (2001-2002), tule perch (Figures 1.8 – 1.11). Catch of the remaining native species have either fluctuated considerably (Figure 1.9 – 1.11) or have remained at relatively low levels (Figure 1.11).

During the course of the Suisun Marsh fish study, native fish abundance has rarely exceeded alien fish abundance. Exceptions include the period between 1980-1982 and 1987-1988 and a single year in 1998 (attributed to a huge stickleback catch in a single trawl; Matern et al.

1998). Since 1982, native fish catch has exceeded alien fish catch only during times of exceptionally low alien fish catch rather than during periods of exceptionally high native fish catch. This is again the case in 2002, where the dramatic decline in introduced fish catch and a continued moderate increase in native fish catch resulted in native species outnumbering introduced species, something that has only happened seven times since 1980 and twice in the last fourteen years. Overall, it appears that current conditions, either physical or biotic, are for the most part, not suitable for many of the native species once found in high abundance in the marsh, although recent rebounds in both the splittail and tule perch populations are encouraging.

Fish catch between 1995 and 2001 has varied depending upon slough sampled (Figure 1.12). In general, there appears to be three average levels of abundance among sampled sloughs (low, 20 fish / trawl; intermediate, > 20 and < 30 fish / trawl; and high - > 30 fish / trawl). Because of the large distance separating upper and lower sampling sites in Suisun Slough (Figure 1.3) and the large differences in catch, the slough is broken up into two locations for discussion purposes (Upper and Lower Suisun Slough). Lowest catches on average have been within Montezuma, Boynton, Upper-Suisun and Nurse sloughs (Figure 1.12). All sloughs with a low catch, with the exception of Boynton, are relatively large in size, thus low catches may be attributed to poor catch rates associated with size of slough or due to fewer individuals actually occupying those larger sloughs. Boynton slough is relatively small in size, thus size alone may not be responsible for the observed low catch rates. Rather, other factors either natural or anthropogenic could be influencing catch rates there. It is interesting to note that Boynton Slough receives sewage outflow from the Fairfield Sewage Treatment Plant, which may be creating physical conditions unfavorable to fish. Intermediate levels of catch between 1995 and 2002 occurred in Cutoff, Peytonia, and Denverton sloughs and the highest catch occurred in Goodyear, Spring Branch and Lower-Suisun sloughs. Striped bass comprised a large percentage of the catch in the highest catch sloughs (Good Year, Spring Branch, and Suisun Lower) making up 22.5, 46.4 and 39.3 % of the total catch, respectively. A majority of these striped bass were young of year (YOY).

<u>Delta smelt and longfin smelt:</u>

Catch of delta smelt (DS) has remained relatively low since the early 1980s, although abundance increased slightly between 1999 and 2001. Catch in 2002 (12 individuals) declined to nearly one-third the catch in 2001 (32 individuals; Figure 1.9). Longfin smelt (LFS) catch in 2002 more than doubled, with 658 individuals captured and an average catch per trawl rate that was the fifth highest since 1980 (CPUE of 2.67; Figure 1.9).

A strong seasonal pattern in LFS size at capture was evident between 1999 and 2001 and somewhat in 2002 with a majority of LFS captured from May through October being < 50 mm in length (< 35mm in May up to 50 mm in October). The size of individuals captured in November and December were between 50 and 100 mm. Large adults captured in January and February in each year were presumably adults from the previous years cohorts. These fish likely spawned within Suisun Marsh, as is evident by the presence of larval longfin smelt present in our samples as early as the first week of February. According to Dryfoos (1965) LFS eggs hatch after approximately 40 days at 7 °C, which suggests that the LFS larvae captured in February were likely to have been spawned in December or January. The presence of high numbers of LFS larvae between February and April 2000 and the presence of large LFS up until February 2000 suggests that LFS experienced an extended spawning season in 2000. Typically our catch of large LFS drops to zero after February and relatively few adults are observed until November of that same year. The lack of LFS following the spawning period (December – March) may be a result of post spawning mortality (Moyle 2002) or adult movement to other areas of the estuary.

Striped bass:

Striped bass catch in 2002 (6.03 striped bass / trawl) was significantly lower than the 2001 catch (17.0 striped bass / trawl). A total of 1483 striped bass were captured by otter trawl in 2002 making up less than 26% of the total catch (5905 individuals of all species), whereas in 2001 striped bass comprised over 50% of the total catch. The abundance of striped bass has fluctuated considerably since 1979 with very low abundances observed in 1990, 1994, 1998, and 2002 followed by dramatic increases in 1991-1992, 1997, and 1999 - 2001. YOY striped bass make up a majority of the total striped bass catch, thus fluctuations resulting from successful recruitment in a given year are largely responsible for the dramatic changes in striped bass abundance. For example, the 2001 catch of striped bass < 100 mm standard length (SL) comprised approximately 94% of the total with a majority of those individuals being less than 60 mm. In 2002, only 70% of the striped bass captured were < 100mm SL and even fewer still (< 35%) were less than 60 mm SL suggesting that recruitment or spawning success was lower in 2002 compared to 2001.

Within the marsh, it appears that based on catch rates three areas are heavily used by striped bass. These areas include lower Suisun, Spring Branch and Goodyear sloughs, in which just over 60% of all the striped bass in Suisun Marsh were caught in 2002. It is uncertain why these areas are so heavily used by striped bass, but it is likely that a high availability of prey, shallow depth, and proximity to the larger bays (at least in the case of lower Suisun and Goodyear) make these areas important for striped bass rearing. One implication of these high abundances of striped bass in Suisun Marsh is that they could potentially be affecting prey availability for other fish species, at least during times of their greatest abundance (summer months).

Splittail:

The otter trawl catch rate of Sacramento splittail in 2001 (4.74 individuals / trawl) was the second highest since sampling began in 1979. In 2002, the catch rate of splittail was the third highest since sampling began (4.61 individuals / trawl). The 2001 and 2002 splittail catch rates are a dramatic increase from the low catch rates observed in the late 1980s and early 1990s and is part of a continued increase observed since 1994. The 2001 and 2002 splittail catches were comprised of multiple age classes and were unlike the 2000 catch, where a majority of individuals were YOY; nearly 65 % (734 of 1186 individuals) of the 2001 fish and 89.9 % (1020 of 1135 individuals) of the 2002 fish were greater than 100 mm SL. A notable exception in 2002 was the fact that relatively few splittail captured were under 100 mm SL (approximately 10 % of the catch) suggesting that spawning success and / or recruitment of the 0+ age class was lower in

2002 perhaps due to the poor spawning conditions during a relatively low outflow year (Sommer et al. 1997).

Splittail captured within Suisun Marsh are generally most abundant within certain sloughs. In 2001, catch rates within Spring Branch, Peytonia and Goodyear comprised over (76 %) of the total splittail catch despite the fact that the number of sites within those sloughs comprised only 40 % of the total sites sampled in Suisun Marsh. In 2002, catch rates were greatest in Cutoff (19.8%), Spring Branch (18.2%), Peytonia (15.5%), and lower Suisun Slough (14.4%). It is not known why splittail abundances are so high within certain sloughs, but a planned investigation examining the environmental and biotic conditions present within those sloughs should provide some insight. One likely explanation centers on the fact that the sloughs with greatest splittail abundance are generally small and shallow, which may result in increased primary productivity and food availability as well as reduced predation risk from large striped bass and Sacramento pikeminnow.

Splittail catch in beach seines further declined in 2002 to a total of 88 individuals making it the lowest beach seine catch since 1995. In previous years, it has been found that splittail YOY make up a large percentage of the beach seine catch (Schroeter and Moyle 2001). Therefore the low beach seine catch in 2002 may be largely explained by the overall poor catch rates of YOY splittail.

Chinook salmon:

The total catch of chinook salmon in 2002 was 27 individuals (0 in otter trawls and 27 in beach seines). The 2002 totals are the highest catch in the marsh since 1995, although the overall catch is still low. All chinook salmon from 1995 through 2001 were fall run as determined using Frank Fisher's (1992) length-at-date criteria and were made up predominantly by YOY.

The origin of the YOY chinook salmon captured in Suisun Marsh is largely unknown. However, the small size of these salmon, their relatively high density in Denverton Slough, and landowner accounts of spawning adults have forced us to consider the possibility that these salmon were spawned in the area and did not recruit from the Sacramento or American Rivers as was previously assumed. However, a more thorough comparison of timing of capture and size at capture of chinook salmon elsewhere in the S.F. Estuary and Delta are needed to rule out their origin. Regardless of the origin of chinook salmon captured in Suisun Marsh, it appears as if rearing of salmon within the marsh occurs during some years, as evidenced by the presence and growth of salmon in the marsh for a period up to several months (e.g. 1995). The opportunity for salmon rearing within the marsh is likely limited by high water temperatures, which can affect survival and growth. In the course of our Suisun Marsh sampling, juvenile chinook salmon have never been captured when water temperatures exceed 17 ° C.

Goby:

Three alien species of goby were collected in Suisun Marsh in 2002. They include the yellowfin goby, shimofuri goby and shokihaze goby (Figure 1.7). The shokihaze goby

(*Tridentiger barbatus*) was first collected in Suisun Marsh in 1999 when a single individual was captured. In 2000, shokihaze goby were absent from our trawls, but had begun to increase in abundance elsewhere in the estuary (Tom Greiner CDFG personal communication). A total of 34 bearded goby were captured during our 2001 sampling and 78 individuals during our 2002 sampling, with a majority of these being juveniles. Although our catch of shokihaze goby has more than doubled since 2001, its total abundance is still relatively low. Given the short time period since the shokihaze goby was first discovered, it is difficult to predict any future trends in abundance in Suisun Marsh.

Little is known about the shokihaze goby, but in the San Francisco Estuary, it has been found in both fresh and brackish water environments with salinities as high as 28 ppt (Tom Greiner, CDFG, personal communication). According to Dotu (1956), shokihaze goby in Ariake Sound, Japan, can live longer than 3 years and reach a size greater than 120 mm, but may mature as early as the first year at a size of 40 – 85 mm. The largest shokihaze goby captured in the San Francisco Estuary was greater than 120 mm total length (Steve Slater, CDFG, personal communication). In Japan, shokihaze goby inhabit oyster beds on muddy tide flats (Dotu 1956). Within the San Francisco Estuary, shokihaze goby are typically found in deep channel habitats, as is the case in Suisun Marsh. The diet of shokihaze goby in the San Francisco Estuary is unknown, but those captured in Ariake Sound consumed annelids, small crustaceans squid, and young fish including other gobies (Dotu 1956). The shokihaze goby thus has the potential to have negative effects on small benthic fishes and invertebrates in newly invaded habitats such as Suisun Marsh.

Yellowfin goby catch in otter trawls in 2001 and 2002 declined considerably from an all time high in 2000 (3427 individuals; 13.6 fish / trawl). In 2001, 513 individuals (2 fish / trawl) were captured by otter trawl, but by 2001 only 151 yellowfin goby were captured. This is a 22 fold reduction in the otter trawl abundance of yellow fin goby. Yellowfin goby catch by beach seine also decreased in 2002, with the lowest catch recorded since 1995. Historically, the yellowfin goby has shown periodic peaks in abundance throughout the span of the Suisun Marsh fish sampling program, most notably in 1993, when high recruitment resulted in a mean catch of 16 gobies per trawl. Catches in 1994 plummeted to less than one goby per trawl but rebounded to almost nine gobies per trawl (most of them YOY, including 665 individuals smaller than 40 mm SL) in 1995. In 1996 mean catch again fell to less than one goby per trawl and remained low until 1999 when goby increased in abundance to over 6 gobies per trawl (Figure 1.7). Historical peaks in abundance of YFG in Suisun Marsh have been short-lived, typically lasting one to three years. Thus, the current decline observed in 2001 and 2002 is fairly typical and will most likely also be short-lived. It is uncertain whether the wildly fluctuating abundances of yellowfin goby is typical for this species or if biotic and or environmental conditions found in the San Francisco Estuary are driving these wild fluctuations.

The shimofuri goby was first collected in Suisun Marsh in 1985 and has subsequently spread throughout the Sacramento-San Joaquin Delta and into southern California via the State Water Project System (Matern and Fleming 1995). Its population peaked briefly in 1989 when it was the most abundant species collected in our trawls but has declined considerably since then. The shimofuri goby catch in our otter trawls in 2001 (659 individuals) was the fifth highest since it first appeared in 1985. Beach seine catch of shimofuri goby increased in 2001 to 122 individuals up from 64 individuals in 2000. The beach seine catch in 2001 was the second highest since 1985. A total of 515 shimofuri goby were captured by otter trawl and 204 individuals by beach seine in 2002. These totals reflect a slight decline in otter trawl abundance, but a slight increase in beach seine abundance from the 2001 levels (Table 1.5).

The shimofuri goby spawns from March through August in Suisun Marsh and we believe that most fish live only one year (if they were born early) or two years (if they were born late). This somewhat annual life cycle is likely to account, at least partially, for the observed wide fluctuations in shimofuri goby abundance. It is also interesting to note that following the initial period of invasion; shimofuri goby have reached their greatest densities only during periods of low yellowfin goby abundance (Figure 1.7). The observed abundance patterns may be a result of differential responses to environmental conditions, but could potentially be a result of biotic interactions between the two species. It will be interesting to observe changes in abundance of shimofuri goby given the dramatic decline in yellowfin goby in 2001 and 2002.

<u>Prickly sculpin, Pacific staghorn sculpin, and Sacramento sucker:</u>

The catch of native prickly sculpin, has been highly variable throughout the course of this study (Figure 1.11). In 2001, prickly sculpin catch declined significantly with only 18 individuals captured in otter trawls and 1 individual captured by beach seine. The low numbers of fish observed in 2001 is a six fold decline from the 2000 catch and is the second lowest catch in the history of the project. Prickly sculpin catch in 2002, was also low with only 68 captured by otter trawl and 1 captured by beach seine. Moderate outflows in the dry water years of 2001 and 2002 may have contributed to the low recruitment and abundance of prickly sculpin, but other environmental and biological factors may also have played a role.

The abundance of staghorn sculpin, a euryhaline marine species, generally decrease in Suisun Marsh in years with high runoff. From 1992 to 1994, catches were near the all time low recorded in 1983. In 1995, catches increased 10-fold despite the heavy freshwater outflows (Figure 1.11). This inconsistency may be explained by the fact that Pacific staghorn sculpin spawn in the winter and therefore experience different spawning conditions from most of the other resident fishes in the marsh. From 1996 through 2002, the pattern (low abundance with moderate to high outflow) re-emerged, with catches falling in the wake of heavy outflow. A total of 48 staghorn sculpin were collected by otter trawl and 101 individuals by beach seine in 2002 (Figure 1.11).

Sacramento sucker, like many native fishes, have been in a long-term decline in Suisun Marsh. Despite a gradual increase in abundance between 1996 and 1998, catches have remained less than one-fifth the catches of 1980 and 1981 (Figure 1.11). Catch of Sacramento sucker in 2001 (44 individuals) and 2002 (56 individuals) was similar to the 1999 and 2000 catch, which was slightly below the catch in the previous three years. The Sacramento sucker may be capable of rebounding given the right conditions because it is relatively long-lived and can tolerate several years between successful spawning. Presumably all Sacramento suckers in the marsh recruit from inflowing streams.

Tule perch:

Tule perch have historically been one of the most abundant native fishes in the marsh (Table 1.5). It is the only freshwater representative of the surfperch family Embiotocidae. Tule perch are year-round residents of the marsh and, like all surfperches, are livebearers. Tule perch catch in our trawls peaked from 1981 to 1982 and again from 1987 to 1988 but for the most part have remained very low for the last decade. In 1999 and 2000 the catch of tule perch in Suisun Marsh declined significantly to the lowest levels ever recorded (Figure 1.10, Table 1.5). However in 2001, tule perch abundance increased significantly (444 individuals) and catch rates were the eighth highest since 1980 and the largest catch since 1988. Tule perch continued to increase in abundance in 2002 with nearly two times as many tule perch captured by otter trawl (856 individuals). The catch of tule perch in 2002 was the sixth highest since sampling began in 1980 and was the highest catch since 1988. As in 2001, multiple age classes were again present in 2002 and the tule perch have clearly demonstrated that they can quickly increase in abundance given suitable environmental conditions. Although the reason for the recent resurgence in abundance is unknown, it may well be associated with dissolved oxygen conditions. Tule perch have been found to be particularly sensitive to low dissolved oxygen concentrations (Cech et al. 1990) and may be limited by the seasonal dissolved oxygen sags observed in several areas of the marsh. Further laboratory and field study is needed to more clearly define the role of low dissolved oxygen concentrations in determining the distribution and abundance of tule perch in Suisun Marsh.

Uncommon species:

Representative members of the family Centrarchidae are typically rare in Suisun Marsh (Table 1.5). The black crappie is the most abundant with high catches typically occurring in years with moderate to high precipitation and outflow. In 2001, 79 black crappie and a single bluegill were captured. In 2002, a similar water year to 2001, 17 black crappie and 2 green sunfish were captured.

Three species in the family Ictaluridae are commonly captured in Suisun Marsh, but like centrarchids, their catch is limited and is generally restricted to sloughs where salinities remain low. In 2002, 31 black bullhead, 204 white catfish, and 2 channel catfish were captured. In addition, 1 brown bullhead was also captured in 2002. White catfish and channel catfish are typically most abundant in Denverton and Nurse Slough, but also occur in low numbers (mostly white catfish) in other sloughs of the marsh. Black bullheads are generally found within Peytonia, Boynton and Spring Branch sloughs.

Several additional unusual or rare species were also captured in 2002. They include the Pacific herring (42 individuals), plainfin midshipman (1 individual) and hitch (2 individuals). In addition, 96 American shad were also captured in 2002, making it the second highest catch of American shad since 1980.

Species collected in beach seines:

Fish catch by seine has fluctuated considerably between 1995 and 2001 with between 2000 and 9000 individuals captured. The mean number of fish per seine haul over this time period was 68 individuals. In 2002, 5768 individuals were captured by seine or 72.1 fish / seine. This is the fourth highest catch since 1995, when Denverton Seining Beach was added to the regular sampling. Based on fish catch over this time period, we see that some fish species are more susceptible to capture by seining as compared to trawling. For instance, from 1995 to 2002 most Sacramento blackfish, bigscale logperch, chinook salmon, Sacramento pikeminnow, and western mosquitofish were taken by seining. The most striking result has been that we captured a majority of inland silverside by seine and relatively few by trawl (Table 1.5, Table 1.6). The inland silverside was the most abundant species captured by seine in 2002 (4033 indiv.) and comprised 69.9 % of the total catch. Striped bass and yellowfin goby were the next two most abundant species (566 and 412 indiv., respectively), together comprising 17 % % of the catch. Although yellofin goby still make up a large percentage of the total fish catch by seine, there numbers have declined considerably over the last few years.

Invertebrates:

The catch of mysid shrimp (as estimated by an average rank abundance) in Suisun Marsh, primarily *N. mercedis*, was high in the early sampling years especially between 1980 and 1990 (Table 1.4). More recently mysid shrimp abundance has declined considerably, but this data has been confounded by the continued invasion of several alien species of mysid shrimp. The impacts of these newly introduced mysids on the native fauna is largely unknown but since their invasion beginning in 1992 it appears that several species of mysids, primarily *Acanthomysis bowmani*, have been replacing the native species *N. mercedis* in the San Francisco Estuary (Orsi and Mecum 1994). It is not possible to identify mysid shrimp under field conditions; thus our current (since 1992) measure of mysid shrimp abundance likely reflects a combination of native (*N. mercedis* and to a lesser extent *N. kadiakensis*) and alien species (*A. bowmani* + others).

The average rank abundance of mysid shrimp in Suisun Marsh in 2002 (1.0) was down from previous sampling years and is considerably below the highs observed between 1980 and 1990. Investigations into the composition and abundance of mysid shrimp in Suisun Marsh are ongoing with Orsi (1998) reporting that in the Fall of 1997 no *N. mercedis* were found in the large sloughs of Suisun Marsh (Suisun and Montezuma) and that *A. bowmani* was abundant. In October 1998, Orsi (1999) found densities of *A. bowmani* up to 179 $m^{-3}$ in Suisun Slough and found *N. mercedis* to be present in low numbers. Preliminary results from our mysid catch in the larval fish trawls shows both species to be present and in 1999 over 60% of all mysids collected between February and May were found to *N. mercedis* and *N. kadiakensis*, another native species. Possible differences in results may be attributed to sampling location within the marsh. Our sites are primarily within the smaller upstream sloughs, whereas Orsi samples larger sloughs adjacent to Grizzly Bay.

The abundance of *C. franciscorum* in Suisun Marsh has fluctuated yearly within the range of 12 to 68 individuals per trawl until 1997, when our average catch increased to 128 individuals per trawl (Figure 1.13). Between 1998 and 2002 the abundance of *C. franciscorum* has remained at or below 35 individuals / trawl. The large fluctuations in abundance of *Crangon* may be explained by fluctuating environmental conditions and the positioning of the population within the estuary. For example, in 1998 the highest density of *C. franciscorum* was found downstream of the marsh (Hieb 1999). Alien species within the genus *Crangon* have recently been introduced into the estuary, but it appears that, at least for now, the species found within Suisun Marsh is still the native *C. franciscorum.*

*Palaemon macrodactylus,* is a relatively large predaceous shrimp which was first introduced into the San Francisco Estuary in the 1950s (Newman 1963). *P. macrodactylus* prefers fresher water than *C. franciscorum,* thus, would be expected to be found in greater abundance in Suisun Marsh during periods of higher outflow. *P. macrodactylus* abundance hit an all-time low in 1994. However, despite high outflows and low salinities, its abundance hit lows again in 1995 and 1996 before rebounding slightly in 1997 and 1998 (Figure 1.13, Table 1.4). In 1999 and 2000, *P. macrodactylus* abundance again declined to very low levels (Figure 1.13). Because *P. macrodactylus* feeds on mysid shrimps, their decline may be related to the recent low abundance of mysids (Jim Orsi, DFG, pers. commun.) or alternatively their low abuandance could be attributed to mysids being found in other areas of the bay-delta during this same time period. However, while mysid shrimp abundance remained low during the 2001 season, *Palaemon* abundance increased 16 times from their catch in 2000 making it the highest abundance since sampling began in 1979. A likely explanation for the dramatic increase in abundance of *P. macrodactylus* in 2001 is that the recently introduced shrimp, *Exopalaemon modestus*, was incorrectly identified as *P. macrodactylus.* *E. modestus* has recently been found in the freshwater portions of the San Francisco Estuary and delta and it was first positively identified in Suisun Marsh in February 2002. At the time of its discovery in Suisun Marsh, over 90% of the shrimp identified as *P. macrodactylus* were in fact *E. modestus*. It is interesting to note that the average annual abundance of *E. modestus* in Suisun Marsh in 2002 (31 *E. modestus* / trawl) was over two times the maximum abundance observed for *P. macrodactylus* across all years sampled (1980-2002) despite the fact that January and December totals were not included in the annual abundance reported since they could not be differentiated from the catch of *P. macrodactylus*.

It is unknown whether the rapid increase in abundance of *E. modestus* will be sustained in future years, or if the species will reach a lower equilibrium abundance once predators and resources come into balance. The consequences of this new invasion on the preexisting aquatic biota are not known, however, if *E. modestus* has predaceous tendancies similar to *P. macrodactylus* (Sitts and Knight 1979) then they may adversely impact mysids and other invertebrates in the marsh as well as vulnerable larval fish. Evidence from the 2003 sampling season suggests that current abundances of *E. modestus* are as high or higher than those observed in 2002, thus there is reason for concern. Several areas of research would greatly improve our understanding of the current and future impacts of *E. modestus* including a detailed diet analyses.

Another introduced species occurring in the marsh is the overbite clam, *Potamocorbula amurensis*. This bivalve can attain densities of over 40,000/$m^2$ (Heather Peterson, DWR, pers. commun.) and is an efficient filter-feeder that is disrupting the food web in the San Francisco estuary. Based on conservative estimates, these clams filter an equivalent volume of water equal to the entire North Bay 1-2 times per day. A consequence of their incredible filtering capacity is thought to be the virtual elimination of the spring phytoplankton bloom (Kimmerer 1998) and the summer/fall chlorophyll bloom as well as a shift from a pelagic food web to a benthic one (Thompson 1998).

The historical occurrence of the overbite clam in Suisun Marsh has been primarily in lower Suisun Slough (SU3 and SU4) and lower Goodyear Slough (GY3). In 2002, 9837 individuals were collected at 8 sites in Suisun Marsh including upper Suisun (SU1), lower Suisun (SU3 and SU4), middle and lower Goodyear (GY2 and GY3) and single individuals collected in both Montezuma (MZ1) and Nurse Slough (NS2). Most of these individuals (9000) were collected in three trawls in lower Suisun (SU4) in May, June and July. Typically, individuals captured in Suisun Marsh are small (< 5 mm) and are mainly collected between January and September (i.e. 2001), although in 2002 individuals were collected in all months with a peak from May - August. It is interesting to note that the occurrence of the overbite clam in our trawls is typically associated with the presence of aquatic vegetation in our nets. This may suggest that there is limited substrate for attachment by the overbite clam within the sloughs of Suisun Marsh.

In 1996, four Chinese mitten crabs (*Eriocheir sinensis*) were collected in Suisun Marsh, marking the first time they had been collected upstream of the Carquinez Strait. Since our first collection of mitten crabs, they have been captured in several locations upstream in the Sacramento-San Joaquin delta where extremely high population abundances were observed (Veldhuizen 1997). In the Fall of 1998, 20,000 to 25,000 mitten crabs per day were collected for several weeks at the federal fish facilities in Tracy (Brown 1998). The catch of mitten crabs in Suisun Marsh has fluctuated considerably since 1996. In 1997, we collected 19 Chinese mitten crabs. The mitten crabs captured in 1997 were primarily males less than 52 mm MCW and were collected between August and December. In 1998 and 1999, we collected 149 and 171 mitten crabs, respectively, mainly in Suisun Slough. The catch in both 1998 and 1999 was comprised of both sexes and a wide range of sizes. Catch again declined in 2000 (17 individuals), rebounded slightly in 2001 (98 individuals) and more recently declined again to low levels (15 individuals).

## Summary / Conclusions

Fish catch in Suisun Marsh has fluctuated considerably since sampling began in 1979. Throughout this time period both native and introduced species have declined in abundance from their historic levels with only a recent increase in native species abundance. Among the introduced species, striped bass and yellowfin goby are generally the most abundant and together often exceed the abundance of all native species combined. However, their abundance has fluctuated widely over the course of our study often driving large swings in introduced species abundance. This is the case in 2002 when both striped bass and yellowfin goby were captured in very low numbers. Historically abundant native species, including longfin smelt, splittail and tule perch, have also fluctuated considerably in abundance and until recently (1999 - 2002) have only been caught in very low numbers. The increase and sustained high abundance of splittail and tule perch in the last few years, is especially encouraging since historically, these two species comprised the largest percentage of the native species catch in Suisun Marsh. Further indications of a healthy population structure for both species are the presence of multiple age classes. Tule perch in particular have significantly increased in abundance and given the large number of adults present in 2002 will most likely continue to increase in abundance if environmental conditions remain favorable.  Despite the recent increases in splittail and tule perch, other native species once abundant in the early sampling years (Sacramento sucker, prickly sculpin, delta smelt and longfin smelt), have largely failed to recover or have only had moderate increases in abundance.

Factors responsible for native species declines are largely unknown, but are likely attributed to habitat alteration and environmental conditions, as well as impacts brought upon by the introduction of numerous fish and invertebrate species into the Sacramento-San Joaquin Estuary.  The continued increase in number of introduced species, the expansion of their range within the S.F. Estuary and the looming threat of future species introductions will likely further affect native species.  For example the recent introduction of the large shrimp, *Exopalaemon modestus* and its current high abundance may have profound effects on various prey species, such as mysid shrimp, which are already known to be an important food source for many of the native fishes in the estuary.  A lack of thorough understanding as to how alien species may affect the aquatic community in Suisun Marsh limits our ability to predict future trends in native and alien species abundance.  Additional studies, particularly addressing the impact of existing introduced species are needed and are being planned for the 2003-2004 field season.  In addition, continued monitoring of the fish populations in Suisun Marsh will enable further evaluation of factors believed to be contributing to native and alien species declines.

**Table 1.1A** Historic Suisun Marsh sampling locations (Priori to 1994). Many historic sites were only sampled between 1979 and 1981 with consistent sampling of 17 sites through 1994 in Suisun, Peytonia, Boynton, Cutoff, Spring Branch, Good Year, Montezuma, Nurse and Denverton Slough.

| Slough | Number of Sites |
|---|---|
| Suisun (SU) | 3 |
| Hill (HL) | 1 |
| Peytonia (PT) | 1 |
| Boynton (BY) | 3 |
| Cutoff (CO) | 2 |
| Grant (GR) | 4 |
| Spring Branch (SB) | 2 |
| Wells (WL) | 3 |
| Good Year (GY) | 1 |
| Montezuma (MZ) | 5 |
| Nurse (NS) | 1 |
| Denverton (DV) | 1 |
| **TOTAL** | **27** |

**Table 1.1B** Current Sampling Sites (1994-present).

| Slough | Site | Latitude | Longitude |
|---|---|---|---|
| Suisun | SU1 | 38° 13’ 2.0” N | 122° 01’ 43.1” W |
| Suisun | SU2 | 38° 12’ 8.2” N | 122° 02’ 22.7” W |
| Suisun | SU3 | 38° 08’ 22.0” N | 122° 04’ 22.7” W |
| Suisun | SU4 | 38° 07’ 36.0” N | 122° 04’ 51.4” W |
| Peytonia | PT1 | 38° 13’ 38.1” N | 122° 03’ 4.5” W |
| Peytonia | PT2 | 38° 13’ 18.0” N | 122° 02’ 34.5” W |
| Boynton | BY1 | 38° 12’ 40.0” N | 122° 03’ 12.5” W |
| Boynton | BY3 | 38° 12’ 41.3” N | 122° 02’ 38.3” W |
| Cutoff | CO1 | 38° 11’ 33.6” N | 122° 01’ 35.5” W |
| Cutoff | CO2 | 38° 11’ 21.7” N | 122° 01’ 13.1” W |
| Spring Branch | SB1 | 38° 12’ 2.8” N | 122° 01’ 48.5” W |
| Spring Branch | SB2 | 38° 11’ 57.1” N | 122° 01’ 53.5” W |
| Goodyear | GY1 | 38° 06’ 8.3” N | 122° 05’ 36.2” W |
| Goodyear | GY2 | 38° 06’ 27.5” N | 122° 05’ 52.1” W |
| Goodyear | GY3 | 38° 07’ 55.8” N | 122° 05’ 10.4” W |
| Montezuma | MZ1 | 38° 05’ 36.6” N | 121° 53’ 9.5” W |
| Montezuma | MZ2 | 38° 07’ 5.2” N | 121° 53’ 18.5” W |
| Nurse | NS2 | 38° 11’ 0.3” N | 121° 55’ 32.6” W |
| Nurse | NS3 | 38° 10’ 19.6” N | 121° 55’ 41.8” W |
| Denverton | DV2 | 38° 12’ 10.6” N | 121° 54’ 23.2” W |
| Denverton | DV3 | 38° 11’ 55.0” N | 121° 54’ 53.9” W |

**Table 1.2** Fishes of Suisun Marsh.

| Common Name | Scientific Name | Abbreviation |
|---|---|---|
| American shad | *Alosa sapidissima* | ASH |
| bay pipefish | *Syngnathus leptorhynchus* | BYP |
| bigscale logperch | *Percina macrolepida* | BLP |
| black bullhead | *Ictalurus melas* | BLB |
| black crappie | *Pomoxis nigromaculatus* | BC |
| bluegill | *Lepomis macrochirus* | BG |
| brown bullhead | *Ictalurus nebulosus* | BB |
| California halibut | *Paralichthys californicus* | CHA |
| channel catfish | *Ictalurus punctatus* | CC |
| chinook salmon | *Oncorhynchus tshawytscha* | KS |
| common carp | *Cyprinus carpio* | CP |
| delta smelt | *Hypomesus transpacificus* | DS |
| fathead minnow | *Pimephales promelas* | FHM |
| golden shiner | *Notemigonus crysoleucas* | GSH |
| goldfish | *Carassius auratus* | GF |
| green sturgeon | *Acipenser medirostris* | GS |
| green sunfish | *Lepomis cyanellus* | GSF |
| hardhead | *Mylopharodon conocephalus* | HH |
| hitch | *Lavinia exilicauda* | HCH |
| inland silversides | *Menidia beryllina* | ISS |
| largemouth bass | *Micropterus salmoides* | LMB |
| longfin smelt | *Spirinchus thaleichthys* | LFS |
| longjaw mudsucker | *Gillichthys mirabilis* | LJM |
| northern anchovy | *Engraulis mordax* | NAC |
| Pacific herring | *Clupea harengeus* | PH |
| Pacific lamprey | *Lampetra tridentata* | PL |
| Pacific sanddab | *Citharichthys sordidus* | PSD |
| Pacific staghorn sculpin | *Leptocottus armatus* | STAG |

**Table 1.2 continued**

| Common Name | Scientific Name | Abbreviation |
| --- | --- | --- |
| plainfin midshipman | *Porichthys notatus* | MID |
| prickly sculpin | *Cottus asper* | SCP |
| rainbow trout | *Oncorhynchus mykiss* | RT |
| rainwater killifish | *Lucania parva* | RWK |
| redear sunfish | *Lepomis microlophus* | RS |
| Sacramento blackfish | *Orthodon microlepidotus* | BF |
| Sacramento pikeminnow | *Ptychocheilus grandis* | SPM |
| Sacramento sucker | *Catostomus occidentalis* | SKR |
| shokihaze goby | *Tridentiger barbatus* | SKG |
| shimofuri goby | *Tridentiger bifasciatus* | SG |
| shiner perch | *Cymatogaster aggregata* | SP |
| speckled sanddab | *Citharichthys stigmaeus* | DAB |
| splittail | *Pogonichthys macrolepidotus* | ST |
| starry flounder | *Platichthys stellatus* | SF |
| striped bass | *Morone saxatilis* | SB |
| surf smelt | *Hypomesus pretiosus* | SS |
| threadfin shad | *Dorosoma petenense* | TFS |
| threespine stickleback | *Gasterosteus aculeatus* | STBK |
| topsmelt | *Atherinops affinis* | TPS |
| tule perch | *Hysterocarpus traski* | TP |
| wakasagi | *Hypomesus nipponensis* | WAK |
| warmouth | *Lepomis gulosus* | WM |
| western mosquitofish | *Gambusia affinis* | MQF |
| white catfish | *Ameiurus catus* | WCF |
| white crappie | *Pomoxis annularis* | WC |
| white croaker | *Genyonemus lineatus* | WCK |
| white sturgeon | *Acipenser transmontanus* | WS |
| yellowfin goby | *Acanthogobius flavimanus* | YFG |

**Table 1. 3** Mean salinity (‰), temperature (°C), secchi depth (cm) and dissolved oxygen (mg/l$O_2$) per month. Seventeen sites were sampled in most months prior to 1994, while 21 sites were sampled after 1994. Monthly dissolved oxygen monitoring began in 2000.

**Salinity (‰)**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1980** | 1.4 | 1.4 | 1.8 | 1.6 | 1.3 | 1.6 | 1.3 | 2.9 | 4.2 | | 4.3 | 4.6 |
| **1981** | 4.4 | 2.8 | 3.0 | 2.1 | 3.0 | 3.9 | 5.3 | 6.8 | 7.9 | 7.6 | 8.8 | 2.8 |
| **1982** | 1.9 | 1.5 | 1.5 | 0.4 | 0.8 | 0.6 | 0.7 | 1.5 | 1.8 | 0.9 | 1.3 | 0.7 |
| **1983** | 0.4 | 0.3 | 0.1 | 0.3 | 0.6 | 0.4 | 0.2 | 0.4 | 0.4 | 0.3 | 0.2 | - |
| **1984** | 0.2 | 0.7 | 0.6 | 0.8 | 1.9 | 2.7 | - | 3.9 | 3.6 | 3.4 | 2.7 | - |
| **1985** | - | 2.5 | 2.2 | 2.9 | 3.3 | - | 4.9 | 8.0 | 8.3 | 10.2 | 8.5 | 7.5 |
| **1986** | 2.7 | 0.6 | 0.7 | 1.1 | 2.8 | 4.4 | 4.3 | - | 4.0 | 3.3 | 4.1 | 4.7 |
| **1987** | 3.9 | 2.5 | 2.5 | 3.1 | 4.3 | 7.7 | 7.2 | 6.1 | 6.4 | 9.6 | 9.5 | 7.0 |
| **1988** | 3.3 | 4.7 | 6.1 | 3.3 | 3.5 | 4.5 | 4.6 | 5.4 | 4.7 | 4.5 | 4.2 | 2.7 |
| **1989** | - | 2.9 | 1.3 | 3.4 | 3.5 | 5.3 | 6.6 | 6.5 | 6.3 | - | 5.0 | 6.3 |
| **1990** | 4.2 | 3.6 | 4.4 | 5.4 | 5.7 | 4.2 | 5.7 | 6.4 | 7.3 | - | 9.3 | 8.8 |
| **1991** | 8.1 | 6.5 | 3.0 | 2.6 | 5.5 | 7.5 | 8.4 | 8.9 | 8.4 | 9.6 | 8.1 | 8.4 |
| **1992** | 7.1 | 4.5 | 2.5 | 2.2 | 4.8 | 6.6 | 7.8 | 9.7 | 9.4 | 10.2 | 8.1 | 4.4 |
| **1993** | 2.1 | 1.4 | 0.9 | 1.7 | 1.1 | 0.9 | 2.2 | 2.5 | 3.5 | 4.4 | 4.1 | 4.1 |
| **1994** | 2.8 | 1.5 | 1.2 | 1.9 | 2.1 | 3.7 | 6.1 | 7.7 | 6.9 | 5.5 | 5.6 | 3.0 |
| **1995** | 1.0 | 0.7 | 0.3 | 0.6 | 0.4 | 0.3 | 0.2 | 1.0 | 1.0 | 1.5 | 3.8 | 2.0 |
| **1996** | 1.2 | 0.5 | 0.6 | 0.8 | 0.8 | 0.6 | 2.4 | 3.4 | 4.2 | 6.3 | 4.4 | 2.1 |
| **1997** | 0.5 | 0.9 | 1.1 | 1.6 | 2.6 | 3.9 | 5.1 | 5.3 | 5.4 | 6.9 | 5.9 | 2.7 |
| **1998** | 1.4 | 0.6 | 0.8 | 0.9 | 1.0 | 0.7 | 0.6 | 0.9 | 1.1 | 1.2 | 1.8 | 1.0 |
| **1999** | 1.0 | 0.7 | 0.6 | 1.2 | 0.8 | 0.9 | 1.7 | 2.6 | 4.0 | 4.4 | 5.4 | 4.5 |
| **2000** | 2.3 | 0.9 | 1.1 | 1.2 | 1.0 | 1.7 | 3.4 | 3.7 | 5.1 | 6.8 | 5.9 | 3.7 |
| **2001** | 2.7 | 1.6 | 1.0 | 1.3 | 1.9 | 2.6 | 5.1 | 7.3 | 8.1 | 9.2 | 6.4 | 1.8 |
| **2002** | 1.2 | 2.5 | 2.2 | 2.2 | 2.6 | 2.5 | 5.5 | 6.7 | 7.3 | 6.2 | 6.9 | 2.9 |

**Table 1. 3 continued**

**Temperature (°C):**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1980** | 9.8 | 11.0 | 12.1 | 17.2 | 18.1 | 20.5 | 20.4 | 21.6 | 20.3 | - | 15.7 | 9.5 |
| **1981** | 9.0 | 12.5 | 15.0 | 17.6 | 20.0 | 21.5 | 22.9 | 22.1 | 20.5 | 16.9 | 15.4 | 10.6 |
| **1982** | 7.7 | 8.9 | 13.2 | 14.5 | 13.1 | 20.0 | 23.9 | 19.8 | 20.9 | 17.3 | 9.7 | 9.1 |
| **1983** | 8.3 | 13.5 | 13.3 | 14.6 | 19.4 | 18.7 | 20.4 | 19.9 | 20.0 | 17.5 | 11.1 | - |
| **1984** | 7.8 | 12.4 | 16.5 | 16.5 | 21.5 | 22.8 | - | 25.6 | 24.4 | 15.0 | 12.8 | - |
| **1985** | - | 8.3 | 10.8 | 18.2 | 21.6 | - | 24.8 | 20.3 | 19.2 | 17.0 | 9.2 | 5.5 |
| **1986** | 10.3 | 15.2 | 17.0 | 19.1 | 21.4 | 20.4 | 20.7 | - | 19.2 | 16.6 | 14.5 | 9.3 |
| **1987** | 7.3 | 11.5 | 15.4 | 20.3 | 18.8 | 19.0 | 22.9 | 21.9 | 20.6 | 17.0 | 12.7 | 8.3 |
| **1988** | 10.5 | 9.7 | 15.5 | 18.5 | 19.7 | 22.3 | 22.2 | 22.9 | 18.0 | 14.0 | 11.8 | 5.5 |
| **1989** | - | 8.6 | 15.4 | 17.2 | 20.5 | 19.4 | 22.7 | 21.5 | 19.7 | - | 11.2 | 10.7 |
| **1990** | 8.1 | 10.3 | 15.5 | 19.0 | 18.9 | 21.0 | 21.3 | 24.1 | 20.7 | - | 12.3 | 9.5 |
| **1991** | 6.7 | 12.2 | 11.8 | 15.0 | 17.7 | 18.4 | 20.3 | 20.9 | 19.1 | 19.1 | 15.3 | 9.4 |
| **1992** | 8.1 | 11.5 | 15.0 | 16.6 | 19.5 | 19.2 | 22.3 | 20.2 | 21.1 | 21.6 | 19.0 | 11.0 |
| **1993** | 8.2 | 12.4 | 17.6 | 17.0 | 20.1 | 24.3 | 22.2 | 23.1 | 20.0 | 19.0 | 12.0 | 11.9 |
| **1994** | 9.5 | 11.0 | 14.9 | 18.2 | 18.7 | 21.1 | 21.3 | 22.9 | 20.5 | 17.9 | 10.5 | 8.6 |
| **1995** | 9.8 | 13.2 | 13.3 | 15.7 | 19.6 | 20.8 | 21.3 | 22.3 | 19.7 | 16.2 | 16.1 | 10.9 |
| **1996** | 9.9 | 13.1 | 15.0 | 17.7 | 19.0 | 21.7 | 21.4 | 19.7 | 19.1 | 15.0 | 14.0 | 11.0 |
| **1997** | 12.7 | 11.7 | 16.1 | 16.9 | 20.1 | 22.6 | 22.9 | 20.5 | 21.0 | 15.4 | 13.8 | 8.7 |
| **1998** | 10.9 | 12.0 | 15.4 | 15.1 | 17.6 | 18.6 | 23.3 | 20.8 | 19.9 | 15.8 | 12.4 | 8.7 |
| **1999** | 6.1 | 11.3 | 13.6 | 16.6 | 18.3 | 19.0 | 22.2 | 20.4 | 19.7 | 19.2 | 12.8 | 9.5 |
| **2000** | 11.4 | 12.2 | 14.6 | 17.5 | 19.2 | 20.2 | 20.2 | 20.6 | 22.6 | 14.5 | 10.6 | 10.4 |
| **2001** | 8.3 | 9.7 | 12.7 | 15.3 | 20.0 | 22.5 | 20.2 | 21.9 | 19.6 | 17.8 | 15.6 | 9.4 |
| **2002** | 8.8 | 11.2 | 12.4 | 16.7 | 19.0 | 22.4 | 21.3 | 21.1 | 21.3 | 21.9 | 13.8 | 11.6 |

**Table 1. 3 continued**

**Secchi (cm):**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1980 | 22.5 | 22.6 | 20.2 | 18.3 | 16.4 | 14.9 | 15.6 | 22.2 | 25.6 | | 25.3 | 27.0 |
| 1981 | 26.6 | 18.5 | 18.2 | 17.5 | 18.8 | 19.9 | 20.8 | 23.8 | 35.2 | 38.7 | 33.7 | 19.3 |
| 1982 | 22.2 | 26.2 | 20.6 | 19.6 | 14.1 | 16.6 | 14.8 | 15.9 | 18.4 | 20.4 | 19.4 | 25.7 |
| 1983 | 28.1 | 21.8 | 19.1 | 19.9 | 15.7 | 16.5 | 19.0 | 20.5 | 27.0 | 19.0 | 25.9 | - |
| 1984 | 30.4 | 22.1 | 16.5 | 16.0 | 22.3 | 41.3 | - | 30.2 | 35.5 | 28.4 | 27.8 | - |
| 1985 | - | 24.6 | 23.1 | 18.0 | 22.5 | - | 21.5 | 24.1 | 33.4 | 39.8 | 49.8 | 41.0 |
| 1986 | 21.6 | 18.1 | 17.8 | 18.8 | 15.6 | 15.8 | 19.1 | - | 20.6 | 24.2 | 24.4 | 29.1 |
| 1987 | 29.5 | 19.9 | 17.9 | 20.6 | 19.8 | 21.4 | 24.9 | 30.3 | 34.2 | 29.6 | 30.6 | 24.4 |
| 1988 | 30.2 | 20.4 | 18.4 | 25.8 | 19.9 | 28.5 | 22.8 | 25.5 | 30.1 | 31.3 | 29.8 | 28.1 |
| 1989 | - | 29.7 | 17.4 | 15.0 | 13.6 | 19.8 | - | 22.8 | 20.4 | - | 22.3 | 28.4 |
| 1990 | 25.4 | 21.7 | 21.3 | 16.1 | 20.7 | 14.9 | 19.0 | 18.8 | 25.1 | - | 27.7 | 28.1 |
| 1991 | 37.8 | 25.4 | 16.1 | 14.0 | 14.0 | 15.8 | 19.6 | 23.3 | 29.2 | 36.3 | 30.7 | 28.1 |
| 1992 | 26.7 | 24.8 | 19.0 | 16.2 | 17.4 | 21.1 | 22.1 | 21.2 | 28.5 | 34.6 | 25.9 | 25.4 |
| 1993 | 18.9 | 16.5 | 21.0 | 17.8 | 16.0 | 13.5 | 16.1 | 14.5 | 16.3 | 22.7 | 25.9 | 28.0 |
| 1994 | 25.0 | 19.2 | 18.3 | 20.4 | 15.9 | 19.3 | 17.9 | 23.5 | 21.9 | 23.3 | 21.9 | 25.6 |
| 1995 | 13.3 | 15.1 | 12.7 | 13.2 | 13.7 | 15.8 | 12.7 | 12.7 | 12.9 | 19.6 | 21.6 | 20.5 |
| 1996 | 16.4 | 16.6 | 16.3 | 15.4 | 16.5 | 14.2 | 22.2 | 20.8 | 25.1 | 33.7 | 25.9 | 23.2 |
| 1997 | 16.0 | 15.4 | 13.2 | 12.1 | 16.9 | 20.0 | 24.4 | 25.7 | 31.5 | 38.6 | 36.1 | 24.9 |
| 1998 | 26.6 | 21.8 | 21.9 | 20.1 | 16.5 | 17.8 | 14.0 | 16.1 | 13.8 | 17.1 | 20.2 | 20.8 |
| 1999 | 24.5 | 16.3 | 23.4 | 16.3 | 12.4 | 12.7 | 15.9 | 18.9 | 21.6 | 25.6 | 28.8 | 22.3 |
| 2000 | 24.0 | 20.6 | 17.9 | 14.3 | 14.7 | 15.3 | 23.8 | 26.3 | 30.6 | 27.2 | 33.6 | 31.3 |
| 2001 | 30.1 | 26.0 | 19.6 | 20.5 | 20.8 | 22.5 | 27.9 | 28.4 | 33.2 | 31.8 | 29.5 | 27.0 |
| 2002 | 22.1 | 21.7 | 22.3 | 20.4 | 23.6 | 25.0 | 26.3 | 37.6 | 35.8 | 32.7 | 32.6 | 24.0 |

**Dissolved Oxygen (mg/l):**

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sept | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 7.9 | 10.3 | 7.6 | 7.5 | 7.0 | 7.0 | 7.6 | 7.9 | 7.2 | 7.6 | 8.3 | 8.0 |
| 2001 | 9.8 | 9.2 | 8.5 | 8.8 | 7.7 | 7.2 | 8.2 | 7.9 | 8.0 | 5.6 | 6.2 | 9.7 |
| 2002 | 9.0 | 8.7 | 8.9 | 9.9 | 6.7 | 7.0 | 7.5 | 7.1 | 6.6 | 6.6 | 8.2 | 9.0 |

**Table 1. 4** Summary of Suisun Marsh data 1979-1998. Fish, Crangon, Palaemon and Exopalaemon (Exopal) are average numbers per trawl. Exopalaemon were first recorded in 2002, but were likely a large component of the Palaemon catch in 2001. Mysids is an abundance index with 5 = most abundant. Salinity (‰), temperature (°C), secchi (cm) and dissolved oxygen (D.O; first recorded in 2000) are yearly averages.

| Year | Fish | Crangon | Palaemon | Exopal | Mysids | Salinity | Temp | DO | Secchi |
|---|---|---|---|---|---|---|---|---|---|
| **1980** | 49.4 | 59.1 | 14.5 | | 1.9 | 2.7 | 16.2 | | 21.5 |
| **1981** | 58.1 | 44.5 | 12.0 | | 1.8 | 4.3 | 17.1 | | 23.0 |
| **1982** | 37.8 | 40.4 | 8.2 | | 2.5 | 1.2 | 15.3 | | 20.1 |
| **1983** | 34.0 | 3.2 | 3.1 | | 2.2 | 0.3 | 16.0 | | 20.5 |
| **1984** | 31.2 | 16.7 | 3.0 | | 2.3 | 2.1 | 17.4 | | 26.8 |
| **1985** | 20.6 | 6.3 | 8.1 | | 2.2 | 5.5 | 15.5 | | 28.6 |
| **1986** | 29.8 | 40.0 | 4.9 | | 1.9 | 2.9 | 16.9 | | 20.4 |
| **1987** | 22.6 | 53.5 | 14.6 | | 1.9 | 5.8 | 16.0 | | 25.2 |
| **1988** | 17.6 | 27.3 | 5.1 | | 1.8 | 4.3 | 15.6 | | 25.8 |
| **1989** | 24.1 | 50.5 | 10.1 | | 2.4 | 4.6 | 17.3 | | 20.6 |
| **1990** | 11.8 | 26.0 | 7.5 | | 2.2 | 6.0 | 16.4 | | 21.6 |
| **1991** | 18.7 | 42.9 | 4.3 | | 1.8 | 7.1 | 15.5 | | 24.2 |
| **1992** | 20.4 | 10.5 | 2.6 | | 1.2 | 6.5 | 17.0 | | 23.6 |
| **1993** | 25.2 | 16.8 | 1.5 | | 0.9 | 2.4 | 17.4 | | 19.0 |
| **1994** | 8.9 | 20.6 | 0.6 | | 0.6 | 4.3 | 16.6 | | 22.3 |
| **1995** | 23.5 | 48.6 | 1.5 | | 0.8 | 1.1 | 16.8 | | 15.5 |
| **1996** | 14.9 | 37.9 | 0.3 | | 1.0 | 2.3 | 16.7 | | 21.5 |
| **1997** | 25.3 | 136.3 | 3.4 | | 1.3 | 3.6 | 17.1 | | 23.6 |
| **1998** | 17.9 | 23.9 | 2.6 | | 1.2 | 1.1 | 16.3 | | 19.3 |
| **1999** | 26.2 | 17.0 | 0.1 | | 1.4 | 2.4 | 15.7 | | 20.1 |
| **2000** | 36.7 | 30.6 | 1.0 | | 1.5 | 3.2 | 16.2 | 7.9 | 23.6 |
| **2001** | 32.3 | 33.2 | 16.0 | | 1.2 | 4.1 | 16.0 | 8.2 | 26.8 |
| **2002** | 24.0 | 20.2 | 5.6 | 31.0 | 1.0 | 4.2 | 16.5 | 7.9 | 27.2 |

**Table 1.5** Total catch per year for species collected in Suisun Marsh trawls January 1979 - December 2002. See Table 1.1 for species represented by abbreviations.

| SPECIES | 1979 | 1980 | 1981 | 1982 | 1983 | 1984 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ASH | 21 | 36 | 156 | 8 | 2 | 5 | 8 | 7 | 7 | 6 | 2 | 16 | 3 | 6 | | 4 | 1 | 1 | 1 | | | 13 | 11 | 96 |
| BB | | 3 | 3 | 2 | 1 | 4 | 4 | 2 | | | 1 | | | | | 1 | | | | 1 | | | | 1 |
| BC | | 2 | 5 | 1 | 1 | | 2 | 78 | 7 | 4 | | | | | | | 1 | 3 | 10 | 5 | 127 | 47 | 79 | 17 |
| BF | 2 | 9 | 2 | 4 | 1 | | | | | | | | | | | | | | | | | | | |
| BG | | 5 | 1 | 4 | 1 | | | 1 | | | | | | | | | 1 | | | | | 1 | 1 | |
| BLB | | 2 | 1 | | | 11 | 17 | 4 | 1 | 1 | | | | | | 1 | 4 | 8 | 5 | 17 | 21 | 24 | 15 | 31 |
| BLP | | | | 10 | 1 | 1 | | 1 | | | | | | | | | | | | | 2 | | | |
| BYP | | | | | | | | | | | | | 1 | | | 1 | | | | | | | | |
| CC | | 4 | | 3 | 1 | 12 | 8 | 5 | 3 | 7 | | 1 | | | | 7 | 52 | 2 | 3 | 4 | 19 | 16 | 2 | 2 |
| CHA | | | | | | | | | | | | | 2 | 1 | | | | | | | | | | |
| CP | 214 | 586 | 586 | 171 | 69 | 69 | 257 | 262 | 74 | 46 | 61 | 44 | 61 | 28 | 45 | 35 | 66 | 53 | 202 | 121 | 89 | 77 | 99 | 146 |
| DAB | | | | | | | | | | | | 1 | | 2 | | | | | | | | | | |
| DS | 17 | 168 | 230 | 33 | 11 | | 1 | | | 1 | 1 | 1 | 5 | 3 | 7 | 16 | 2 | 12 | | 2 | 26 | 16 | 33 | 12 |
| FHM | | 6 | 2 | | | | 6 | 1 | | | 1 | | | | | | 1 | | 1 | | | | | 2 |
| GF | 6 | 23 | 5 | 2 | | 21 | 100 | 7 | 3 | 3 | 2 | | | 1 | 3 | 2 | | | 1 | 1 | 3 | 16 | 2 | 7 |
| GS | | | | | | | | | | | | | | | | | | 1 | | 2 | | | | |
| GSF | | 1 | 1 | | | | | | | | | | | | | | | | 1 | | | | | 2 |
| GSH | | | | | | | | | 2 | 1 | | | | | | | | | | | | | | |
| HCH | | 13 | 24 | 8 | 6 | 6 | 19 | 2 | 10 | 9 | | 3 | 1 | 1 | | 1 | 2 | | | 1 | | | | 2 |
| HH | | | | | | | | | | | | | | | | | | | | | | | 1 | |
| ISS | 10 | 25 | 54 | 6 | 3 | 22 | 128 | 8 | 16 | 22 | 14 | 13 | 18 | 7 | 3 | 15 | 12 | 4 | 7 | 4 | 7 | 6 | 12 | 16 |
| KS | | 13 | 19 | | 11 | 1 | | 13 | 1 | 1 | 1 | | | | | | 2 | 1 | | 1 | 2 | 3 | 2 | |
| LFS | 14 | 3244 | 954 | 1701 | 279 | 553 | 161 | 102 | 110 | 194 | 131 | 242 | 21 | 3 | 3 | 6 | 82 | 8 | 5 | 21 | 1131 | 393 | 290 | 658 |
| LJM | | | | | 1 | | | | | | | | | | | | | | | | | | | |
| MID | | | | | | | | | | | | 2 | | 1 | 1 | 4 | | 2 | | | | | | 1 |
| MQF | | | 4 | 2 | | 4 | | 1 | | | | | | | 1 | 1 | | | 2 | | | 1 | | 1 |
| NAC | 2 | 14 | 155 | | | 1 | 15 | 1 | 6 | 5 | 2 | 2 | 3 | 22 | | | | | | | | | 27 | |
| PH | | | 24 | 3 | 2 | 5 | 33 | 1 | 6 | 40 | 1 | 7 | 49 | | 1 | 4 | 1 | 25 | 11 | 2 | 3 | 7 | 56 | 42 |
| PL | | 1 | 4 | | | | | 1 | | | | 1 | | 6 | | | 19 | 1 | 1 | 4 | 1 | 2 | 1 | 1 |
| PSD | | | | | | | | | | | | | | | | | | 1 | | | | | | 1 |
| RS | | | | | | | | | | | | | | | | | | | 1 | | 1 | | | |
| RT | | | | 2 | | | 2 | | | 1 | | | | | | | | | 1 | | | | | 1 |
| RWK | | 3 | | | | 1 | | | | 1 | 3 | | 2 | | | | | | | 6 | | | | |
| SB | 4256 | 6471 | 9209 | 3252 | 3962 | 2287 | 2247 | 2694 | 1414 | 1232 | 1169 | 383 | 1582 | 2691 | 1010 | 792 | 1481 | 1517 | 3045 | 700 | 2060 | 2843 | 4246 | 1483 |
| SCP | 308 | 1572 | 650 | 639 | 1176 | 127 | 74 | 376 | 51 | 114 | 41 | 11 | 175 | 137 | 242 | 68 | 674 | 523 | 543 | 397 | 152 | 312 | 18 | 68 |
| SF | 19 | 567 | 236 | 28 | 79 | 20 | 29 | 39 | 15 | 36 | 9 | 14 | 50 | 12 | 6 | 34 | 17 | 39 | 138 | 68 | 20 | 10 | 1 | 23 |
| SG | | | | | | | 2 | | 82 | 282 | 1253 | 819 | 696 | 353 | 117 | 534 | 117 | 48 | 1202 | 133 | 384 | 140 | 659 | 515 |
| SKG | | | | | | | | | | | | | | | | | | | | | 1 | | 34 | 78 |
| SKR | 155 | 544 | 610 | 172 | 183 | 99 | 141 | 101 | 68 | 51 | 21 | 21 | 6 | 7 | 18 | 19 | 34 | 63 | 58 | 68 | 51 | 52 | 44 | 56 |
| SP | | 2 | 3 | | | | | | 1 | | | 11 | | | | | | | | | | | | |
| SPM | 16 | 44 | 22 | 6 | 3 | 5 | 2 | 9 | 5 | 1 | | | | | | | 2 | | | 1 | | 1 | | 2 |
| SS | | 2 | 2 | | | | | | | | | | | | | | | | | | | | | |
| ST | 2048 | 3714 | 1848 | 1147 | 709 | 192 | 151 | 665 | 442 | 163 | 108 | 80 | 197 | 134 | 62 | 51 | 260 | 438 | 227 | 266 | 388 | 555 | 1186 | 1135 |
| STAG | 91 | 353 | 366 | 32 | 9 | 40 | 100 | 54 | 18 | 97 | 76 | 52 | 169 | 18 | 14 | 19 | 271 | 51 | 48 | 11 | 32 | 77 | 46 | 48 |
| STBK | 74 | 2962 | 5475 | 949 | 518 | 49 | 53 | 209 | 664 | 69 | 153 | 141 | 581 | 137 | 65 | 48 | 317 | 279 | 339 | 1275 | 102 | 760 | 80 | 141 |
| TFS | 35 | 380 | 404 | 87 | 42 | 218 | 37 | 42 | 69 | 20 | 2 | 10 | 5 | 18 | 24 | 17 | 10 | 91 | 20 | 34 | 52 | 57 | 56 | 106 |
| TP | 886 | 1922 | 2375 | 1559 | 175 | 109 | 499 | 602 | 1278 | 1275 | 237 | 184 | 189 | 210 | 97 | 158 | 93 | 85 | 251 | 158 | 40 | 56 | 444 | 856 |
| WAK | | | | | | | | | | | | | | | | | | | | | 1 | 5 | 1 | |
| WCF | 1 | 4 | 4 | 6 | 132 | 32 | 24 | 14 | 6 | 8 | | 6 | 2 | 1 | 3 | 6 | 51 | 190 | 79 | 276 | 232 | 331 | 109 | 204 |
| WC | | | | 6 | 2 | 1 | 3 | 9 | 8 | 3 | | | | 1 | 3 | | 9 | 44 | | 2 | | | | |
| WCK | | | | | | | | | | | | | | | | 1 | | | | | | | | |
| WM | | 1 | | | | | | | | | | | | | | | | | | | | | | |
| WS | | 4 | 1 | 4 | 8 | 5 | | 1 | 3 | 2 | | | 1 | 1 | 1 | 1 | 4 | 8 | 1 | 4 | 1 | 1 | 3 | |
| YFG | 173 | 1157 | 231 | 197 | 23 | 1004 | 206 | 559 | 278 | 112 | 368 | 145 | 34 | 336 | 3371 | 174 | 2176 | 249 | 182 | 284 | 1590 | 3427 | 513 | 151 |
| **TOTAL** | **8348** | **23857** | **23666** | **10044** | **7411** | **4904** | **4329** | **5871** | **4648** | **3807** | **3657** | **2210** | **3853** | **4137** | **5097** | **2020** | **5762** | **3747** | **6385** | **3869** | **6538** | **9249** | **8071** | **5905** |
| **# TRAWLS** | **79** | **483** | **407** | **266** | **218** | **157** | **210** | **197** | **206** | **216** | **152** | **188** | **206** | **203** | **202** | **228** | **245** | **252** | **252** | **216** | **250** | **252** | **250** | **246** |
| **CATCH/TRAWL** | **105.7** | **49.4** | **58.1** | **37.8** | **34.0** | **31.2** | **20.6** | **29.8** | **22.6** | **17.6** | **24.1** | **11.8** | **18.7** | **20.4** | **25.2** | **8.9** | **23.5** | **14.9** | **25.3** | **17.9** | **26.2** | **36.7** | **32.3** | **24.0** |

**Table 1. 6** Total catch per year for species collected in Suisun Marsh seine hauls from January 1995 **-** December 2002. See Table 1.1 for species represented by abbreviations.

| | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
|---|---|---|---|---|---|---|---|---|
| **ASH** | | | 1 | | | | 1 | 1 |
| **BC** | | | | 6 | 2 | 3 | 3 | 2 |
| **BF** | 5 | | | | | | | |
| **BG** | 1 | | | 1 | | | | |
| **BLB** | | | | | 2 | 1 | | |
| **BLP** | | 1 | | | 1 | | | |
| **CC** | | | 1 | 1 | 4 | | | |
| **CP** | 3 | 7 | 33 | 33 | 74 | 7 | 8 | 4 |
| **DS** | 17 | 2 | 1 | 1 | 1 | 5 | 1 | 1 |
| **FHM** | 1 | 3 | 6 | 3 | 3 | | | |
| **GF** | | 1 | | 1 | 4 | 3 | | |
| **GSH** | | | | 1 | | | | |
| **HCH** | 1 | | | 1 | 1 | | | |
| **ISS** | 1827 | 1991 | 4794 | 1091 | 1670 | 3052 | 4284 | 4033 |
| **KS** | 48 | 6 | 1 | 4 | 14 | 4 | 8 | 27 |
| **LFS** | 2 | | | | 2 | 1 | 1 | |
| **LMB** | | | | 1 | | | | |
| **MQF** | 18 | 19 | 35 | 22 | 30 | 2 | 1 | 1 |
| **PH** | | 1 | 4 | | 5 | 9 | 4 | 5 |
| **RT** | | 1 | | | 1 | | 1 | 1 |
| **RWK** | 6 | 1 | 1 | 1 | | 1 | 3 | 2 |
| **SB** | 203 | 492 | 1906 | 90 | 376 | 481 | 506 | 566 |
| **SCP** | 38 | 21 | 16 | 8 | 6 | 25 | 1 | 1 |
| **SF** | 4 | 18 | 23 | 2 | | 2 | | 1 |
| **SG** | 170 | 43 | 274 | 106 | 33 | 64 | 122 | 204 |
| **SKR** | 3 | 6 | 8 | 1 | 5 | 2 | 1 | 3 |
| **SPM** | 11 | 2 | 9 | 7 | 1 | 1 | 3 | |
| **ST** | 246 | 99 | 107 | 153 | 446 | 207 | 120 | 88 |
| **STAG** | 373 | 92 | 146 | 63 | 310 | 260 | 213 | 101 |
| **STBK** | 130 | 195 | 99 | 44 | 54 | 48 | 95 | 164 |
| **TFS** | 203 | 415 | 144 | 340 | 210 | 85 | 166 | 124 |
| **TP** | 95 | 41 | 27 | 100 | 13 | 19 | 17 | 26 |
| **WAK** | | | 1 | | | 3 | | |
| **WCF** | | 3 | 3 | 43 | 21 | 2 | 12 | 1 |
| **YFG** | 2075 | 909 | 611 | 770 | 1977 | 2288 | 708 | 412 |
| **Total** | 5480 | 4369 | 8251 | 2894 | 5266 | 6575 | 6279 | 5768 |
| **Number of siene hauls** | 72 | 84 | 84 | 74 | 84 | 84 | 84 | 80 |
| **Mean fish per haul** | 76.1 | 52.0 | 98.2 | 39.1 | 62.7 | 78.3 | 74.8 | 72.1 |

Figures

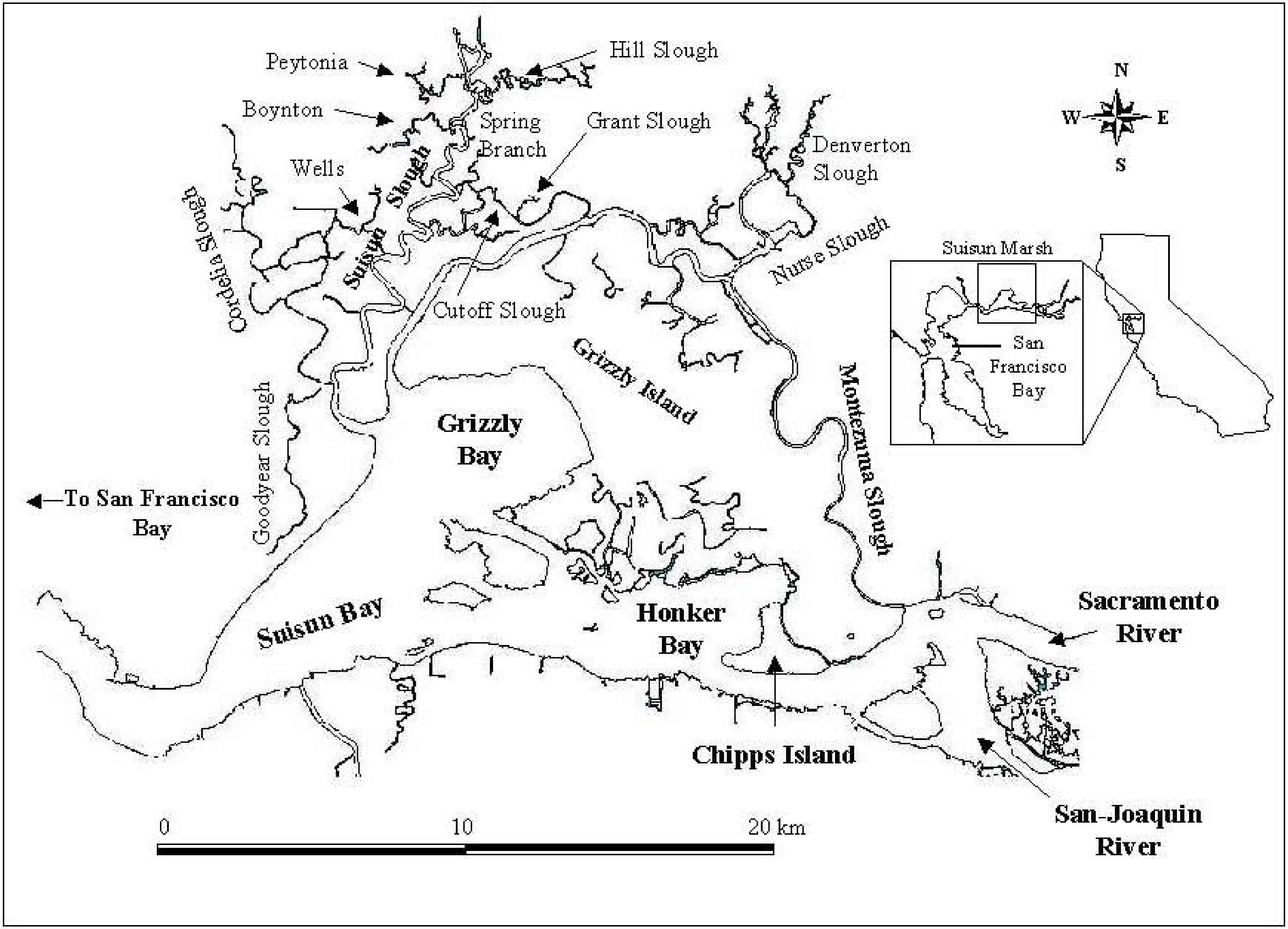
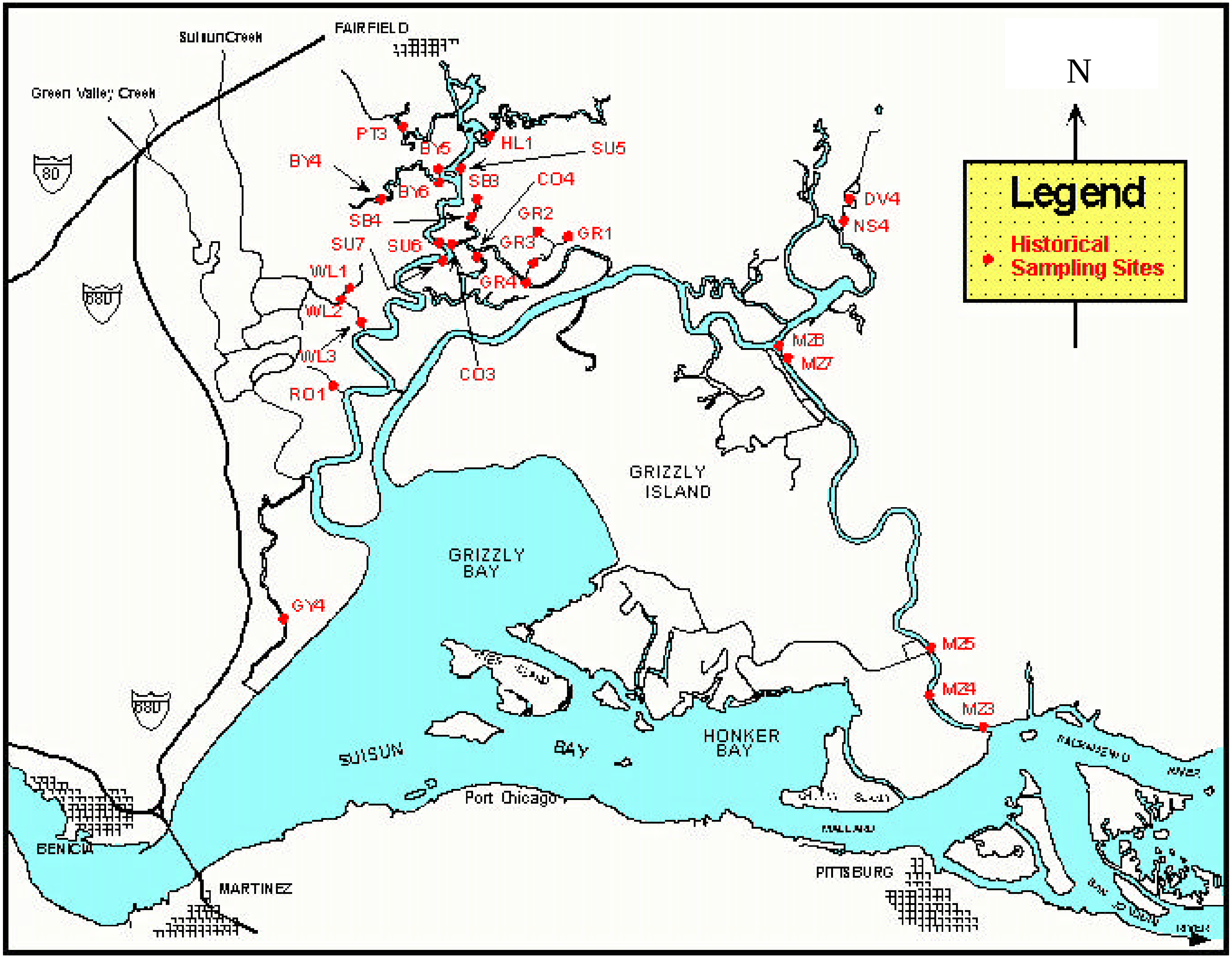

Hill Slough
Peytonia
Boynton
Spring Branch
Grant Slough
Denverton Slough
Wells
Suisun Slough
Cordelia Slough
Nurse Slough
Cutoff Slough
Grizzly Island
Montezuma Slough
Grizzly Bay
Goodyear Slough
To San Francisco Bay
Suisun Bay
Honker Bay
Sacramento River
Chipps Island
San-Joaquin River
0
10
20 km
N
W
E
S
Suisun Marsh
San Francisco Bay



Figure 1.1



FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
680
N
Legend
Historical Sampling Sites
PT3
BY5
HL1
SU5
BY4
BY6
SB3
CO4
SB4
GR2
GR1
GR3
SU7
SU6
WL1
GR4
WL2
DV4
NS4
MZ6
MZ7
WL3
CO3
RO1
GRIZZLY ISLAND
GRIZZLY BAY
GY4
MZ5
MZ4
MZ3
HONKER BAY
SUISUN
BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG




Figure 1.2

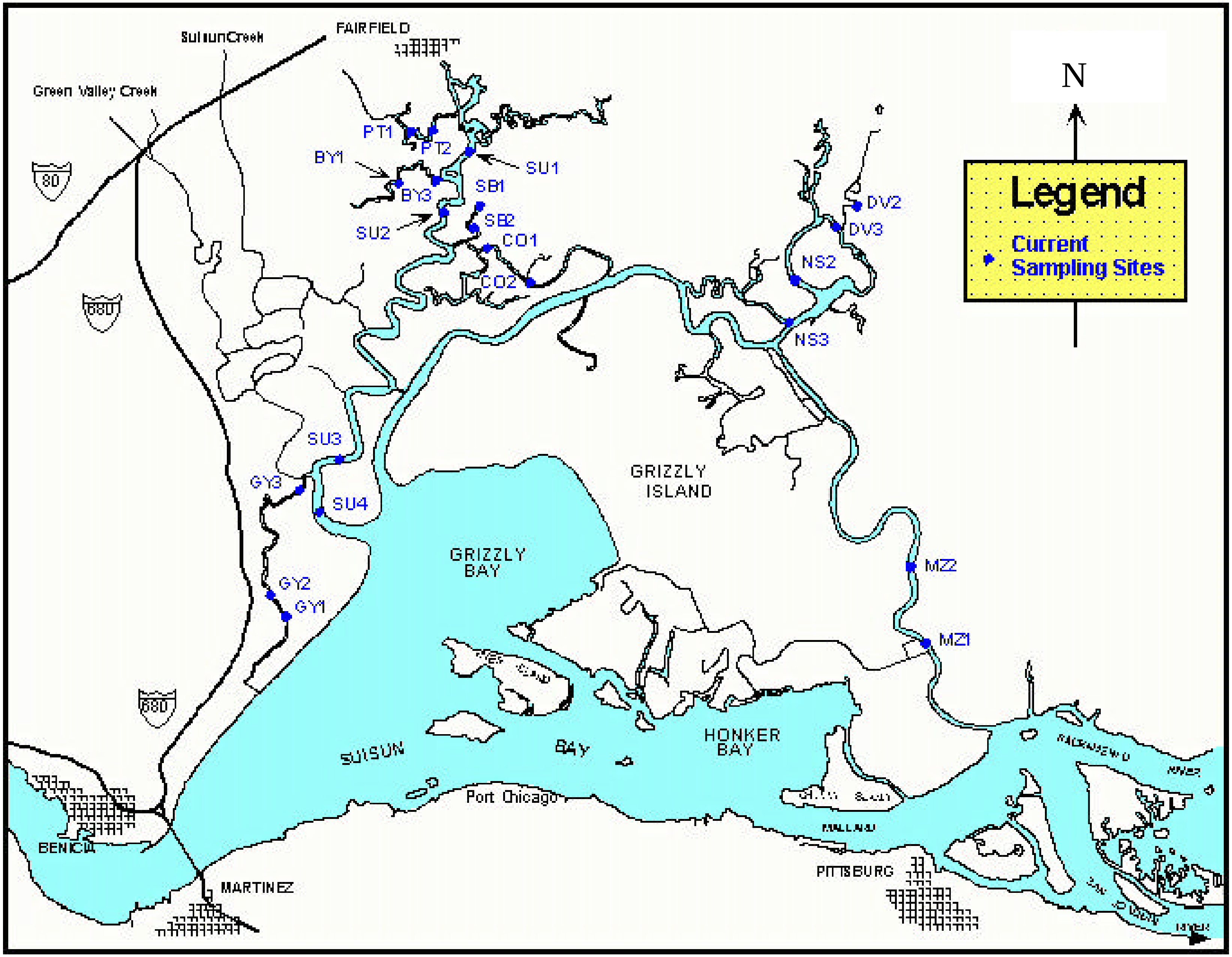
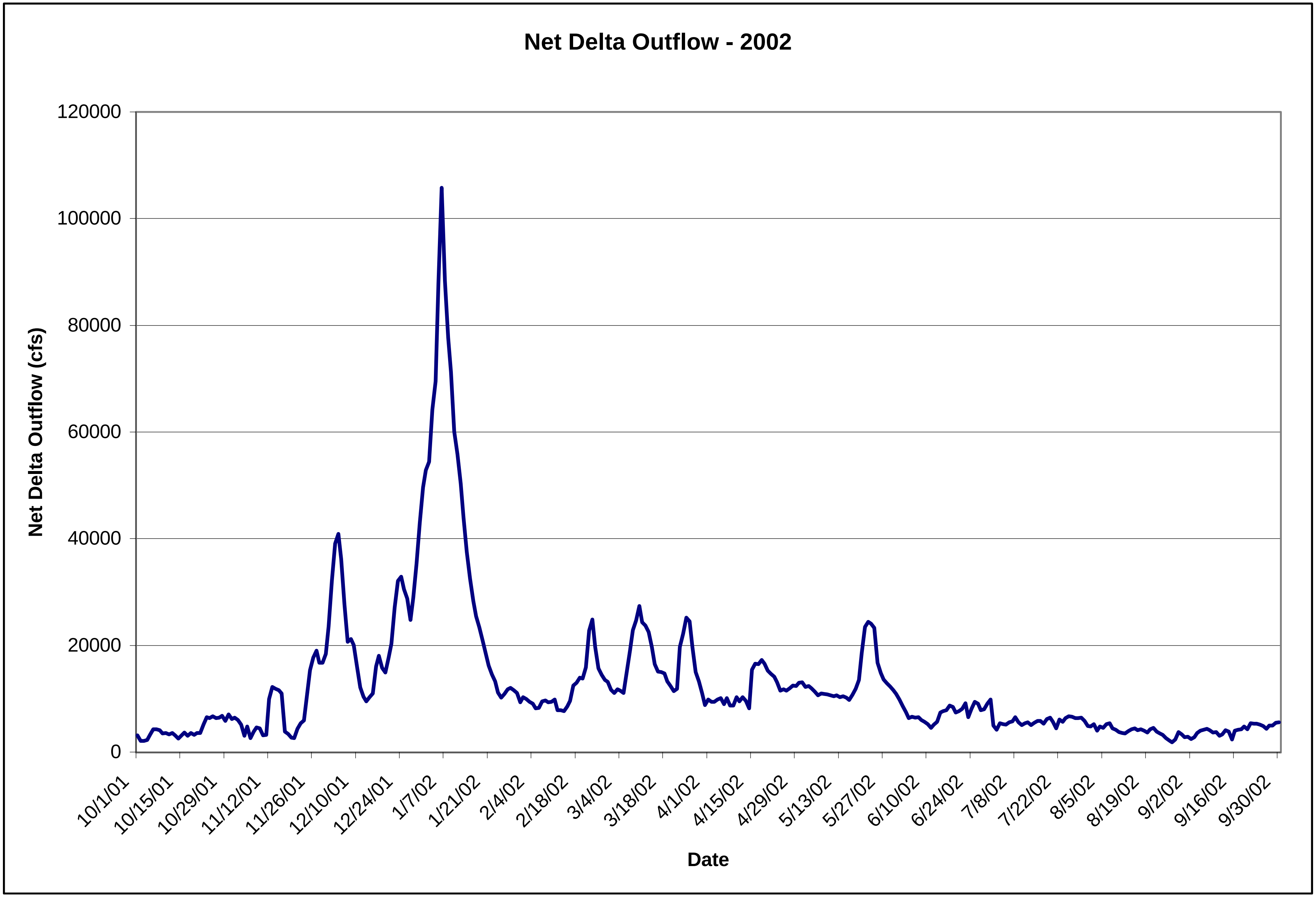

FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
680
N
Legend
Current Sampling Sites
PT1
PT2
BY1
BY3
SU1
SB1
SB2
SU2
CO1
CO2
DV2
DV3
NS2
NS3
SU3
GY3
SU4
GY2
GY1
MZ2
MZ1
GRIZZLY ISLAND
GRIZZLY BAY
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG



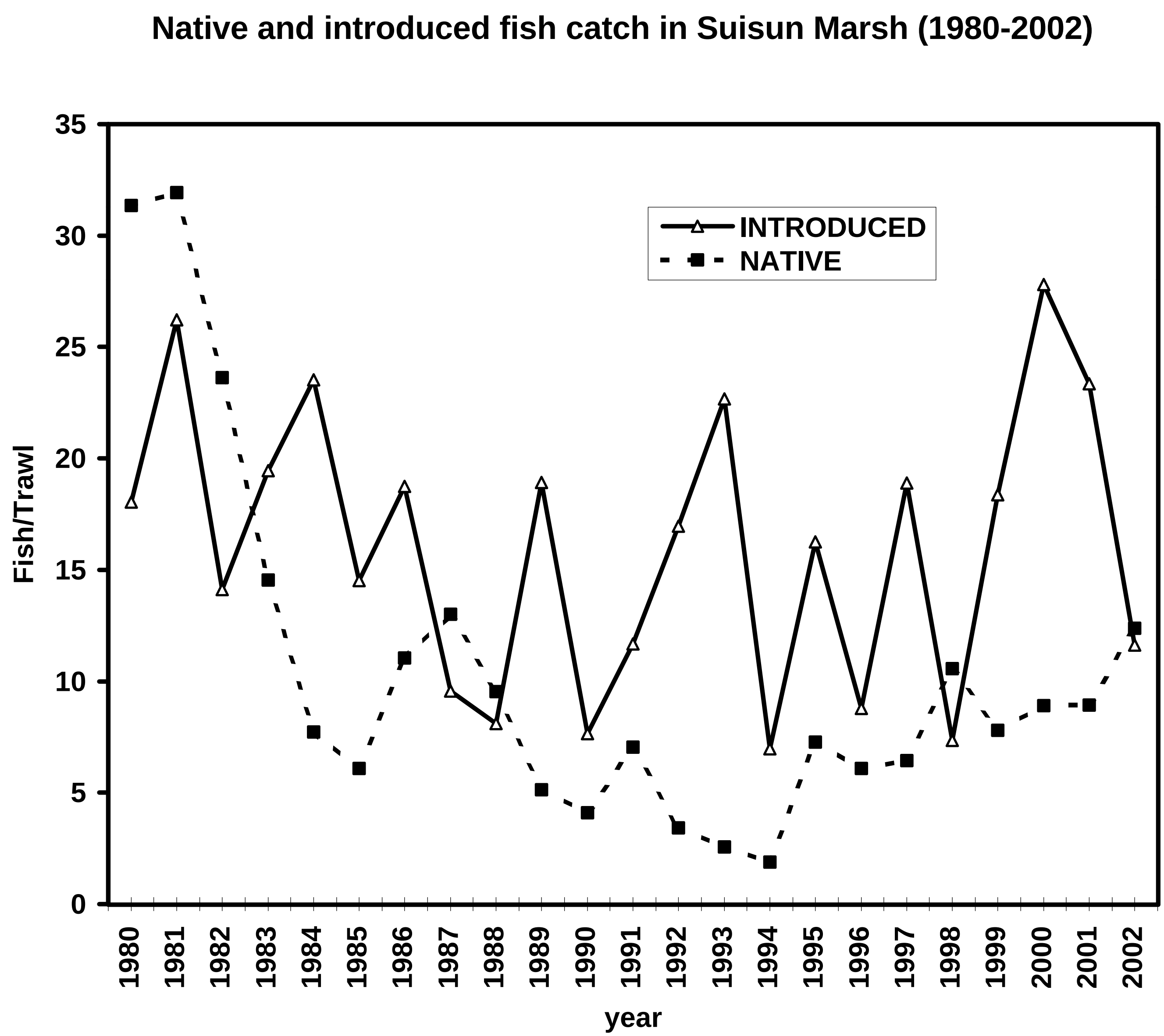
Figure 1.3



Net Delta Outflow - 2002
120000
100000
80000
60000
40000
20000
0
Net Delta Outflow (cfs)
10/1/01
10/15/01
10/29/01
11/12/01
11/26/01
12/10/01
12/24/01
1/7/02
1/21/02
2/4/02
2/18/02
3/4/02
3/18/02
4/1/02
4/15/02
4/29/02
5/13/02
5/27/02
6/10/02
6/24/02
7/8/02
7/22/02
8/5/02
8/19/02
9/2/02
9/16/02
9/30/02
Date




Figure 1.4



Native and introduced fish catch in Suisun Marsh (1980-2002)
INTRODUCED
NATIVE
Fish/Trawl
35
30
25
20
15
10
5
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
year




Figure 1.5

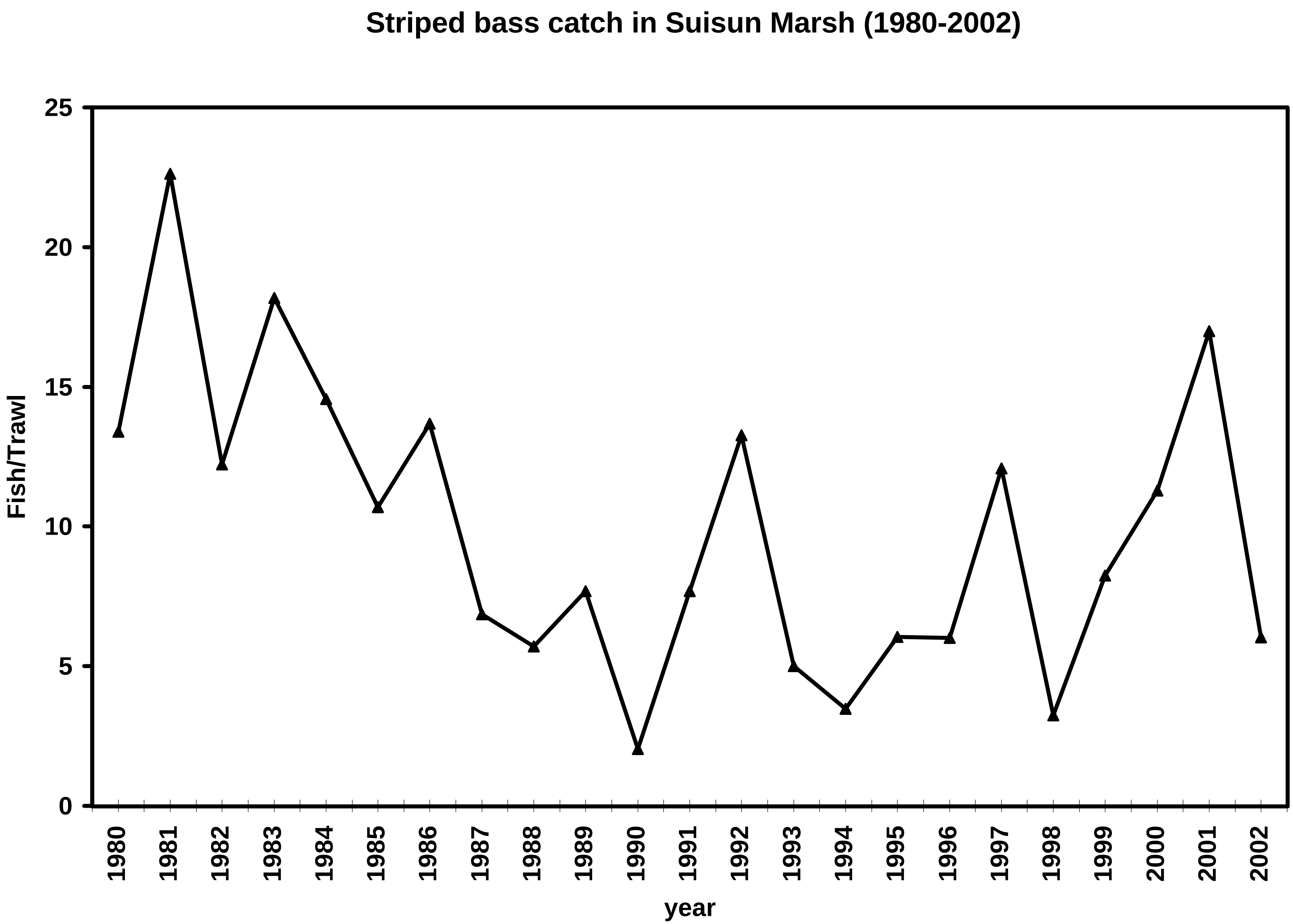
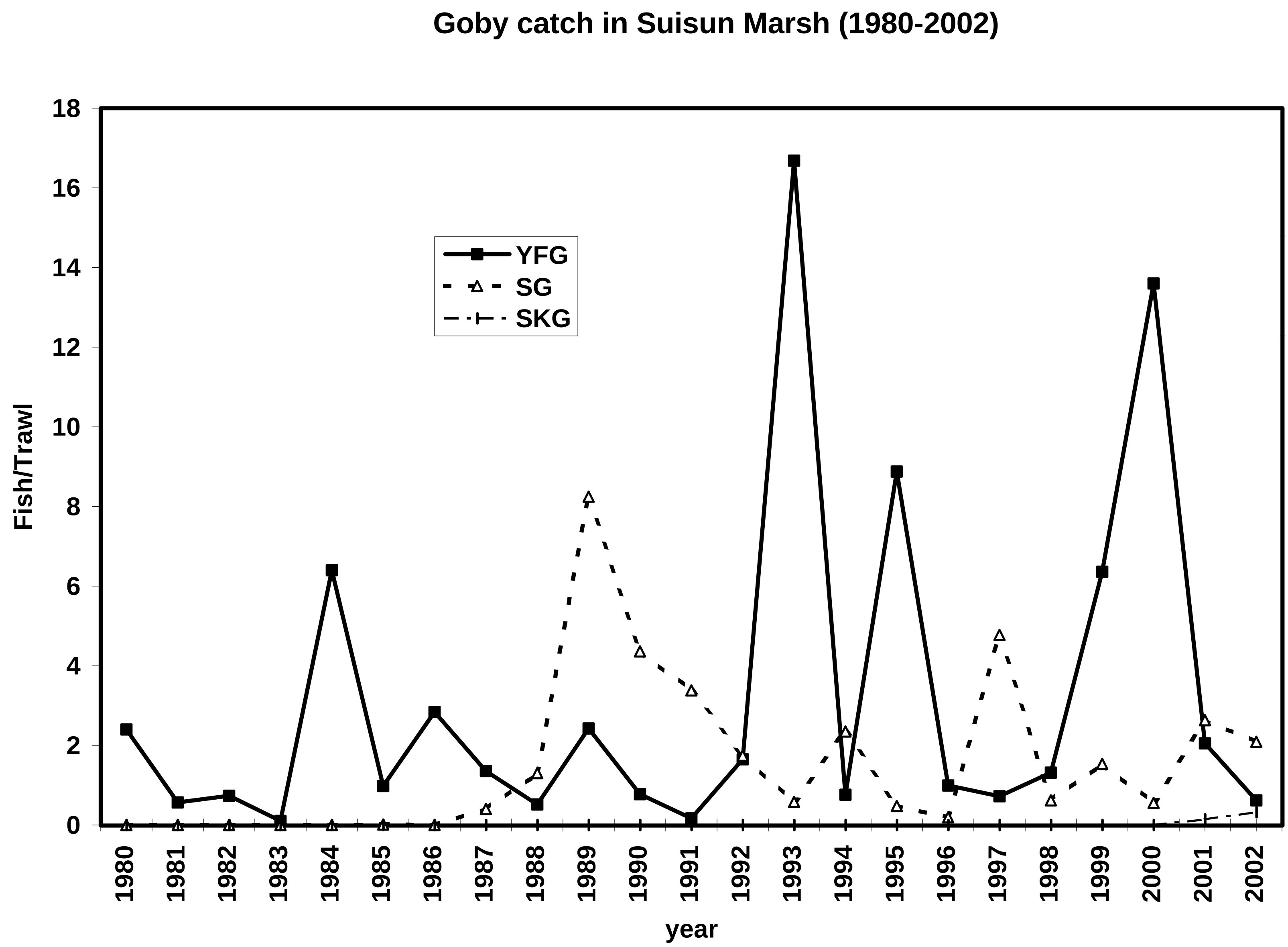

Striped bass catch in Suisun Marsh (1980-2002)
25
20
15
10
5
0
Fish/Trawl
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
year



Figure 1.6



Goby catch in Suisun Marsh (1980-2002)
Fish/Trawl
18
16
14
12
10
8
6
4
2
0
YFG
SG
SKG
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
year




Figure 1.7

## Splittail catch in Suisun Marsh (1980-2002)

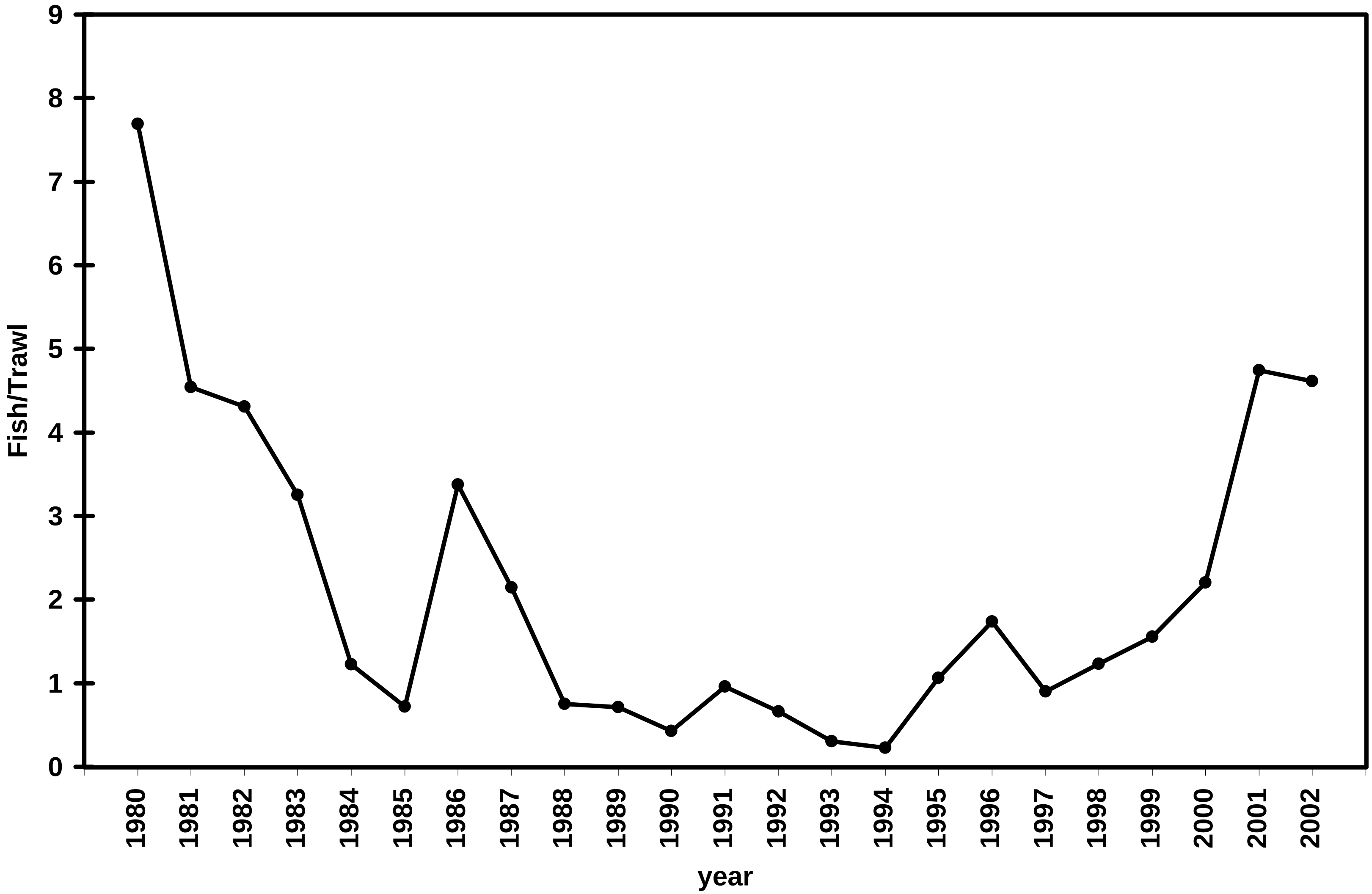





Figure 1.8

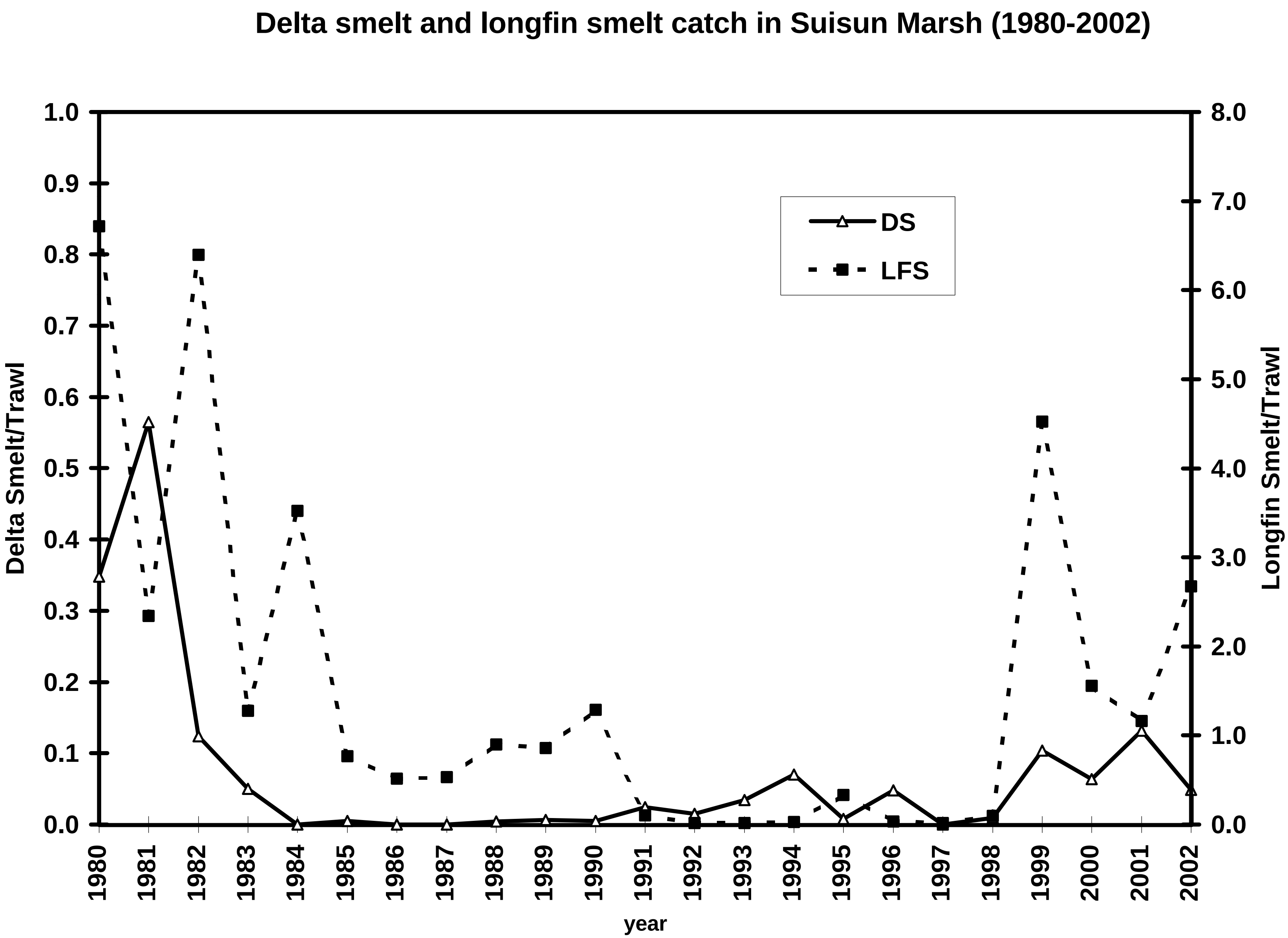
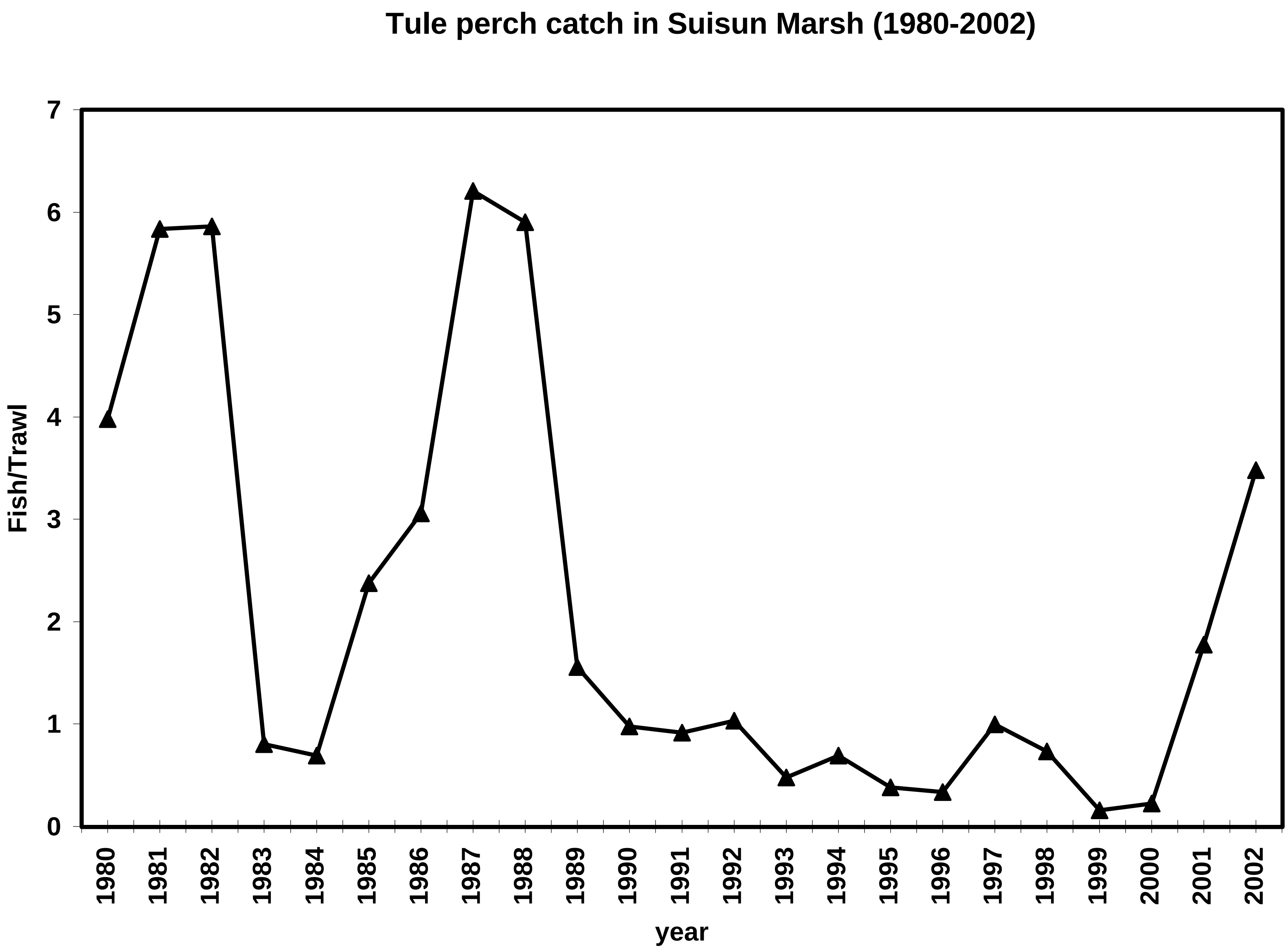

Delta smelt and longfin smelt catch in Suisun Marsh (1980-2002)
DS
LFS
Delta Smelt/Trawl
Longfin Smelt/Trawl
year
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002



Figure 1.9



Tule perch catch in Suisun Marsh (1980-2002)
Fish/Trawl
0
1
2
3
4
5
6
7
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
year




Figure 1.10

Sculpin and Sucker catch in Suisun Marsh (1980-2002)

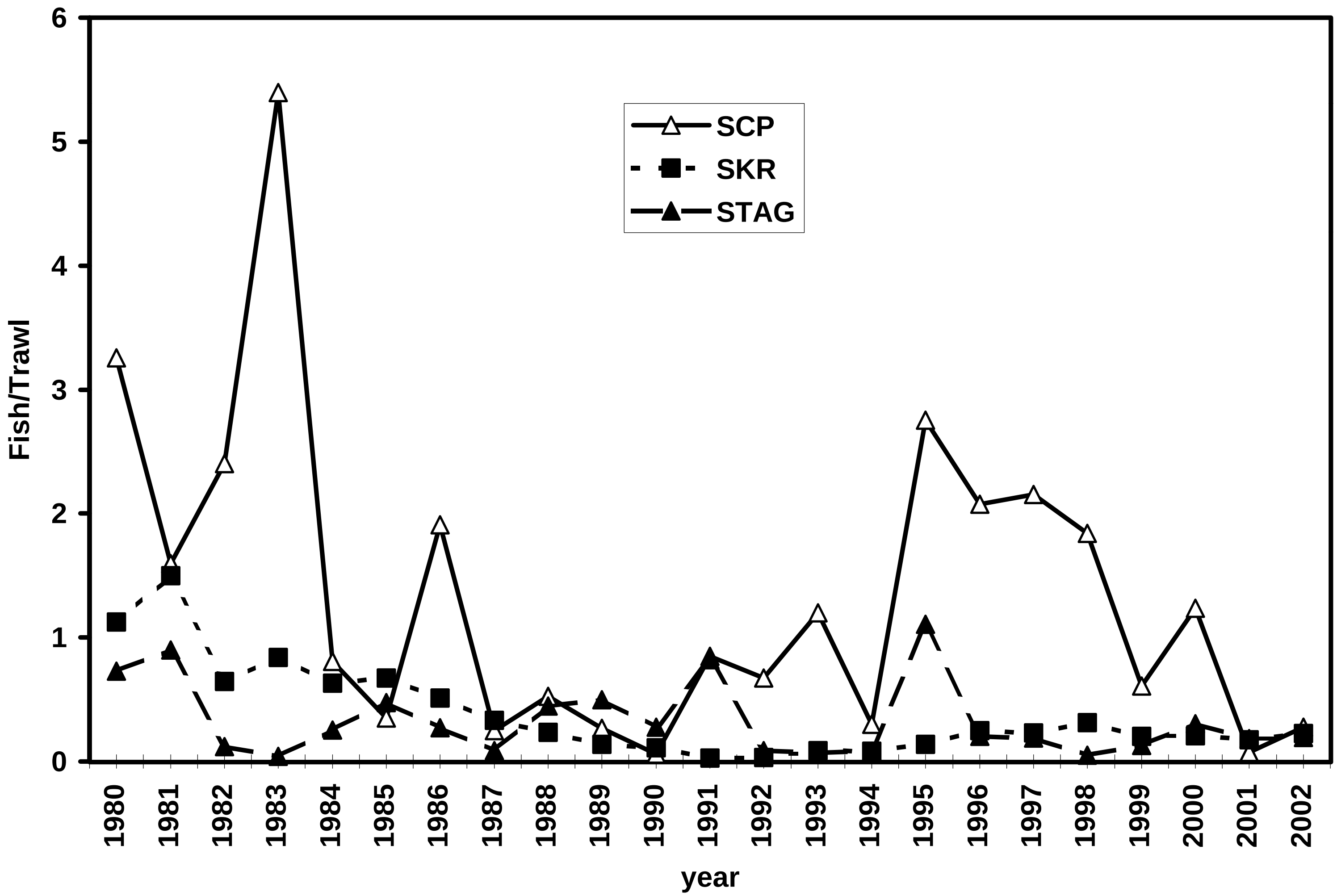





Figure 1.11

**1995-2002 Average fish catch per trawl (all species) by slough listed in order of increasing abundance**

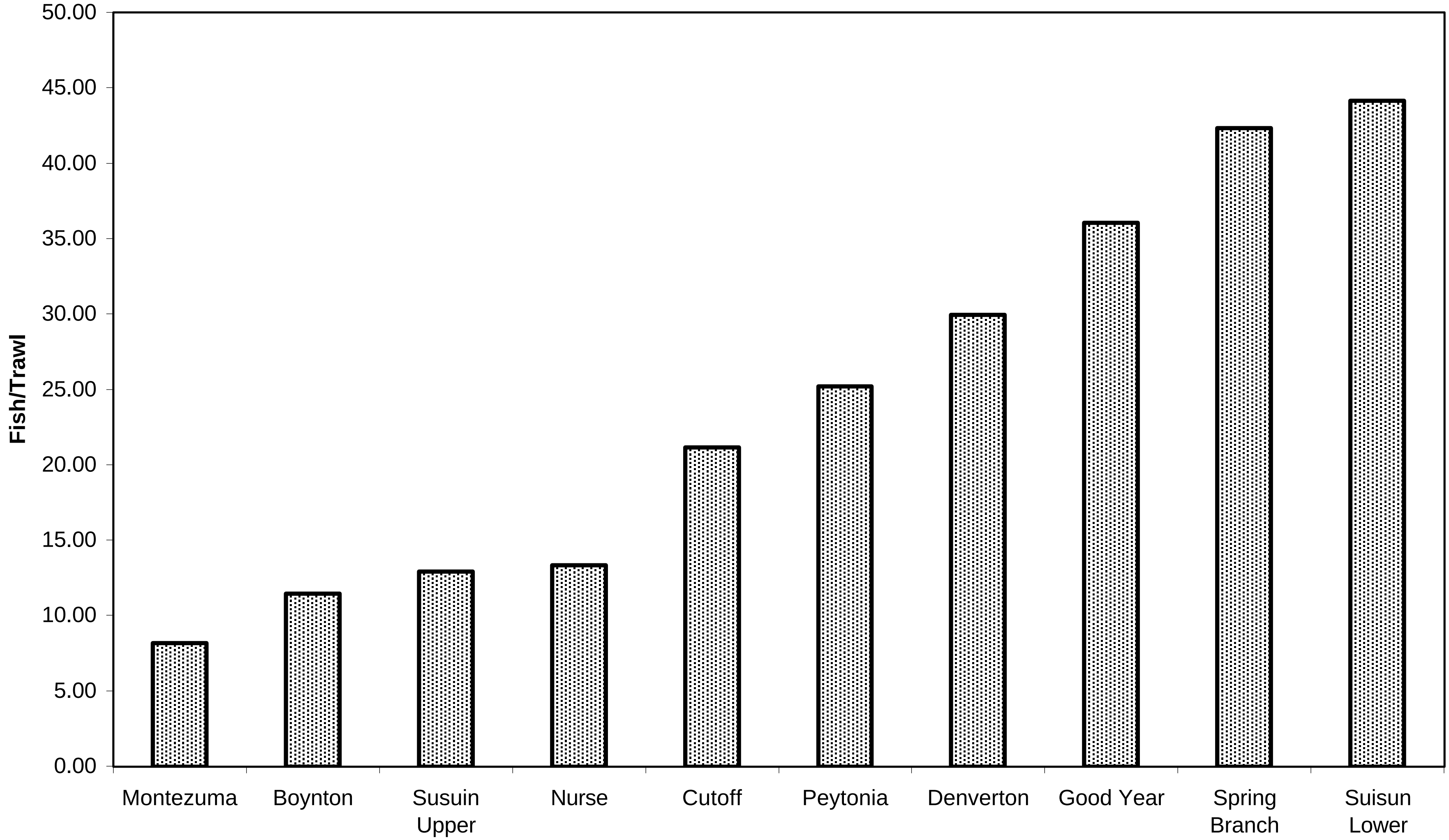





Figure 1.12

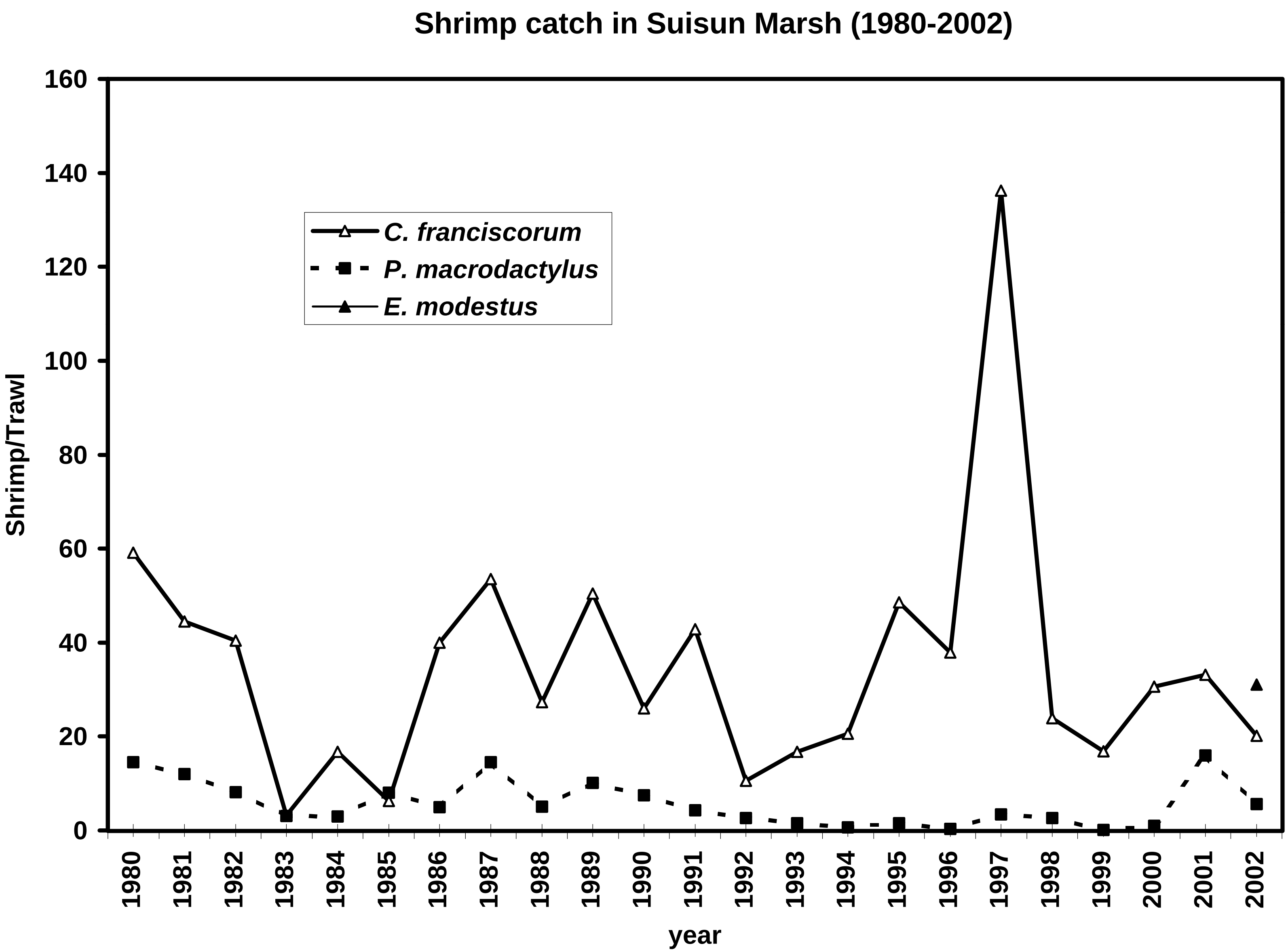

Shrimp catch in Suisun Marsh (1980-2002)
C. franciscorum
P. macrodactylus
E. modestus
Shrimp/Trawl
160
140
120
100
80
60
40
20
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
year



Figure 1.13

## Part 2: Suisun Marsh Larval Fish Survey
## February 1 – June 5, 2002

### Introduction

Prompted by the observed decline and low abundance of several of the native estuarine-dependent fish species of the Sacramento-San Joaquin Delta and a general lack of understanding of their various life history stages, an investigation of the use and importance of Suisun Marsh for fish spawning and rearing was initiated by UCD in April of 1994. The goals of the Suisun Marsh larval fish study were: (1) to augment our understanding of adult fish communities of the marsh with information on multiple fish life history stages; (2) to determine the extent the relatively undisturbed habitat of the marsh is used by fish for spawning and rearing; and (3) to determine if special status species such as delta smelt, longfin smelt, and splittail are using the marsh for spawning and rearing. Meng and Matern (2001) summarized the first six years of larval fish data (1994-1999) and in doing so significantly improved our understanding of larval fish use of the system. This section of the report (Part 2) presents the findings from the ninth and final year (2002) of the Suisun Marsh larval fish study. In addition, a final wrap up summary for all sampled years with reference to the results reported in Meng and Matern (2001) is included at the conclusion of this report.

### Methods

Larval fish in Suisun Marsh were sampled weekly from February 1 to June 5, 2002 with a 505-micron mesh net (3 m long with a 0.362 $m^2$ mouth opening) mounted on a sled. Five sloughs were sampled with three replicate, 5-minute tows in each slough: Suisun, Spring Branch (upper marsh), Nurse, Denverton (eastern marsh), and Cordelia (western marsh). Sampling sites are shown in Figure 2.1. Generally, the western marsh, farthest downstream, is the most saline, the eastern marsh, closest to the Sacramento River has the lowest salinities, and the upper marsh, fed by small streams, has intermediate salinities. A flow meter was attached to the larval fish sampling sled and samples were adjusted for the amount of water that passed through the net. In 2002, the volume of water passing through the net averaged 120 $cm^3/s$ and ranged from 89-201 $cm^3/s$. There was greater variation in the sample volumes in 2002, primarily as a result of a required vessel change due to mechanical failure. For each site the tidal stage, temperature (°C), salinity (‰), specific conductance (μS), and water transparency (secchi depth in cm) were recorded.

Larval fish samples were preserved in 5% formalin solution tinted with rose bengal to aid fish identification. The total number of fish in each sample was counted unless samples were very large. If a jar contained more than 1000 larvae, total number of fish was estimated to the nearest 100. When more than 400 fish were caught in a replicate, only 200 were identified by random subsampling. In samples containing more than 400 fish, the number of fish within each species-family group was adjusted for extra fish in the sample by multiplying number of fish in each species-family group by the sum of total fish identified and extra fish divided by total fish identified [i.e. ((total fish identified + extra fish)/total fish identified) multiplied by number of fish identified in each species-family group]. Johnson Wang identified fish to species or family.

## Results

Water Year and Environmental Conditions

The California Department of Water Resources (CDWR - DAYFLOW) classified 2002 as a "Dry" water year (Table 2.5) with the net delta outflow from February 1 through June 30, 2002 (1,865,315 cfs) being the lowest since 1994 when the larval sampling program began. The 2002 water year was most similar in outflow to the "Critical" water year of 1994 (1,515,166 cfs) and the 2001 water year (2,166,759 cfs), also classified as "Dry". Environmental conditions in 2002 were most similar to those observed in 1994 and 2001 for salinity and 1994 for water temperature patterns, although the 2002 spring and early summer salinities were the highest on record. Mean water clarity in 2002 ranged from 20.8 cm in March to 27.5 cm in June (Table 2.1). Average dissolved oxygen (DO) levels during the larval sampling time period were slightly lower in 2002, especially in May (Table 1.3). Based upon the three years of dissolved oxygen data collected (2000-2002), DO sags are consistently occurring in the marsh during two time periods including (1) Spring and or early Summer (typically May – June) and (2) Fall (October – November). The DO sag observed towards the end of the larval sampling period (May – June) may be affecting larval fish survival, however data on larval fish tolerances to low DO have, as of yet, not been established for the species in the estuary.

Larval Fish Catch

During the 2002 sampling season, 63,236 fish larvae from 10 families were captured in 271 trawls. A total of 15 species were captured in 2002, down from a total catch of 21 species in 2001. In total, 5 introduced species were captured making up 11.4% (7,196) of the total larval fish catch. Ten native species made up the remaining 88.6% of the catch with a total of 56,040 individuals.

Larval fish catch in April yielded the greatest number of species (11 species; Table 2.1, Figure 2.2). A range of 7 - 8 species were observed in the February and March samples, whereas 10 - 11 species were captured in April and May. Greatest diversity in catch on a per slough basis occurred in Cordelia (12 species), followed by Spring Branch (11 species) and Suisun (11 species) sloughs (Figure 2.3 and Table 2.2). Denverton Slough had the lowest catch, as in 2001, with only 8 species captured. Numerous marine species such as northern anchovy, Pacific herring, cheekspot goby, and longjaw mudsucker were again captured in 2002. This is the second consecutive year where cheekspot goby were collected in Suisun Marsh. Far fewer freshwater species were captured in 2002, most likely due to the low outflow and higher salinities present in the marsh. Unlike most sampling years, the greatest catch in 2002 occurred in February and March. Typically the months with greatest larval fish abundance are May and June, due largely to the high abundance of shimofuri goby and striped bass. However, in 2002 fewer larval gobies and striped bass were captured and considerably more larval longfin smelt and sculpin were captured (Table 2.3).

Unlike past years, there was only a single peak in larval fish abundance over the 2002 sampling season (Figure 2.2). This was primarily due to the very high abundance of longfin smelt and the moderate catch of prickly sculpin and Pacific herring in the first few months of sampling (February – April), but also due to the low catch of shimofuri goby and striped bass from April to June, which prevented a late season peak in total fish abundance.

Overall, the longfin smelt was the most abundant species comprising 62.3 % (39,391 individuals) of the total (February – June) larval fish catch. Prickly sculpin was the second most abundant species comprising 20.9 % of the total catch. The next most abundant species made up 10.8 % (shimofuri goby) and 5.2 % (Pacific herring) of the total catch. The remaining species were rare, collectively comprising less than 1.0 % of the total larval fish catch (Figure 2.2; Table 2.2).

Catch of Special Status Species

A total of 39,391 longfin smelt were captured in 2002, with their greatest catch occurring in February and March (Figure 2.4), although they were captured in all months sampled except June (Figure 2.4 and Tables 2.3 and 2.4). In addition, longfin smelt were captured in all sampled sloughs (Table 2.2 and Figure 2.5), but they were most abundant in Cordelia Slough (36,321indiv.) followed by Denverton Slough (9240 indiv.).

A total of 14 delta smelt larvae were captured in 2002, down from 33 individuals in 2001 and 122 individuals in 2000. Delta smelt larvae were captured between February and May 2002, but were most abundant in April (Figure 2.4 and Tables 2.3 and 2.4). Delta smelt were captured in all sampled sloughs, but they were most abundant in Cordelia Slough (5 indiv.; Figure 2.5). No wakasagi larvae were captured in the 2002 sampling season. In addition, no splittail larvae were captured in 2002.

## Discussion

The larval fish catch in 2002 was different from previous years primarily because native species dominated the catch while alien species were only found in low abundance and also because a greater numbers of native marine species were found in the marsh. The environmental conditions associated with the low outflow “Dry” water year of 2002 most likely resulted in the dramatic changes observed in the fish community. Specifically, the high abundance of longfin smelt and prickly sculpin, as well as other native species more commonly encountered in higher salinity waters downstream of the marsh (i.e. cheekspot goby, Pacific herring, and northern anchovy) most likely benefited from the low outflow, yet cool water conditions found early in the sampling season. Conversely, species more commonly associated with greater freshwater flow including delta smelt, Sacramento sucker, Sacramento splittail, bigscale logperch and *Pomoxis* sp. were either absent or caught in very low numbers in 2002. The low catch of shimofuri goby and striped bass in 2002 was most likely due to a number of factors including the cool early season conditions and the higher than usual salinity found during the typical breeding months.

Special Status Species

Overall, the sampling results from 2002 were unique in that we observed a strong resurgence in abundance of longfin smelt larvae in Suisun Marsh. The catch of longfin smelt in 2002 (39,391 individuals) was the highest recorded catch since sampling began in 1994 and it is more than 9 times greater than the previous high catch in 2001 (4048 individuals) and nearly 23 times greater than the third highest catch in 2000 (Figure 2.6). The progressively increasing and consecutive high catches of longfin smelt between 2000 and 2002 is encouraging and suggests that this species may be having its greatest reproductive success since sampling began in 1994. However, it remains a possibility that the greater numbers of longfin smelt larvae captured in the marsh is merely a result of more adult longfin smelt spawning within or adjacent to Suisun Marsh than in previously sampled years, as opposed to a dramatic increase in the number of spawning adults or greater survival success of larvae.

Only 14 delta smelt were captured in 2002, down from 33 individuals in 2001. The low catch in both 2001 and 2002 was most likely due to spawning individuals moving further upstream due to the low outflow conditions and the resultant higher salinities found within Suisun Marsh. Of all the estuarine-dependent species, delta smelt seem to have the narrowest tolerance for variability in outflow (Moyle et al. 1992). When flows are too high they may be washed away from their preferred rearing grounds in Suisun Bay. Low flows may position them up in the river where nursery conditions are not as favorable, as they likely did in 2001 and 2002.

No splittail larvae were captured during our 2002 sampling, which suggests that, as in past years, very limited spawning occurred within Suisun Marsh or the areas adjacent to Suisun Marsh, which is not surprising given their life history strategy of spawning and rearing in floodplain habitats.

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## Summary of Larval Fish Sampling Results (1994-2002)

As previously mentioned, the Suisun Marsh larval fishes have been sampled since 1994. Results from the first six years of larval fish data (1994-1999) are reported in Meng and Matern (2001). The results from the last three years (2000-2002) of the larval fish project (2002) are summarized below along with the results from the previous sampling years and those reported in Meng and Matern (2001). The following discussion includes a general summary of catch, some relationships between water year and fish abundance and diversity, and some specific discussion in regards to special status species.

Summary of Catch

As reported in Meng and Matern (2001), 227,900 larval fish were captured between 1994 and 1999. Between 2000 and 2002 an additional 137,100 larval fish were captured resulting in a total catch of 365,000 larval fish since our sampling first began in 1994. Between the years of

1998 and 2002, the years in which we have comparable taxonomic resolution, the total number of species captured within Suisun Marsh ranged between 11 and 20 species (Table 2.7). The lowest species diversity occurred in 1999, a moderate outflow year and the greatest species diversity occurred in 2001, a low outflow water year. The most abundant species captured over the course of our study was the shimofuri goby, which comprised just over 50% of the total catch (> 185,000 individuals). The next most abundant species was the prickly sculpin, comprising nearly 30% of the total catch (> 108,000 individuals). The third and fourth most abundant species were the longfin smelt (~ 47,000 individuals) and the striped bass (~15,000 individuals), which made up 13% and 4%, respectively, of the total catch. All other species accounted for less than 3% of the total catch. The largest annual catches occurred in 1994 (59,617), 1997 (57,538) and 2002 (63,240), although the 1994 catch is inflated due to trawl lengths being double those in subsequent years (10 minutes in 1994 and 5 minutes between 1995 and 2002).

<u>Relationship Between Water year and Environmental Conditions and Fish Abundance and Diversity</u>

Of the nine years larval fish have been sampled in Suisun Marsh, five were classified as wet, one as above normal, two as dry and one as critical (Table 2.5). The total Delta Outflow during our sampling season (February - June) has ranged from 1.5 million cfs to 16.6 million cfs (Table 2.5) with the four lowest outflow years occurring in 1994, 2002, 2001 and 1997, respectively (Table 2.5). Total catch during these highly variable water years has fluctuated considerably. However, some predictable trends, primarily associated with precipitation / runoff patterns within any given year, have emerged. For instance, the highest total catch usually occurs in low to moderate outflow years (Table 2.5) such as in 1994, 1997, 2001, and 2002 or under high outflow conditions when water temperatures are fairly warm in the middle of the sampling period (i.e. April 1995 see Table 1.3). This is largely due to a strong response by introduced species such as the shimofuri goby and striped bass to the warm water conditions, although in some years, such as 2002, longfin smelt also comprised a large percentage (> 60%) of the overall fish catch. In addition, drier conditions also often resulted in the increased abundance and diversity of marine larvae in the marsh, particularly at the western end of the marsh (Cordelia Slough). For example, northern anchovy, Pacific herring, cheekspot goby, jacksmelt, longjaw mudsucker and staghorn sculpin, all generally found in higher salinity waters, were captured in the “dry” water years of 2001 and 2002. This is most likely a reflection of increased salinity associated with decreased outflow. Moderate outflow conditions, such as in 1997 and 2001, have generally resulted in the greatest larval fish diversity due to conditions being favorable for both freshwater species and marine species.

High outflow conditions, such as in 1995, 1996 and 1998, have had less of a predictable effect on total abundance. Overall, total larval fish abundance and diversity is typically low under high outflow conditions, perhaps due to system flushing (nutrients, sediments etc.) and the vulnerability of larval fish to high flow conditions, but also due to lower and more consistent temperatures over the sampling period (February – June). In years with high precipitation and outflow, there is generally increased spawning in the upper marsh by characteristically freshwater species and / or also greater transport of their larvae into our sampling areas due to high flow conditions, although abundance of these species is generally low. The catch of larval delta smelt, splittail, Sacramento sucker, bigscale logperch, wakasagi and centrarchids in the upper marsh in 1996 and again between 1998 and 2000 is consistent with these observations.

As mentioned in Meng and Matern (2001), there are also two very consistent seasonal peaks in species occurrence and abundance within any given year with most native species being found in greatest abundance in the early sampling months (Feb – April) and introduced species increasing in abundance later in the season (May – June). Meng and Matern (2001) attributed this pattern to water temperature conditions and patterns of outflow. Outflow is generally greatest in February and March and tapers off considerably in May and June of most years at which time the water temperatures often increase dramatically. The observed switch in dominance, as measured by abundance, of various species of larval fish within any given year and between years is clear evidence that time of sampling and environmental conditions can have strong effects on catch of larval fish species. An example of this is the finding that prickly sculpin and longfin smelt generally dominate the Suisun Marsh larval fish catch in February, March, and occasionally in April, most likely due to cooler water temperatures. Longfin smelt and prickly sculpin are almost entirely replaced by shimofuri goby and striped bass in May and June as water temperatures begin to warm. In 2002, the observed low temperatures in Suisun Marsh as late as March and April most likely delayed shimofuri goby spawning and thus, significantly reduced our catch during our February – June sampling season. Given the extended spawning season of the shimofuri goby (late spring through the summer), a low catch of shimofuri goby larvae in our trawls from February through the middle of June does not necessarily translate into low recruitment potential in that given year.

Special Status Species

Overall, our catch of larvae of special status fish species in Suisun Marsh has been fairly limited with only longfin smelt being captured in large numbers. Delta smelt larvae are occasionally abundant in the marsh, although their abundance has been low since 1996. Splittail larvae are rarely captured in the marsh, most likely due to their life history strategy of spawning in floodplain habitats within which the larvae rear until outmigrating as juveniles (Moyle 2002). Thus, based on our study results to date, only longfin smelt spawn with any regularity in the marsh or the surrounding habitats, although different outflow conditions may certainly change the likelihood of spawning by delta smelt and splittail. Despite the lack of consistent spawning by delta smelt and splittail in Suisun Marsh, several patterns in occurrence and distribution have been observed.

Longfin smelt catch over the 9 years of sampling has shown some consistent trends. First, the abundance of longfin smelt in recent years (2000-2002) has been the highest since sampling first began in 1994. Over the last two years of sampling (2001 and 2002) we have observed an especially strong resurgence in abundance of longfin smelt larvae in Suisun Marsh, most notably in 2002. Longfin smelt abundance in 2002 (39,391 individuals) was the highest recorded catch since sampling began in 1994 and it is more than 9 times the previous high catch in 2001 (4048 individuals) and 23 times higher than the third highest catch in 2000 (1700). The dramatic increase in the catch of longfin smelt larvae indicates that spawning conditions have been more favorable in recent years either in or adjacent to Suisun Marsh under the existing low flow conditions. A second important pattern in longfin smelt catch that has become evident from our larval fish sampling is that there is also a strong negative correlation between larval longfin smelt abundance and outflow (Figure 2.7). Longfin smelt larvae are found in low abundance in high outflow years possibly due to flushing from the upper estuary under high flows, spawning occurring in areas farther downstream in the estuary, or simply due to our decreased catch efficiency when flows are high. Another interesting pattern is that the distributions of larval longfin smelt in Suisun Marsh have remained constant across the years sampled. Longfin smelt are occasionally captured in high abundance in Nurse Slough, although their greatest abundance seems to be in areas adjacent to high salinity waters such as in Cordelia Slough. This finding lends support to the possibility that the high abundance of longfin smelt in Cordelia Slough may be due to local spawning either in Cordelia Slough or immediately adjacent to it. It is also possible that the circulation of water through Grizzly Bay and into Suisun Marsh via lower Suisun Slough could be pushing longfin smelt larvae into the marsh along with tidal flows. Tidal transport of larvae into the marsh would account for the occasional high abundance of larvae in Nurse Slough as well as into other areas of the marsh. Another interesting pattern in catch of longfin smelt in Suisun Marsh is that larvae are usually captured over an extended period of time (i.e. February to April or May). Thus, it appears as if longfin smelt are either fractional spawners or that there exists a large degree of variation in maturation and or reproductive development in the population of longfin smelt spawning in the marsh. Finally, longfin smelt spawning seems to consistently take place well before our sampling begins the first week of February, thus we may not be sampling the entire larval production period. Based upon the catch of large mature adults (50 – 100 mm) in our otter trawls between November and February in both 2001 and 2002 the spawning season may begin as early as middle to late January. Thus future studies targeting longfin smelt larvae should adjust their sampling schedule accordingly.

Delta smelt spawn in areas with lower salinity than longfin smelt and we generally observe an opposite trend in the catch of Delta smelt with more larvae captured during periods of moderate to high outflow (Figure 2.7). Overall our catch of Delta smelt has remained relatively low with the greatest catch occurring in 1996 (954 individuals). The next highest catch of larval Delta smelt occurred in 2000 when 122 individuals were captured. Catch of delta smelt declined considerably in 2001 and 2002 to only 33 and 14 individuals, respectively, most likely due to spawning adults bypassing the marsh due to the low outflow and the resultant higher salinities. Of all the estuarine-dependent species, delta smelt seem to have the narrowest preference or tolerance for variability in outflow (Moyle et al. 1992). When flows are too high they may be washed away from their preferred rearing grounds in Suisun Bay. Low flows may position them up in the river where nursery conditions are not as favorable, as they likely did in 2001 and 2002. The low number of Delta smelt captured in Suisun Marsh over the course of this study, relative to other species, suggests that habitats currently sampled in the marsh are only occasionally used as spawning habitat for Delta smelt. This is further supported by the high catch of larval Delta smelt in habitats farther upstream in the Sacramento and San Joaquin Rivers during this same time period. The delta smelt larvae that were captured in the marsh were more or less spread equally across the sampling sites, although, there were slightly more individuals captured in Nurse Slough and Spring Branch Slough.

Over the course of our study, Sacramento splittail larvae have also only been caught in relatively low numbers. The greatest catch occurred in the high outflow year of 1995 when 65 individuals were captured.  This suggests that the spawning conditions in the marsh are only occasionally favorable for splittail or alternatively that the surface larval fish trawl may not be adequately sampling for larval spltitail larvae.  Given the life history strategy of Sacramento splittail spawning primarily in floodplain habitats (Moyle 2002), it makes sense that relatively few splittail larvae would be captured in our larval fish trawls.  Based on our current understanding of the system, splittail larvae generally reside within floodplain habitats until they outmigrate as juveniles to the rivers and eventually the estuary (Moyle 2002).  When splittail larvae are captured in the marsh, they are generally collected in highest abundance in Denverton Slough, Nurse Slough and also occasionally in Spring Branch Slough.

## Conclusion

In summary, the large fluctuation in larval fish catch of native and introduced species in Suisun Marsh across the sampled years (1994-2002) strongly suggests that the estuarine conditions in any given year largely determines which species will spawn and rear within the waters of Suisun Marsh.  For the native species found within Suisun marsh, low outflow years result in greater abundance of longfin smelt and more marine native species (herring, anchovy, cheekspot goby etc., whereas high outflow conditions result in the greater abundance of delta smelt and splittail (see Figure 2.7 for some of the species vs. outflow relationships and Meng and Matern 2001 for more details).  Intermediate outflows result in either high abundance of the freshwater native species group or marine species group, or depending on the timing of outflow, both groups of species.  The abundance of prickly sculpin in Suisun Marsh is fairly consistent across all outflows with only a slight increase in sculpin abundance as outflow increases.

Among the introduced species, only shimofuri goby and striped bass larvae were captured in high enough densities to examine their abundance relationship with outflow (Figure 2.8).  The abundance of Shimofuri goby larvae in relation to outflow is a fairly flat response, similar to prickly sculpin, with only a slight decline in abundance with increasing outflow.  Striped bass abundance was more positively associated with increasing outflow, although the relationship was also fairly week.  The remaining introduced species found in low abundance (i.e. threadfin shad, inland silverside, centrarchids, bigscale logperch, etc.) are most commonly captured during high outflow conditions.

Suisun Marsh has been categorized as an important nursery area for several species of interest (striped bass, salmon etc.) and species of special concern (delta smelt, longfin smelt, splittail) in the San Francisco Estuary.  This study has verified that the marsh appears to be serving as an important nursery area for large numbers of species with up to 20 species rearing within the marsh in certain years.  Our results further demonstrate that certain species will be found in the system under differing environmental conditions, which are largely tied to outflow.  This suggests that future variation in outflow will differentially affect the species that spawn and rear within the system.  For species of special concern, higher outflows will most likely result in greater abundance of delta smelt larvae and splittail larvae while low outflows will most likely result in greater abundances of longfin smelt larvae.

Some factors that may affect future outflow through the San Francisco Estuary include climatic shifts such as prolonged drought cycles or increased periods of precipitation and even decreased outflow due to increased water diversion as the demand for water continues to increase in the state. As the system changes and more demand is placed on the SF Estuary water supply, we may see a shift towards lower outflow especially if a dry precipitation pattern persists. Under this scenario, we would predict that longfin smelt spawning and rearing of larvae in the marsh would increase and the abundance of delta smelt larvae and splittail larvae would decrease. It is unknown whether spawning and rearing specifically within Suisun Marsh affords any special advantages to the species of special concern (i.e. increased growth and / or survival) compared to other habitats in the estuary (i.e. riverine or bay rearing), but given their life histories, their tendencies to be found within marsh habitats, and the current lack of marsh habitat in the San Francisco Estuary, it is not unrealistic to assume that Suisun Marsh affords special advantages to many species in the system.

## Potential Directions for Future Research

Based upon our study results to date, we have obtained a solid understanding of larval fish use in Suisun Marsh. However, there are several areas in which we could improve our understanding of the contribution of marsh habitat in Suisun Marsh to the species that utilize it. These include (1) obtaining a better understanding of the relationship between larval fish production and juvenile recruitment in the same year and subsequent years in the surrounding estuarine waters as well as in Suisun Marsh; (2) examining the effects of potential predators such as the recently introduced Siberian prawn (*Exopalaemon modestus*), which is currently found in very high abundance in Suisun Marsh; and (3) investigating whether low dissolved oxygen levels found in late spring and early summer may be adversely affecting the survival and recruitment of larval fishes.

**Table 2.1** Data from the Suisun Marsh larval fish survey conducted from February 1, 2002 to June 5, 2002. SPP = Maximum number of species-family categories caught. Temperature, salinity, and secchi are in degrees C, ppt, and cm, respectively.

| | | Month | | | | | |
|---|---|---|---|---|---|---|---|
| **Slough** | **Data** | **February** | **March** | **April** | **May** | **June** | **Overall Avg. or Total** |
| **Cordelia** | Average of Temp | 10.56 | 13.93 | 16.49 | 18.40 | 21.63 | 15.34 |
| | Average of Sal | 3.62 | 2.87 | 2.97 | 3.45 | 2.80 | 3.20 |
| | Average of Secchi | 23.83 | 19.93 | 18.09 | 20.00 | 24.00 | 20.68 |
| | Sum of FISH | 21787 | 14024 | 76 | 402 | 32 | 36321 |
| | Avg of FISH/$M^3$ | 15.52 | 8.13 | 0.05 | 0.22 | 0.07 | 5.48 |
| | Total # SPP | 5 | 8 | 8 | 9 | 2 | 12 |
| **Denverton** | Average of Temp | 10.26 | 13.05 | 16.60 | 18.91 | 22.23 | 15.03 |
| | Average of Sal | 2.71 | 3.51 | 2.77 | 2.62 | 2.93 | 2.94 |
| | Average of Secchi | 22.83 | 20.57 | 24.50 | 26.78 | 26.00 | 23.50 |
| | Sum of FISH | 2383 | 3934 | 1326 | 967 | 630 | 9240 |
| | Avg of FISH/$M^3$ | 1.66 | 2.25 | 0.96 | 0.50 | 1.25 | 1.34 |
| | Total # SPP | 4 | 3 | 7 | 7 | 3 | 8 |
| **Nurse** | Average of Temp | 9.93 | 13.03 | 16.21 | 18.00 | 21.67 | 14.75 |
| | Average of Sal | 2.10 | 2.65 | 2.39 | 2.44 | 2.87 | 2.44 |
| | Average of Secchi | 22.00 | 20.07 | 23.00 | 29.36 | 30.67 | 23.71 |
| | Sum of FISH | 3572 | 3331 | 681 | 539 | 787 | 8910 |
| | Avg of FISH/$M^3$ | 2.46 | 1.79 | 0.52 | 0.27 | 1.85 | 1.27 |
| | Total # SPP | 5 | 5 | 8 | 5 | 3 | 9 |
| **Spring Branch** | Average of Temp | 10.37 | 13.97 | 17.00 | 18.12 | 25.87 | 15.22 |
| | Average of Sal | 1.86 | 2.11 | 2.09 | 2.18 | 2.43 | 2.08 |
| | Average of Secchi | 20.91 | 21.00 | 22.11 | 25.33 | 28.67 | 22.32 |
| | Sum of FISH | 907 | 1554 | 559 | 778 | 280 | 4078 |
| | Avg of FISH/$M^3$ | 0.66 | 0.93 | 0.43 | 0.44 | 0.69 | 0.62 |
| | Total # SPP | 6 | 4 | 8 | 7 | 3 | 11 |
| **Suisun** | Average of Temp | 10.68 | 13.63 | 16.35 | 19.01 | 22.93 | 15.49 |
| | Average of Sal | 1.68 | 1.98 | 1.78 | 1.97 | 1.90 | 1.87 |
| | Average of Secchi | 21.50 | 22.53 | 24.91 | 24.36 | 28.00 | 23.50 |
| | Sum of FISH | 1099 | 1305 | 679 | 900 | 704 | 4687 |
| | Avg of FISH/$M^3$ | 0.77 | 0.79 | 0.48 | 0.49 | 1.44 | 0.67 |
| | Total # SPP | 3 | 5 | 8 | 5 | 3 | 11 |
| **Total Average of Temp** | | 10.36 | 13.52 | 16.51 | 18.50 | 22.87 | 15.17 |
| **Total Average of Salinity** | | 2.39 | 2.62 | 2.42 | 2.56 | 2.59 | 2.51 |
| **Total Average of Secchi** | | 22.24 | 20.82 | 22.57 | 24.98 | 27.47 | 22.74 |
| **Total Sum of Fish** | | 29748 | 24148 | 3321 | 3586 | 2433 | 63236 |
| **Total Average of Fish / $M^3$** | | 4.21 | 2.78 | 0.49 | 0.38 | 1.06 | 1.88 |
| **Total Number of Species** | | 7 | 8 | 11 | 10 | 5 | 15 |

**Table 2.2 Families and species captured in five sloughs sampled by the Suisun Marsh larval fish survey in 2002. YFG = yellowfin goby, SG = shimofuri goby, CSG = cheekspot goby, LJM = longjaw mudsucker, SCP = pirckly sculpin, STAG = staghorn sculpin, SB = striped bass, , HER = Pacific herring, ANCH = anchovy, ISS = inland silverside, STBK = threespine stickleback, DS = delta smelt, LFS = longfin smelt, CP = carp, SKR = Sacramento sucker**

| | SLOUGH | | | | | |
|---|---|---|---|---|---|---|
| | Cordelia | Denverton | Nurse | Spring Branch | Suisun | Total All Sloughs |
| SG | 219 | 2132 | 1492 | 1000 | 2004 | 6847 |
| CSG | 107 | 4 | 7 | 1 | 1 | 120 |
| YFG | 42 | 0 | 7 | 7 | 48 | 104 |
| LJM | 2 | 0 | 0 | 0 | 0 | 2 |
| SCP | 1826 | 5578 | 2282 | 1904 | 1598 | 13188 |
| STAG | 0 | 0 | 1 | 4 | 0 | 5 |
| SB | 66 | 38 | 29 | 83 | 22 | 238 |
| LFS | 31468 | 1351 | 4849 | 867 | 856 | 39391 |
| DS | 5 | 1 | 3 | 3 | 2 | 14 |
| HER | 2577 | 134 | 239 | 204 | 153 | 3307 |
| STBK | 6 | 0 | 0 | 2 | 0 | 8 |
| CP | 0 | 0 | 0 | 3 | 2 | 5 |
| SKR | 1 | 0 | 0 | 0 | 1 | 2 |
| ANCH | 2 | 0 | 0 | 0 | 1 | 3 |
| ISS | 0 | 2 | 0 | 0 | 0 | 2 |
| Total # Individuals | 36321 | 9240 | 8910 | 4078 | 4687 | 63236 |
| Total # Species | 12 | 8 | 9 | 11 | 11 | 15 |

**Table 2.3** Families and species captured by the Suisun Marsh larval fish survey by month in 2002. YFG = yellowfin goby, SG = shimofuri goby, CSG = cheekspot goby, LJM = longjaw mudsucker, SCP = prickly sculpin, STAG = staghorn sculpin, SB = striped bass, TFS = threadfin shad, HER = Pacific herring, ISS = inland silverside, JACK = jacksmelt, STBK = threespine stickleback, DS = delta smelt, LFS = longfin smelt, WAK = wakasagi, CP = carp, ST = Sacramento splittail, FHM = fathead minnow, SKR = Sacramento sucker, CENT = Centrarchidae - Pomoxis sp., BLP = bigscale logperch, . Sloughs were sampled weekly from February 1, 2002 through June 5, 2002.

| | February | March | April | May | June | Total All Months |
|---|---|---|---|---|---|---|
| **SG** | 0 | 0 | 1319 | 3128 | 2400 | 6847 |
| **CSG** | 0 | 1 | 7 | 110 | 2 | 120 |
| **YFG** | 11 | 37 | 7 | 49 | 0 | 104 |
| **LJM** | 0 | 0 | 2 | 0 | 0 | 2 |
| **SCP** | 5018 | 6697 | 1439 | 34 | 0 | 13188 |
| **STAG** | 5 | 0 | 0 | 0 | 0 | 5 |
| **SB** | 0 | 0 | 20 | 191 | 27 | 238 |
| **LFS** | 23366 | 15690 | 318 | 17 | 0 | 39391 |
| **DS** | 2 | 4 | 7 | 1 | 0 | 14 |
| **WAK** | 0 | 0 | 0 | 0 | 0 | 0 |
| **HER** | 1342 | 1713 | 199 | 54 | 0 | 3307 |
| **STBK** | 4 | 4 | 0 | 0 | 0 | 8 |
| **CP** | 0 | 0 | 2 | 0 | 3 | 5 |
| **SKR** | 0 | 2 | 0 | 0 | 0 | 2 |
| **ANCH** | 0 | 0 | 0 | 2 | 1 | 3 |
| **ISS** | 0 | 0 | 1 | 1 | 0 | 2 |
| **Total # of Indiv** | 29748 | 24148 | 3321 | 3586 | 2433 | 63236 |
| **Total # of SP** | 7 | 8 | 11 | 10 | 5 | 15 |

**Table 2.4** Delta smelt ($DS/M^3$), longfin smelt ($LFS/M^3$), and splittail ($ST/M^3$) densities per cubic meter sampled by the Suisun Marsh larval fish survey in 2002. Sloughs were sampled weekly from February 1, 2002 through June 5, 2002. Temperature, salinity, and secchi are in degrees Centigrade, parts per thousand, and cm, respectively. In all cases, minimum densities were 0.

| | | MONTH | | | | | |
|---|---|---|---|---|---|---|---|
| **SLOUGH** | | **February** | **March** | **April** | **May** | **June** | **Grand Total** |
| **Cordelia** | Average of $DS/M^3$ | 0.000 | 0.002 | 0.001 | 0.001 | 0.000 | 0.001 |
| | Max of $DS/M^3$ | 0.000 | 0.030 | 0.008 | 0.009 | 0.000 | 0.030 |
| | Average of $LFS/M^3$ | 13.943 | 6.897 | 0.003 | 0.008 | 0.000 | 4.753 |
| | Max of $LFS/M^3$ | 44.832 | 43.537 | 0.017 | 0.033 | 0.000 | 44.832 |
| | Average of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Max of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Denverton** | Average of $DS/M^3$ | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Max of $DS/M^3$ | 0.008 | 0.000 | 0.000 | 0.000 | 0.000 | 0.008 |
| | Average of $LFS/M^3$ | 0.548 | 0.309 | 0.016 | 0.001 | 0.000 | 0.211 |
| | Max of $LFS/M^3$ | 3.652 | 0.686 | 0.056 | 0.009 | 0.000 | 3.652 |
| | Average of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Max of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Nurse** | Average of $DS/M^3$ | 0.001 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| | Max of $DS/M^3$ | 0.008 | 0.010 | 0.008 | 0.000 | 0.000 | 0.010 |
| | Average of $LFS/M^3$ | 1.774 | 1.115 | 0.154 | 0.000 | 0.000 | 0.699 |
| | Max of $LFS/M^3$ | 4.975 | 3.540 | 0.681 | 0.000 | 0.000 | 4.975 |
| | Average of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Max of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Spring Branch** | Average of $DS/M^3$ | 0.000 | 0.000 | 0.003 | 0.000 | 0.000 | 0.001 |
| | Max of $DS/M^3$ | 0.000 | 0.000 | 0.021 | 0.000 | 0.000 | 0.021 |
| | Average of $LFS/M^3$ | 0.184 | 0.317 | 0.072 | 0.001 | 0.000 | 0.155 |
| | Max of $LFS/M^3$ | 0.837 | 1.583 | 0.203 | 0.009 | 0.000 | 1.583 |
| | Average of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Max of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Suisun** | Average of $DS/M^3$ | 0.000 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 |
| | Max of $DS/M^3$ | 0.000 | 0.000 | 0.009 | 0.000 | 0.000 | 0.009 |
| | Average of $LFS/M^3$ | 0.177 | 0.348 | 0.018 | 0.001 | 0.000 | 0.133 |
| | Max of $LFS/M^3$ | 0.620 | 2.586 | 0.071 | 0.010 | 0.000 | 2.586 |
| | Average of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| | Max of $ST/M^3$ | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Total Average of $DS/M^3$** | | 0.000 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 |
| **Total Max of $DS/M^3$** | | 0.008 | 0.030 | 0.021 | 0.009 | 0.000 | 0.030 |
| **Total Average of $LFS/M^3$** | | 3.325 | 1.797 | 0.051 | 0.002 | 0.000 | 1.231 |
| **Total Max of $LFS/M^3$** | | 44.832 | 43.537 | 0.681 | 0.033 | 0.000 | 44.832 |
| **Total Average of $ST/M^3$** | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| **Total Max of $ST/M^3$** | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

**Table 2.5** Monthly total Net Delta Outflow (cfs), number of fish, and number of samples from the Suisun Marsh larval fish survey from 1994-2002. Outflow data and dry, wet, and normal water year designations were provided by the Califonia Department of Water Resources.

| | | February | March | April | May | June | Total |
|---|---|---|---|---|---|---|---|
| **1994** | **Outflow** | 575459 | 329991 | 244689 | 246295 | 118732 | 1515166 |
| **Critical** | **Fish** | | | 4450 | 8786 | 44331 | 57567 |
| | **Samples** | | | 42 | 60 | 44 | 146 |
| | **# Fish / Sample** | | | 106 | 146 | 1008 | 394 |
| **1995** | **Outflow** | 2037777 | 6220911 | 2725494 | 3040257 | 1405074 | 15429513 |
| **Wet** | **Fish** | 1141 | 6286 | 6771 | 16737 | 13775 | 44710 |
| | **Samples** | 10 | 75 | 60 | 60 | 45 | 250 |
| | **# Fish / Sample** | 114 | 84 | 113 | 279 | 306 | 179 |
| **1996** | **Outflow** | 3680341 | 2760590 | 1261687 | 1428760 | 462661 | 9594039 |
| **Wet** | **Fish** | 2518 | 6492 | 4717 | 10317 | 2376 | 26420 |
| | **Samples** | 60 | 75 | 57 | 66 | 15 | 273 |
| | **# Fish / Sample** | 42 | 87 | 83 | 156 | 158 | 97 |
| **1997** | **Outflow** | 3325676 | 1042711 | 425284 | 382311 | 249328 | 5425310 |
| **Wet** | **Fish** | 3896 | 4961 | 2702 | 35505 | 10474 | 57538 |
| | **Samples** | 60 | 60 | 60 | 75 | 15 | 270 |
| | **# Fish / Sample** | 65 | 83 | 45 | 473 | 698 | 213 |
| **1998** | **Outflow** | 6466792 | 3230457 | 2651428 | 2102350 | 2152735 | 16603762 |
| **Wet** | **Fish** | 181 | 5038 | 2736 | 8755 | 3035 | 19745 |
| | **Samples** | 6 | 60 | 60 | 39 | 30 | 195 |
| | **# Fish / Sample** | 30 | 84 | 46 | 224 | 101 | 101 |
| **1999** | **Outflow** | 2766464 | 2141511 | 1064838 | 687096 | 413782 | 7073691 |
| **Wet** | **Fish** | 4675 | 9274 | 5760 | *405 | | *20114 |
| | **Samples** | 60 | 60 | 60 | *12 | | *192 |
| | **# Fish / Sample** | 78 | 155 | 96 | *34 | | *105 |
| **2000** | **Outflow** | 2730402 | 2721645 | 813100 | 687628 | 269150 | 7221925 |
| **Above** | **Fish** | 7798 | 6347 | 3248 | 7128 | 3917 | 28439 |
| **Normal** | **Samples** | 58 | 75 | 60 | 60 | 30 | 283 |
| | **# Fish / Sample** | 134 | 85 | 54 | 119 | 131 | 100 |
| **2001** | **Outflow** | 548945 | 725948 | 366814 | 299358 | 225694 | 2166759 |
| **Dry** | **Fish** | 6657+ | 7849 | 2215 | 19000 | 9749 | 45470 |
| | **Samples** | 45+ | 73 | 60 | 75 | 30 | 283 |
| | **# Fish / Sample** | 147.93+ | 108 | 37 | 253 | 325 | 161 |
| **2002** | **Outflow** | 337753 | 526030 | 357091 | 419626 | 224815 | 1865315 |
| **Dry** | **Fish** | 29748 | 24148 | 3321 | 3586 | 2433 | 63236 |
| | **Samples** | 60 | 75 | 57 | 65 | 14 | 271 |
| | **# Fish / Sample** | 495.80 | 321.97 | 58.26 | 55.17 | 173.79 | 233.34 |

*In 1999, larval fish sampling was stopped after May 6 due to delta smelt take restrictions. Larval fish totals and the grand total will reflect this early end to the sampling season. +February 2001 totals are based upon three weeks of samples (no samples were collected in the second week of February).

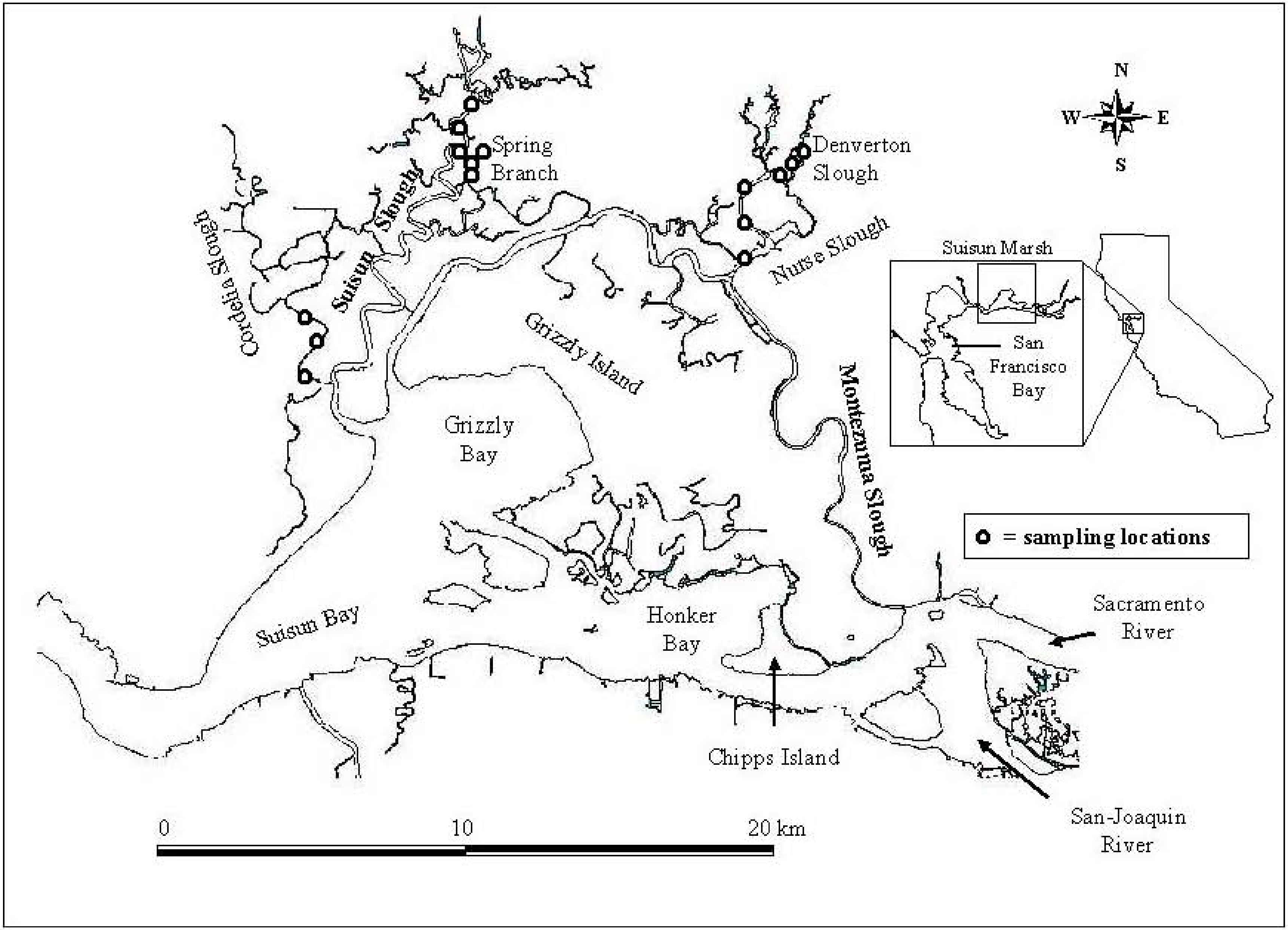
**Table 2.6** Species of concern captured during the Suisun Marsh larval fish survey between 1994 and 2002. The abundance of Splittail in 1994 was unavailable. It is important to note that sampling effort and number of months sampled varied between sampling years.

| Year | Longfin smelt | Delta smelt | Splittail | # Of Samples |
|---|---|---|---|---|
| **1994** | 19 | 13 | | 146 |
| **1995** | 22 | 77 | 61 | 250 |
| **1996** | 271 | 954 | 6 | 273 |
| **1997** | 1273 | 20 | 0 | 270 |
| **1998** | 17 | 53 | 19 | 195 |
| **1999** | 250 | 99 | 0 | 192 |
| **2000** | 1700 | 122 | 7 | 283 |
| **2001** | 4048 | 33 | 1 | 283 |
| **2002** | 39391 | 14 | 0 | 271 |

**Table 2.7** Fishes captured during the Suisun Marsh larval fish survey between 1994 and 2002. Between 1994 and 1997 several family groups including Gobiidae, Cottidae, Clupeidae and Plueronectidae were not seperated to the species level.

| Year | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
|---|---|---|---|---|---|---|---|---|---|
| LFS | 20 | 22 | 271 | 1273 | 17 | 250 | 1700 | 4048 | 39391 |
| DS | 20 | 95 | 954 | 20 | 53 | 99 | 122 | 33 | 14 |
| WAK | | 10 | 30 | 0 | 50 | 5 | 32 | 2 | 0 |
| GOBIIDAE | 57797 | 25965 | 5317 | 45263 | | | | | |
| SG | | | | | 9679 | 64 | 9292 | 25500 | 6847 |
| CSG | | | | | 0 | 0 | 0 | 107 | 120 |
| YFG | | | | | 47 | 1 | 135 | 110 | 104 |
| LJM | | | | | 0 | 0 | 0 | 2 | 2 |
| COTTIDAE | 1199 | 15549 | 13867 | 9780 | | | | | |
| SCP | | | | | 8612 | 19481 | 15081 | 11629 | 13188 |
| STAG | | | | | 0 | 0 | 0 | 3 | 5 |
| STBK | 10 | 22 | 26 | 58 | 23 | 12 | 48 | 16 | 8 |
| SB | 444 | 2419 | 4949 | 573 | 1001 | 124 | 1922 | 3313 | 238 |
| CLUPEIDAE | | | 770 | 208 | 0 | 0 | 0 | 0 | 0 |
| HER | 67 | 223 | | | 0 | 0 | 16 | 267 | 3307 |
| TFS | | | | | 97 | 0 | 9 | 46 | 0 |
| ASH | | | | | 1 | 0 | 0 | 0 | 0 |
| ANCH | 7 | 0 | 0 | 231 | 0 | 0 | 0 | 326 | 3 |
| ST | NA | 65 | 6 | 0 | 19 | 0 | 7 | 1 | 0 |
| CP | 21 | 45 | 10 | 27 | 12 | 0 | 7 | 33 | 5 |
| FHM | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 5 |
| SKR | 0 | 56 | 112 | 34 | 67 | 48 | 58 | 4 | 2 |
| CENTRARCHIDAE | 0 | 0 | 8 | 14 | 7 | 22 | 2 | 8 | 0 |
| MQF | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| PLEURONECTIDAE | 1 | 0 | 2 | 7 | 0 | 0 | 0 | 0 | 0 |
| BLP | 0 | 1 | 1 | 0 | 9 | 8 | 1 | 0 | 0 |
| ISS | 30 | 24 | 93 | 50 | 50 | 0 | 7 | 20 | 2 |
| # Of Samples | 146 | 250 | 273 | 270 | 195 | 192 | 283 | 283 | 271 |
| Total # of Indiv | 59617 | 44495 | 26416 | 57538 | 19745 | 20114 | 28439 | 45470 | 63240 |
| Total # of SP | NA | NA | NA | NA | 17 | 11 | 16 | 20 | 15 |

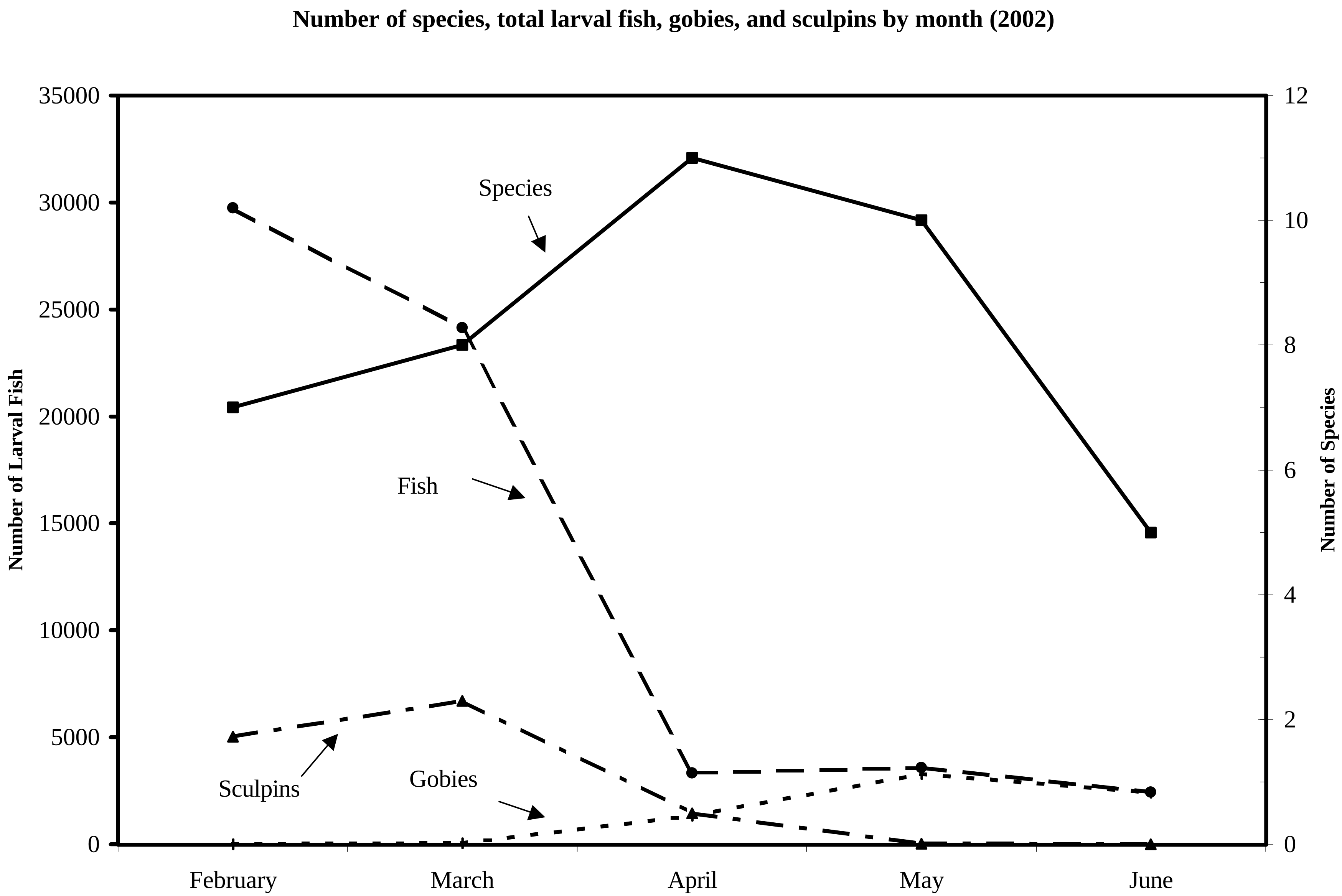
Figures



N
W
E
S
Spring
Branch
Denverton
Slough
Suisun Slough
Cordelia Slough
Nurse Slough
Suisun Marsh
San
Francisco
Bay
Grizzly Island
Montezuma Slough
Grizzly
Bay
= sampling locations
Suisun Bay
Honker
Bay
Sacramento
River
Chipps Island
San-Joaquin
River
0
10
20 km

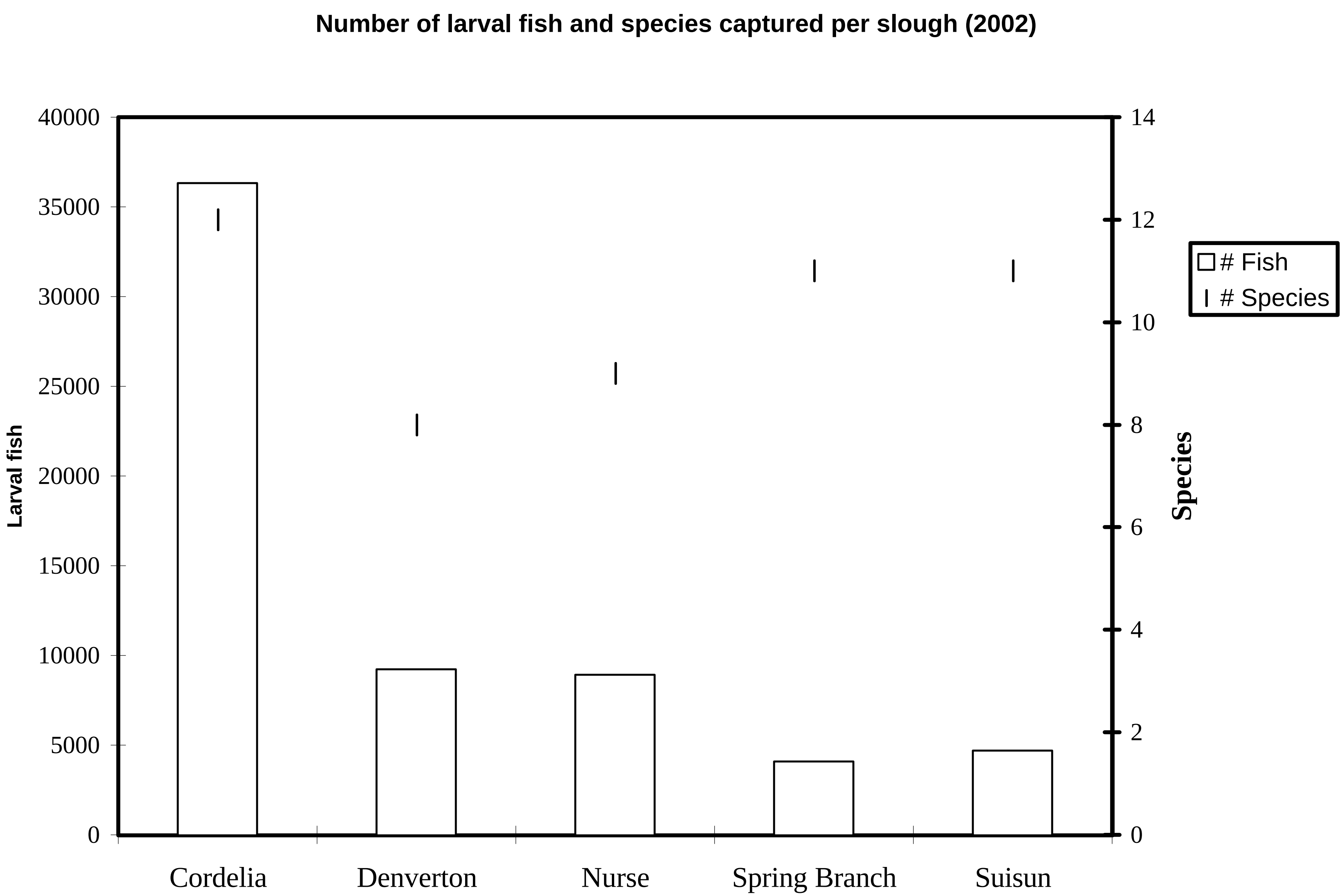



Figure 2.1



Number of species, total larval fish, gobies, and sculpins by month (2002)
Number of Larval Fish
Number of Species
Species
Fish
Sculpins
Gobies
35000
30000
25000
20000
15000
10000
5000
0
12
10
8
6
4
2
0
February
March
April
May
June


Figure 2.2



Number of larval fish and species captured per slough (2002)
40000
35000
30000
25000
20000
15000
10000
5000
0
Larval fish
14
12
10
8
6
4
2
0
Species
# Fish
# Species
Cordelia
Denverton
Nurse
Spring Branch
Suisun




Figure 2.3

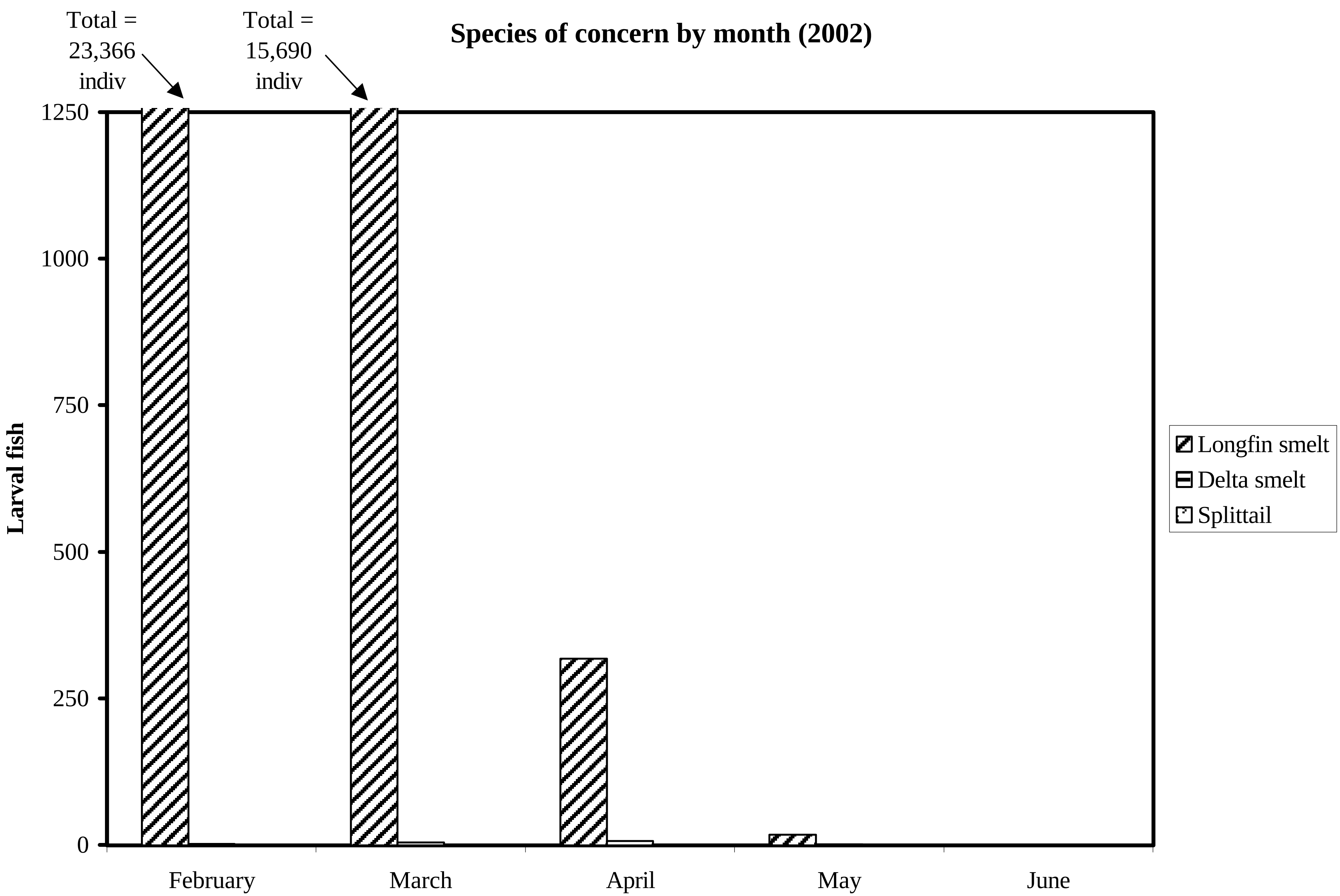

Species of concern by month (2002)
Total = 23,366 indiv
Total = 15,690 indiv
Larval fish
1250
1000
750
500
250
0
February
March
April
May
June
Longfin smelt
Delta smelt
Splittail

Figure 2.4

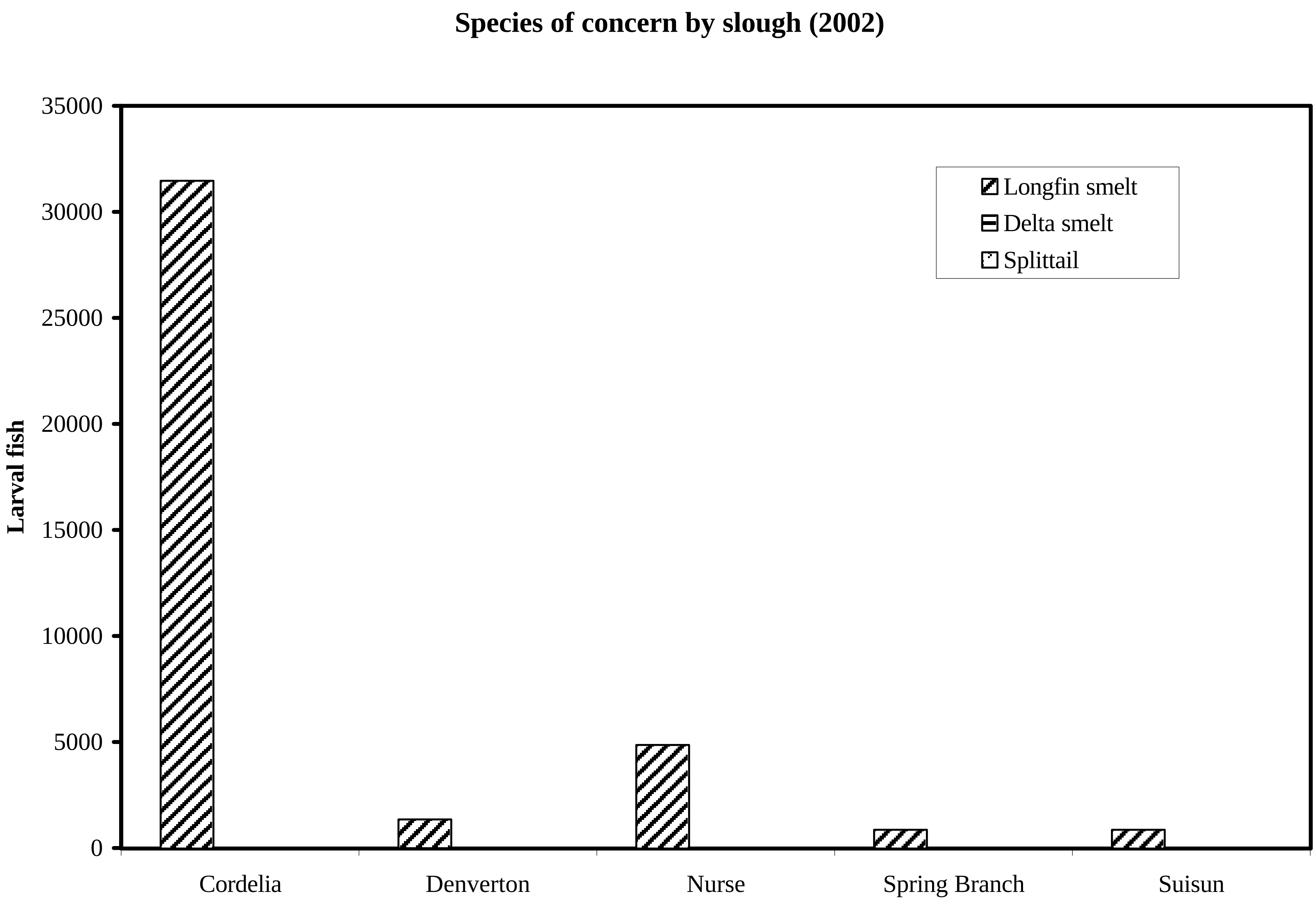

Species of concern by slough (2002)
Larval fish
35000
30000
25000
20000
15000
10000
5000
0
Longfin smelt
Delta smelt
Splittail
Cordelia
Denverton
Nurse
Spring Branch
Suisun

Figure 2.5

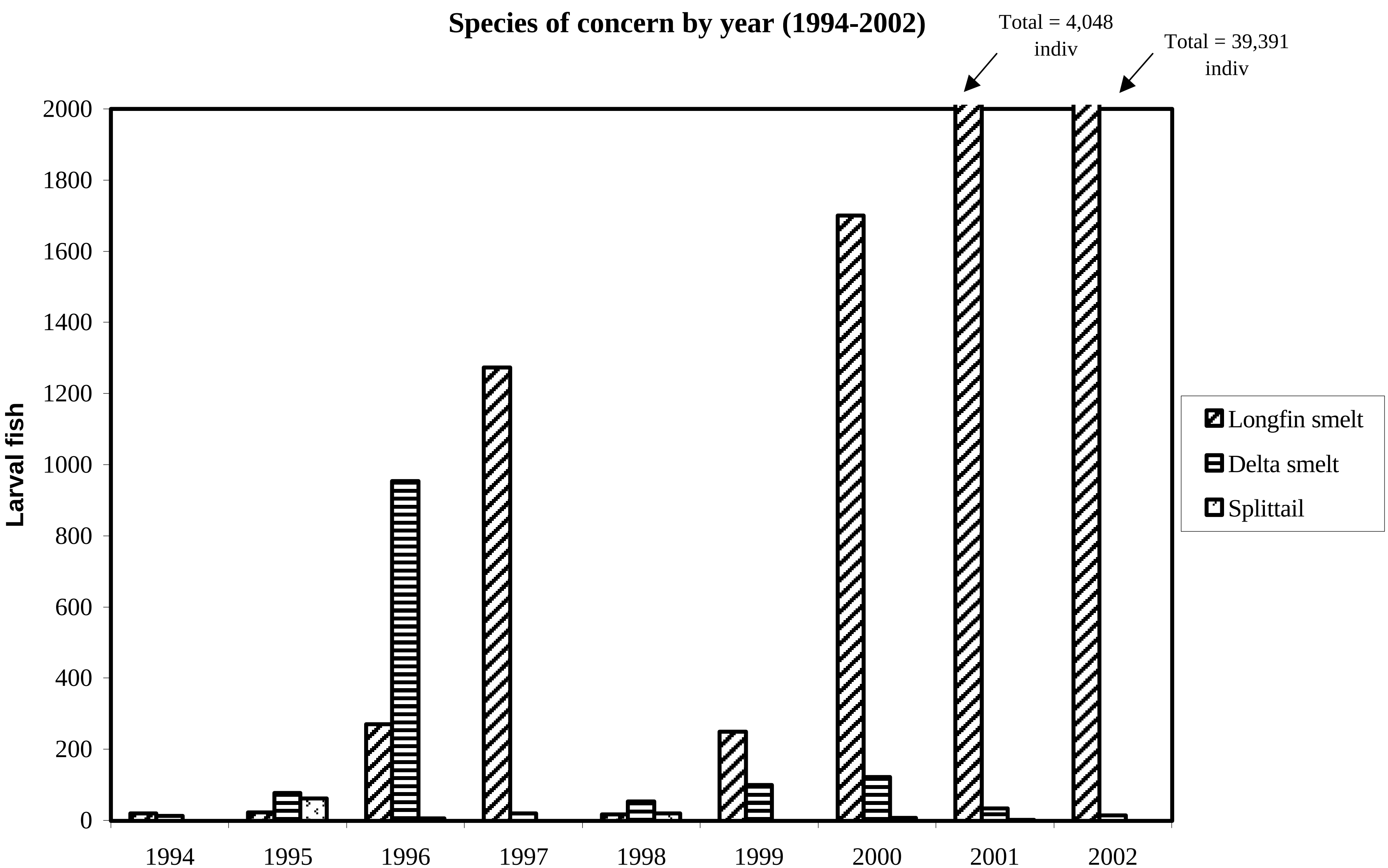

Species of concern by year (1994-2002)
Total = 4,048
indiv
Total = 39,391
indiv
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Larval fish
1994
1995
1996
1997
1998
1999
2000
2001
2002
Longfin smelt
Delta smelt
Splittail



Figure 2.6

## 2002 Native species larval fish catch / trawl vs. total season outflow

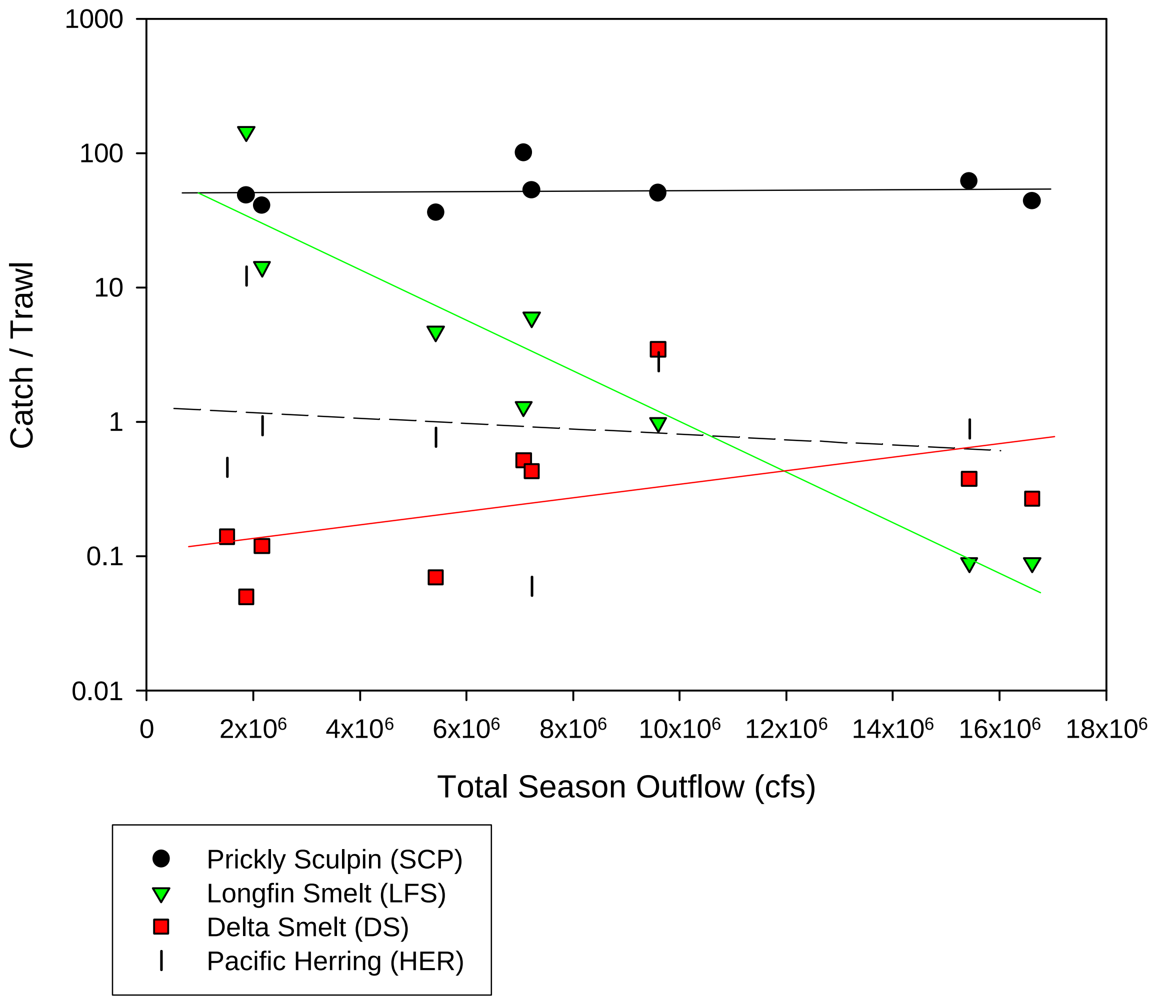





Figure 2.7

**2002 Introduced species larval fish catch / trawl vs. total season outflow**

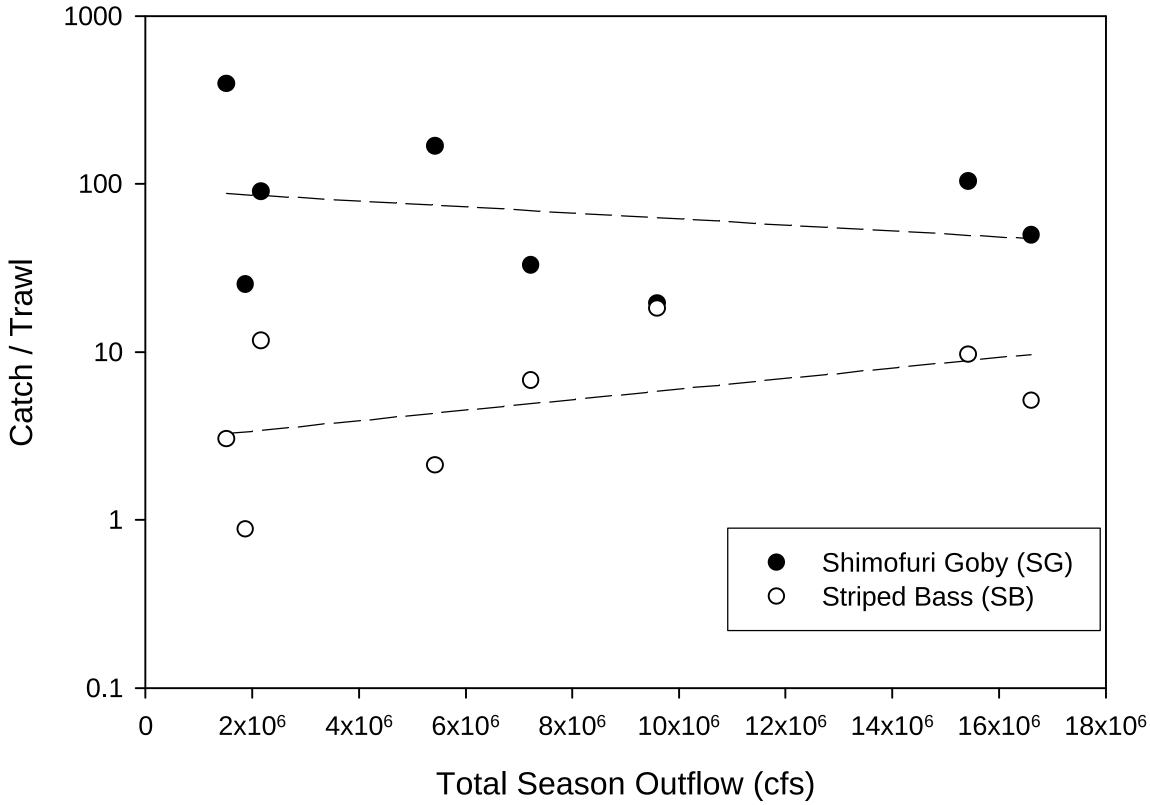





Figure 2.8

Literature Cited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**Appendix** Mean catch per trawl for several categories of fish and invertebrate species captured in Suisun Marsh.

| yr | trawls | intros | natives | SB | YFG | SG | SKG | ST | DS | LFS | TP | SCP | SKR | STAG | Cra | Exo | Pal |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Figure 1.5 | | Fig. 1.6 | Figure 1.7 | | | Fig 1.8 | Figure 1.9 | | Fig. 1.10 | Figure 1.11 | | | Fig. 1.13 | | |
| 1980 | 483 | 18.03 | 31.36 | 13.40 | 2.40 | 0.00 | | 7.69 | 0.35 | 6.72 | 3.98 | 3.25 | 1.13 | 0.73 | no data | | no data |
| 1981 | 407 | 26.21 | 31.94 | 22.63 | 0.57 | 0.00 | | 4.54 | 0.57 | 2.34 | 5.84 | 1.60 | 1.50 | 0.90 | 44.54 | | 11.95 |
| 1982 | 266 | 14.12 | 23.64 | 12.23 | 0.74 | 0.00 | | 4.31 | 0.12 | 6.39 | 5.86 | 2.40 | 0.65 | 0.12 | 40.41 | | 8.16 |
| 1983 | 218 | 19.45 | 14.55 | 18.17 | 0.11 | 0.00 | | 3.25 | 0.05 | 1.28 | 0.80 | 5.39 | 0.84 | 0.04 | 3.25 | | 3.08 |
| 1984 | 157 | 23.52 | 7.72 | 14.57 | 6.39 | 0.00 | | 1.22 | 0.00 | 3.52 | 0.69 | 0.81 | 0.63 | 0.25 | 16.74 | | 2.99 |
| 1985 | 210 | 14.52 | 6.10 | 10.70 | 0.98 | 0.01 | | 0.72 | 0.00 | 0.77 | 2.38 | 0.35 | 0.67 | 0.48 | 6.27 | | 8.09 |
| 1986 | 197 | 18.76 | 11.05 | 13.68 | 2.84 | 0.00 | | 3.38 | 0.00 | 0.52 | 3.06 | 1.91 | 0.51 | 0.27 | 40.03 | | 4.92 |
| 1987 | 206 | 9.74 | 13.00 | 6.86 | 1.35 | 0.57 | | 2.15 | 0.00 | 0.53 | 6.20 | 0.25 | 0.33 | 0.09 | 53.50 | | 14.58 |
| 1988 | 216 | 8.09 | 9.53 | 5.70 | 0.52 | 1.31 | | 0.75 | 0.00 | 0.90 | 5.90 | 0.53 | 0.24 | 0.45 | 27.33 | | 5.09 |
| 1989 | 152 | 18.92 | 5.14 | 7.69 | 2.42 | 8.24 | | 0.71 | 0.01 | 0.86 | 1.56 | 0.27 | 0.14 | 0.50 | 50.45 | | 10.12 |
| 1990 | 188 | 7.64 | 4.11 | 2.04 | 0.77 | 4.36 | | 0.43 | 0.01 | 1.29 | 0.98 | 0.06 | 0.11 | 0.28 | 25.96 | | 7.51 |
| 1991 | 206 | 11.67 | 7.04 | 7.68 | 0.17 | 3.38 | | 0.96 | 0.02 | 0.10 | 0.92 | 0.85 | 0.03 | 0.82 | 42.87 | | 4.30 |
| 1992 | 203 | 16.96 | 3.42 | 13.26 | 1.66 | 1.74 | | 0.66 | 0.01 | 0.01 | 1.03 | 0.67 | 0.03 | 0.09 | 10.53 | | 2.60 |
| 1993 | 202 | 22.67 | 2.56 | 5.00 | 16.69 | 0.58 | | 0.31 | 0.03 | 0.01 | 0.48 | 1.20 | 0.09 | 0.07 | 16.76 | | 1.50 |
| 1994 | 228 | 6.97 | 1.89 | 3.47 | 0.76 | 2.34 | | 0.22 | 0.07 | 0.03 | 0.69 | 0.30 | 0.08 | 0.08 | 20.63 | | 0.64 |
| 1995 | 245 | 16.25 | 7.27 | 6.04 | 8.88 | 0.48 | | 1.06 | 0.01 | 0.33 | 0.38 | 2.75 | 0.14 | 1.11 | 48.57 | | 1.52 |
| 1996 | 252 | 8.77 | 6.10 | 6.02 | 0.99 | 0.19 | | 1.74 | 0.05 | 0.03 | 0.34 | 2.08 | 0.25 | 0.20 | 37.92 | | 0.28 |
| 1997 | 252 | 18.90 | 6.44 | 12.09 | 0.72 | 4.77 | | 0.90 | 0.00 | 0.02 | 1.00 | 2.15 | 0.23 | 0.19 | 136.25 | | 3.42 |
| 1998 | 216 | 7.35 | 10.56 | 3.24 | 1.31 | 0.62 | | 1.23 | 0.01 | 0.10 | 0.73 | 1.84 | 0.31 | 0.05 | 23.90 | | 2.65 |
| 1999 | 251 | 18.30 | 7.79 | 8.21 | 6.34 | 1.53 | | 1.55 | 0.10 | 4.51 | 0.16 | 0.61 | 0.20 | 0.14 | 16.89 | | 0.12 |
| 2000 | 252 | 27.79 | 8.91 | 11.28 | 13.60 | 0.56 | 0.00 | 2.20 | 0.06 | 1.56 | 0.22 | 1.24 | 0.21 | 0.31 | 30.63 | | 0.95 |
| 2001 | 250 | 23.36 | 8.93 | 16.98 | 2.05 | 2.64 | 0.14 | 4.74 | 0.13 | 1.16 | 1.78 | 0.07 | 0.18 | 0.18 | 33.15 | | 15.98 |
| 2002 | 246 | 11.62 | 12.39 | 6.03 | 0.61 | 2.09 | 0.32 | 4.61 | 0.05 | 2.67 | 3.48 | 0.28 | 0.23 | 0.20 | 20.20 | 31.00 | 5.60 |