Trends in Fish Populations of Suisun Marsh
January 2004 - December 2004

Annual Report For:
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Suisun Marsh Fish Survey, January 2004 - December 2004

STUDY BACKGROUND

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 (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 have been 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 and continued through 2002. The larval fish sampling was conducted to gain a better understanding of larval fish use of Suisun Marsh. At present only the juvenile and adult fishes are sampled.

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.* 1995-1998, Schroeter and Moyle 1999-2003) 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.

Large fluctuations in native fish abundance and increases in the number and abundance of introduced species in Suisun Marsh have prompted further investigation. This report presents the findings from the 2004 fish sampling season with comparison to earlier collection data.

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 2-10 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 remaining native species are positively influenced by periods of low and intermediate salinity. The majority of alien fish 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.

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, Asian clam, and Siberian prawn; 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, Schroeter and Moyle 1994 – 2003). In general, abundance of the various species within the marsh has been declining since the early sampling years (1980 - 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-fifth year (2004) of the Suisun Marsh juvenile and adult fish survey.

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 1.5 X 4.3 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 (mg/l and %saturation; first sampled in 2000) 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. In 2004, the delta outflow was considerably altered in June by the Jones Tract levee failure as well. For three days in June the outflow was -3,300 to -29,000 cfs. 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 reduced outflow resulted in elevated salinities for much of that time period. The above normal water year of 1993 resulted in considerable outflow which resulted in fresher conditions in the marsh. In 1994, outflow again decreased dramatically resulting in more saline conditions in the marsh. Between 1995 and 2000 the water year classifications were all considered to be above normal or wet years (DWR DAYFLOW data), although there were considerable differences in the timing and magnitude of rainfall and environmental conditions. The past four years were drier, with the exception of 2003 which was an above normal water year in the Sacramento River drainage (but still a below normal water year in the San Joaquin River drainage). Both 2001 and 2002 water years were classified as dry with considerably reduced outflow moving into the San Francisco Estuary. The year 2004 was classified as a below normal and dry in the Sacramento and San Joaquin River drainages, respectively (DWR DAYFLOW data; Figure 1.4).

Salinity. Salinities in Suisun Marsh are strongly influenced by river runoff (Sacramento and San Joaquin Rivers) and the resultant outflow that moves into the upper San Francisco Estuary. Periods of low outflow result in elevated concentrations of salinity in Suisun Marsh as marine water intrudes into the upper estuary. Periods of high runoff and outflow result in lower levels of salinity observed in the sloughs and channels of Suisun Marsh. These effects have been clearly observed in our recorded salinities (Table 1.3). In summary, the outflow in most years has resulted in maximum salinities exceeding 6 ‰ (16 of the 25 years sampled with salinities exceeding 9 ‰ in 5 of those years), although average salinities are usually < than 7 ppt (Table 1.4). High outflow conditions have resulted in average high salinities below 2.5 ‰ in three years (1982, 1983, and 1998) and between 2.5 and 6 ‰ in 5 years (1980, 1984, 1986, 1993, and 1995). The drought years of 1985-1992 resulted in the most extreme changes in salinity, with recorded salinities above 2 ‰ for all months except three (February 1986, March 1986 and March 1989).

Seasonal changes in salinity observed in Suisun Marsh are important and can vary quite dramatically. The January – April (occasionally May) time period is usually characterized by increased outflow and reduced salinities, with increasing salinities through December. Very dry periods with little outflow often result in dramatic increases in salinity between May and June.

The 2004 water year resulted in an average salinity of 3.9 ‰, and with an average monthly high of 7 ‰ in October, slightly earlier than the preceding 2 years (in 2002-2003 the monthly high occurred in November), but characteristic of other years (i.e. 1997, 2000, 2001).

Temperature and Water Transparency. The temperature regimes in Suisun Marsh vary seasonally, and annually with warmest temperatures recorded in summer months (May – September), with considerable cooling observed in Fall and Winter (Table 1.3, Table 1.4). Average temperatures can be quite high during the summer months which may significantly affect the use of the marsh by traditionally more cold water species including Salmonids and Osmerids and more marine species. In 2004 temperatures were elevated in the summer months, but were lower than highs in the 2003 year, when average summer water temperatures exceeded 24 °C in July. However, the average August water temperature in 2004 was the sixth highest since 1980 (22.6 °C) and the September average was again the second highest since 1980 (23.26 °C).

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). This is most likely due to the mobilization of materials in the river channels leading into the upper estuary as well as in the local tributaries surrounding Suisun Marsh under high outflow conditions. The last four years (2001-2004) have consistently yielded high secchi depths with the annual average in 2004 being the highest, and the 2001-2003 averages being the fifth, the fourth, and the third highest since 1980 respectively. The low flow outflow conditions in 2001 and 2002 likely contributed to these results although 2003 had high secchi depths and an above normal (AN) water year. The effect of decreased water transparency has not been investigated in the marsh, but it may result in reduced phytoplankton production and overall productivity if light levels become limiting for photosynthesis. Average secchi depths in Suisun Marsh are generally less than 30 cm and more commonly are less than 25 cm, thus light limitation and decreased productivity is quite possible. A tradeoff may exist however in that reduced light transparency conditions (high outflow / runoff) may result in greater availability of nutrients for phytoplankton and thus, greater productivity overall. More study is needed to understand the relationship between productivity and light limitation in Suisun Marsh.

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 - 2004 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 monthly dissolved oxygen concentrations in Suisun Marsh generally are at or above 7 mg/l (Table 1.3). Although, two notable periods in which dissolved oxygen levels are depressed are evident. These include the early summer period primarily the month of June (and occasionally May) and also the fall months of September through November. These two sags correspond in time and space with land use practices in the marsh, primarily duck pond draining and maintenance. In

June *average* DO levels often fall below 7 mg/l and occasionally 6 mg/l and in the fall it is common for average DO levels to fall below 6 mg/l. For instance in 2004, in October and November DO levels were recorded as low as 2.8 mg/l for three sites, and a low of 2.3 mg/l was recorded in Goodyear Slough. These low DO events are often associated with large fish kills or absence of native species that are intolerant of low DO.

<u>General trends in fish abundance:</u>

Throughout the twenty-four years of fish sampling in Suisun Marsh, otter trawl catch of native and alien species has fluctuated considerably (Figure 1.5). The largest fluctuations have occurred in the abundance of alien species with 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. 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 fish species through 2004 (Table 1.5, Figure 1.6 and 1.7, respectively). The abundance of yellowfin goby catch has significantly declined since 2000, while shimofuri goby numbers maintained substantial levels, comparable to years 2001-2002. The alien species catch continues to be dominated by striped bass, although the catch was lower in 2004 than in 2003. 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. In 2003, striped bass comprised 75% of the alien fish catch with yellowfin goby and shimofuri goby comprising just over 10% of the total alien catch. By comparison, in 2004 striped bass comprised only 60% of the alien fish catch with yellowfin goby comprising 9% and shimofuri goby comprising over 18% of the total alien catch.

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 considerable increase in abundance of native species from 1995-2003 (Figure 1.5). This increase in native fish abundance is driven primarily by increased catches of Sacramento splittail and more recently (2001-2003) tule perch (2002 and 2003; Figures 1.8 – 1.11), but longfin smelt and delta smelt have also increased in abundance since 1998 (Figure 1.9). Catch of the remaining native species have either fluctuated considerably (Figure 1.11) or have remained at relatively low levels (Table 1.5; Figure 1.11). In 2004, there was a decline in native species abundance as compared to recent years, however the numbers were still comparable to those observed since 1995.

The catch of alien fishes again outnumbered that of native fishes in 2003 and 2004, reversing a short-lived trend (2002) in native fish catch exceeding that of aliens. 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 was 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 improving for native fishes in Suisun Marsh as is evident in their continued increase in abundance.

Fish catch between 1995 and 2004 has varied depending upon slough sampled (Figure 1.12). In general, there appears to be three levels of abundance among sampled sloughs (low, ≤ 15 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, but it can't be ruled out that fewer individuals may actually occupy the 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 resulting in physical conditions unfavorable to fish found in Suisun Marsh. Intermediate levels of catch between 1995 and 2004 occurred in Cutoff, Peytonia, and Denverton sloughs and the highest catch occurred in Goodyear, Spring Branch and Lower-Suisun sloughs. Striped bass made up the largest portion of the catch in the highest catch sloughs (Good Year, Spring Branch, and Suisun Lower) with a majority of these striped bass being young of year (YOY). Tule perch and splittail also made up a large percentage of the catch in Spring Branch Slough.

Delta smelt and longfin smelt:

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) and 2003 (11 individuals) declined to nearly one-third the catch in 2001 (32 individuals; Figure 1.9). The downward trend continued in 2004, with the lowest catch (seven individuals) since 1998. Longfin smelt (LFS) catch in 2004 was also the lowest catch since 1998 (133 individuals, CPUE of 0.53). This is a short downward trend that started in 2003, following a large LFS catch in 2002. The 2002 catch consisted of 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 has been particularly evident from 2000-2004, with adults being captured during the spawning period (January and February) and postlarvae and juveniles captured between February and June. The size of individuals captured in November and December are generally between 50 and 100 mm. Large adults captured in January and February in each year are presumably adults from the previous years cohorts with few fish being caught over 100 mm. The presence of larval longfin smelt present in our larval fish samples as early as the first week of February indicates that the adults likely spawn in Suisun Marsh. 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. 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. In 2004, adults were captured in the Marsh until February, as in the previous three years, but juveniles were not captured until April. We continued to capture juveniles into July although total numbers of juveniles decreased.

Striped bass:

Striped bass catch per unit effort declined sharply in 2004 (8.87 striped bass/trawl) from the 2003 catch per unit effort (14.14 striped bass / trawl), which was the fifth highest since 1980. However, this year's catch was still the sixth highest catch in eighteen years. A total of 2235 striped bass were captured by otter trawl in 2004 making up over 38.7 % of the total catch (5770 individuals of all species), compared to 45% of the total catch in 2003. These totals and the percent composition are similar to the highs observed in 2001 when 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, 1999 – 2001, and again in 2003. YOY striped bass make up a majority of the striped bass catch, thus fluctuations resulting from successful recruitment in a given year are largely responsible for the dramatic changes in striped bass abundance in Suisun Marsh. 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. If catch is associated with recruitment or spawning success, than 2003 and 2004 were better years for striped bass than 2002, with 91% and 83% of the striped bass catch being < 100 mm SL respectively. As in previous years, the majority of those fish caught that were < 100 SL were also < 60 mm SL.

In the past, it appeared that based on catch rates within the Marsh, three areas were 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 and 76% in 2003. However, in 2004, less striped bass were caught in Goodyear Slough, and the majority of striped bass (65%) were caught in lower Suisun and Spring Branch. Low dissolved oxygen throughout 2004 in Goodyear Slough likely contributed to low catches for striped bass. It is uncertain why certain regions within the Marsh 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 of Sacramento splittail in 2004 (657 individuals; 2.61 individuals / trawl) was lower than the past three years, but still the forth highest since 1987. Years 2001-2003 had high catches comparable with the historical high catches in the early sampling period between 1980 and 1982. The 2001 – 2004 splittail catches were comprised of multiple age classes and were unlike the 2000 catch, where a majority of individuals were YOY. From 2001 to 2004 at least 64% of the splittail caught were greater than 100 mm SL (almost 65 % of the 2001 fish, 89.9 % of the 2002 fish, 68% of the 2003 fish and 64% of 2004 fish). A notable exception in 2002 was the fact that relatively few splittail captured were less than 100 mm SL 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). In 2003 there were two very distinct size classes of YOY that moved into the marsh. The first entered the marsh in April and the second group (noticeable size difference between the two) entered the marsh in May and June.

Splittail captured within Suisun Marsh are generally most abundant within certain sloughs. In 2004, catch rates were greatest in Spring Branch (30%), Goodyear (23%), and lower Suisun Sloughs (14%). Peytonia and Cutoff Sloughs also had substantial catches of splittail (12% and 11% of the catch respectively). In 2001, catch rates within Spring Branch, Peytonia and Goodyear comprised over (76 %) of the total splittail catch, while only making up 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 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.

The 2004 splittail beach seine catch was the highest since 1999 and the third highest since 1995 (224 individuals). Young of the year make up the largest percentage of the splittail beach seine catch (Schroeter and Moyle 2001). The increase is substantial compared to the 2002-2003 years where the seine catch declined to 88 (2002) and 82 (2003) individuals. The 2002-2003 catches were the lowest beach seine catches since 1995. and the low catch in 2002 and 2003 is largely explained by the overall poor catch rates of YOY splittail.

Chinook salmon:

The total catch of chinook salmon in 2004 was 17 (7 in the otter trawls and 10 in the beach seines). These totals are similar to the 2003 totals (15 individuals, 0 in otter trawls and 15 in beach seines), but are distinct in that more fish were caught in otter trawls in 2004 than in 2003. In addition, both 2003 and 2004 had catches lower than the 27 individuals captured in 2002, which was the highest catch in the marsh since 1995. All chinook salmon captured from 1995 through 2004 were fall run as determined using Frank Fisher's (1992) length-at-date criteria.

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 2003. 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, 78 individuals during our 2002 sampling, 52 individuals during our 2003 sampling, and 51 individuals in 2004, a majority of which were juveniles. Overall, the catch of shokihaze goby in Suisun Marsh has remained 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, although their continued low abundance for the last 4 years does suggest that their abundance may remain relatively low.

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 has remained relatively low over the last few years (2001 – 2004). In 2004, 343 individuals (1.36 fish / trawl) were captured by otter trawl. A similar number of yellowfin gobies were caught in 2003. Yellowfin goby catch by beach seine increased in 2004 (527 individuals). The 2004 catch was much greater than the 2003 beach seine catch (370 individuals), which was 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, 1995 and 2000. A majority of the fish making up the peaks in abundance are YOY, which was again the case in 2004 (52% of the fish were less than 30 mm SL). Historical peaks in abundance of YFG in Suisun Marsh have been short-lived, typically lasting one to three years. Thus, the current decline observed between 2001 and 2003 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 it has declined considerably since then. The shimofuri goby catch in our otter trawls in 2004 was 691 individuals, similar to the 2001 and 2002 totals (659 and 515, respectively). In 2003 only 170 individuals were caught, but this does not appear to be a trend given the 2001, 2002 and 2004 catches. The beach seine catch of shimofuri goby in 2003 (68 individuals) was also down considerably from previous sampling years (Table 1.5), but was higher in 2004 (97 individuals).

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 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. The decline in yellowfin goby abundance and a corresponding low shimofuri goby abundance does not support the claim that biotic interactions may be affecting goby abundance in the marsh.

Prickly sculpin, Pacific staghorn sculpin, and Sacramento sucker:

The catch of native prickly sculpin, has been highly variable throughout the course of this study (Figure 1.11). In 2003 and 2004, prickly sculpin catch was low with only 96 and 95 individuals captured in otter trawls (respectively) and 5 individual captured by beach seine (both years). The low numbers of prickly sculpin observed in 2003 and 2004 is a considerable decline from the 1995-1998 time period as well as the 2000 catch. 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 36 staghorn sculpin were collected by otter trawl and 57 individuals by beach seine in 2002 (Figure 1.11). The past two years have seen declines in staghorns in both the beach seine and the otter trawl catches, but only 2003 was a high outflow year. The beach seine catches in 2003 and 2004 were the lowest since 1995 (57 and 56 individuals respectively). The otter trawl catches were also low in 2003 (36 individuals) and 2004 (23 individuals) being the 8th and 5th lowest catches in 25 years. The majority of staghorns caught in 2004 (69%) were less than 40 mm SL but in 2003 the majority caught were greater than 40 mm SL (71%).

Sacramento sucker, like many native fishes, have for the most part been in a long-term decline in Suisun Marsh (Figure 1.11) despite a modest upswing in abundance in 2003 (86 individuals caught). A total of 44 individuals were captured by otter trawl in 2004 and 2 were captured by beach seine. Despite a relative low overall abundance, the 2003 and 2004 catches were comprised of multiple age classes which is encouraging. The Sacramento sucker is highly 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. A likely factor likely limiting the return of large numbers of suckers is elevated salinity, stream discharge, and overall stream condition.

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 remained very low between 1989 to 2001. 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; 1.78 TP / trawl) 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; 3.5 TP / trawl). The catch of tule perch in 2002 was the sixth highest since sampling began in 1980 and was the highest catch since 1988. Tule perch abundance again increased in 2003 with 1097 individuals captured by otter trawl (4.35 TP / trawl). In 2004 the tule perch otter trawl catch dropped to 553 individuals (2.19 TP / trawl), although this still represented the third highest catch since 1989. However, it should also be noted that the beach seine catch had the lowest number of individuals caught since 1995 and that this low number of YOY may affect next year's catch. As in 2001 - 2003, multiple age classes were again present in 2004. The tule perch have clearly demonstrated that they can quickly increase in abundance given suitable environmental conditions. Although the reason for the 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 (see table 1.3). 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.

<u>Uncommon species:</u>

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. In 2003 and 2004, the number of black crappie further declined to 7 individuals for both years. The 2003 catch was surprising given the lower salinities and higher outflow observed for much of the year. In 2004 the high salinities were consistent with the past low catches of black crappies. Salinity is likely the most influential environmental factor controlling the abundance of centrarchids in Suisun Marsh.

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 2004, 9 black bullhead, 107 white catfish, and zero channel catfish were captured. These numbers are similar to 2003, where the majority of Ictalurids captured were white catfish (121 individuals), and only a few black bullhead (3 individuals) were caught. 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 2004. They include the Sacramento pikeminnow (2 individuals) and hitch (1 individual). In addition, 27 American shad were also captured in 2004, substantially lower than catches from 2002 and 2003 (96 and 154 individuals respectively), but still the third highest catch since 1981. One other species worth noting is the Pacific herring, which was not caught at all in 2004. In 2003, herring numbers were the highest on record (133 individuals).

<u>Species collected in beach seines:</u>

Fish catch by seine has fluctuated considerably between 1995 and 2002 with between 2000 and 9000 individuals captured. The mean number of fish per seine haul over this time period was 69.5 individuals. In 2004, 6794 individuals were caught by seine or 80.9 fish/seine. This is the third highest catch since we began sampling in 1995 when Denverton Seining Beach was added to the regular sampling. In 2003, 8518 individuals were captured by seine which was the highest catch by beach seine since 1995. Based on fish catch over this time period, it appears that some fish species are more susceptible to capture by seining as compared to trawling. For instance, from 1995 to 2003 most Sacramento blackfish, bigscale logperch, chinook salmon, Sacramento pikeminnow, rainwater killifish, 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). As in all previous years, the inland silverside was the most abundant species captured by seine in 2004 (4721 individuals) and comprised 69 % of the total catch. Yellowfin goby, threadfin shad, and striped bass were the next three most abundant species (527, 466, and 439 individuals, respectively), together comprising 21 % of the total seine catch. The threadfin shad catch for 2004 was the largest number of individuals caught in the beach seines since 1995. Although yellowfin goby still make up a large percentage of the total fish catch by seine, their 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 2004 (0.96) 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 only low numbers. Orsi has observed continual declines of N. mercedis over the last few years with very few to none captured especially in 2002 and 2003. 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. We are currently processesing and identifying mysid shrimp collected between 1999 and 2002 (UC Davis Larval Fish Survey) and are also conducting a more detailed mysid shrimp community study (CalFed Invertebrate Study) throughout the sloughs of Suisun Marsh,so we will be able to address the discrepancies between studies and should have some more insight into possible habitat segregation and species replacement between the native Neomysis and the introduced mysid species.

The abundance of *C. franciscorum* in Suisun Marsh has fluctuated yearly within the range of 3 to 59 individuals per trawl until 1997, when our average catch increased to 136 individuals per trawl (Figure 1.13). Between 1998 and 2002 the abundance of *C. franciscorum* has remained at or below an average of 35 individuals / trawl with further declines in 2003 (11.6 individuals / trawl) and 2004 (8.8 individuals / trawl). The large fluctuations in abundance of *Crangon* may be explained by fluctuating environmental conditions (especially salinity) 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). However, competition with the recently introduced and highly abundant *Exopalaemon modestus* (see below) may also be playing a role in the recent decline. Other alien species within the genus *Crangon* have also 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 in part on mysid shrimps, their decline may be related to the recent low abundance of mysids (Jim Orsi, DFG, pers. commun.) or alternatively their low abundance 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, *P. macrodactylus* 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* may have been 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*. The catch of *E. modestus* continued to increase dramatically in 2003 with an average catch rate of 53.8 individuals / trawl, a 3 - 4 fold increase over the highest catch of *P. macrodactylus* over the last 24 years. The catch of *P. macrodactylus* dramatically declined in 2003 to an all time low of 0.1 individuals / trawl. It is uncertain whether environmental conditions were unfavorable for *P. macrodactylus* in 2003 or if competition or other biotic interactions with *E. modestus* may be responsible for its decline. In 2004, numbers of *E. modestus* sharply declined to an average catch rate of 13.65 individuals / trawl, but remains the most commonly caught fish or invertebrate species caught in the Marsh, with the exception of introduced *Potamocorbula amurensis*. Lower numbers of abundance could be correlated with the higher salinities in the Marsh observed in 2004. *E. modestus* is considered a freshwater prawn

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 drop in numbers in 2004 could be indicative of a leveling off for *E. modestus.* However, what is certain is that *E. modestus* is well established as multiple size classes and ovigerous shrimp are found throughout the marsh.

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. Given their substantial abundance there is reason for concern. At present we are investigating sex, size class, and breeding season (from 2004 – 2005) within the Marsh as well as environmental variables associated with abundance and distribution to increase our general understanding of *E. modestus* in the Marsh. A preliminary analysis of diet revealed that *E. modestus* is eating largely detritus and vegetation, as no hard body parts from animals were observed. However this analysis was only on a few shrimp (50 individuals) and cannot be considered thorough. A detailed diet analyses and behavioral studies would greatly enhance our understanding of the current and future impacts of *E. modestus.*

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. communication.) 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 2004, 17,023 individuals were captured, lower than 21,473 individuals captured in 2003. However, the past two years are the highest catches in Suisun Marsh since first detection of *P. amurensis* in 1988. In the past individuals captured in Suisun Marsh were typically small (< 5 mm) and were mainly collected between January and September (i.e. 2001). However patterns have been more erratic in recent years. In 2002 and 2003 individuals were collected in all months with a peak from May - August. In 2004, *P. amurensis* were collected in all months as well, but a large number of *P. amurensis* were captured in March (7054 individuals), and substantial numbers were also captured monthly from July – December (1200 – 2400 individuals/month), with the exception of November where only 170 individuals were captured). In addition, the *P. amurensis* caught in 2004 were considerably larger on average than those observed in the past (approximately 10 mm).

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, but has generally declined since 1999. In 1997, we collected 19 Chinese mitten crabs. In 1998 and 1999, we collected 149 and 171 mitten crabs, respectively, mainly in Suisun Slough. Catch again declined in 2000 (17 individuals), rebounded slightly in 2001 (98 individuals) and declined again to low levels from 2002 to 2004 (15, 1, and 4 individuals respectively).

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 recent increases 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. Historically abundant native species, including longfin smelt, splittail and tule perch, have also fluctuated considerably in abundance and until recently (1999 - 2003) have only been caught in very low numbers. The increase and sustained high abundance of splittail and tule perch during recent years was 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 significantly increased in abundance in the past few years. Lower tule perch numbers in 2004 are still greater than in the past ten years and may reflect less favorable environmental conditions. 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. Declines in the 2004 catch for these natives appear to continue this pattern of low abundance. The low abundance of some native species since the early 1980s (such as hitch, Sacramento blackfish, pikeminnow, sucker, delta smelt, and prickly sculpins) may be partially explained by the increased salinities observed.

Factors responsible for native species declines are largely unknown, but are likely attributable 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 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. 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/lO_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	1.51	1.72	1.95	1.75	1.55	1.69	1.53	3.07	4.2		4.5	4.64
1981	4.44	2.84	3.01	2.07	3.07	3.95	5.29	6.77	7.91	7.59	8.76	2.73
1982	2.09	1.5	1.22	0.43	1.11	0.6	0.74	1.56	1.78	0.93	1.31	0.71
1983	0.41	0.27	0.14	0.34	0.62	0.33	0.23	0.39	0.48	0.25	0.23	
1984	0.19	0.7	0.59	0.83	1.87	2.69		3.91	3.61	3.31	2.68	
1985		2.56	2.18	3.13	3.32		4.9	8	8.25	10.18	8.54	7.5
1986	2.71	0.58	0.68	1.07	2.83	4.39	4.26		3.98	3.31	4.12	4.66
1987	4.08	2.48	2.46	3.1	4.27	7.74	7.22	6.08	6.44	9.59	9.51	6.99
1988	3.3	4.65	6.13	3.34	3.54	4.55	4.59	5.42	4.7	4.45	4.16	2.71
1989		2.91	1.33	3.39	3.54	5.26	6.63	6.18	6.26		5.03	6.32
1990	4.18	3.66	4.67	5.42	5.92	4.19	5.66	6.42	7.25		9.34	8.79
1991	8.12	6.46	3.05	2.59	5.54	7.8	8.37	8.91	8.61	9.65	8.09	8.59
1992	7.18	4.48	2.64	2.24	4.83	6.57	7.76	9.69	9.39	10.19	8.02	5.02
1993	2.13	1.43	0.86	1.65	1.05	0.86	2.19	2.52	3.56	4.39	4.38	4.12
1994	2.82	1.45	1.21	1.91	2.13	4.11	6.28	7.84	6.73	5.74	5.69	3.05
1995	0.94	0.7	0.22	0.73	0.25	0.22	0.14	1.18	1	1.49	3.92	2
1996	1.45	0.45	0.58	0.68	0.76	0.6	2.59	3.46	4.26	6.65	4.5	2.01
1997	0.58	1.03	1.09	1.75	2.91	4.23	5.11	5.2	5.48	6.93	6.04	2.77
1998	1.69		0.86	0.91	0.87	0.61	0.56	0.9	1.04	1.28	1.95	0.98
1999	0.96	0.74	0.56	1.22	0.75	0.93	1.87	2.59	4.27	4.61	5.48	4.53
2000	2.36	0.96	1.05	1.2	0.94	1.82	3.63	3.71	5.34	7.04	5.89	3.92
2001	2.87	1.56	0.89	1.39	2.12	2.91	5.29	7.07	8.41	9.43	6.43	1.85
2002	1.18	2.55	2.15	2.19	2.73	2.56	5.72	6.83	7.56	6.32	7	3.04
2003	1.3	1.91	2.2	1.97	0.99	1.45	2.91	3.57	4.8	5.77	7.03	6.08
2004	1.80	1.53	1.38	1.60	1.34	4.22	5.01	5.52	6.62	7.13	5.44	5.53

Table 1. 3 continued

Temperature (°C):

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1980	9.99	10.56	13.05	17.14	17.71	19.67	21.2	20.97	20.25		15.47	9.46
1981	9.01	12.52	15.02	17.45	20.01	21.57	22.94	22.14	20.47	16.86	15.4	10.74
1982	7.7	8.85	13.15	14.12	18.4	19.95	23.92	19.54	20.9	17.33	9.68	9.05
1983	8.26	12.97	12.61	14.66	19.61	19.13	20.37	19.88	22.35	17.54	11.13	
1984	7.76	12.4	16.48	16.48	21.47	22.77		25.61	24.41	14.84	12.81	
1985		8.4	10.74	17.73	21.56		24.78	20.31	19.2	16.97	9.21	5.48
1986	10.26	15.63	16.97	19.08	21.38	20.43	20.71		19.16	16.62	14.49	9.34
1987	6.97	11.5	15.35	20.32	18.78	18.99	22.9	21.93	20.58	17.04	12.66	8.34
1988	10.46	9.68	15.47	18.55	19.69	22.35	22.18	23.49	17.33	13.97	11.81	5.53
1989		8.56	15.35	17.24	20.55	19.39	22.74	21.66	19.67		11.2	10.71
1990	8.11	10.14	15.34	19.31	18.94	21.04	21.28	24.08	20.74		12.29	9.45
1991	6.74	12.17	11.82	14.98	17.72	18.53	20.28	20.9	19.39	19.09	15.32	9.49
1992	8.05	11.48	14.29	16.63	19.46	19.17	22.25	20.25	21.07	21.74	19.32	10.79
1993	8.18	12.36	17.63	17.05	20	24.3	22.18	23.06	19.95	19.01	12.22	11.89
1994	9.61	11	14.85	18.16	19.78	20.03	20.89	22.99	20.47	18.03	10.68	8.62
1995	9.8	13.2	13.09	15	21.76	22.43	21.49	22.4	19.82	17.29	16.08	10.91
1996	9.94	13.71	16.31	19.18	19.1	21.39	21.36	19.88	19.29	15.2	14.06	10.98
1997	12.53	11.66	17.78	18.49	19.75	23.16	22.25	20.5	21	15.53	13.96	8.85
1998	10.87		16.9	15.13	15.62	18.7	23.15	21.07	20.14	16.05	12.56	8.82
1999	6.1	11.11	13.35	16.48	18.4	19.16	22.17	20.48	19.62	19.18	12.88	9.78
2000	11.39	12.08	14.61	17.6	19.28	20.24	20.32	20.67	22.4	14.71	10.71	10.5
2001	8.45	9.65	12.64	15.16	20.1	21.51	20.31	21.84	19.86	17.73	15.74	9.38
2002	8.81	11.29	12.47	16.94	19.02	22.41	21.27	20.8	21.06	19.43	14	11.74
2003	10.63	12.73	13.99	16.23	18.65	21.92	24.67	22.15	22.58	18.43	13.94	10.99
2004	9.90	12.58	16.74	17.73	20.48	22.14	21.81	22.60	23.26	17.00	13.94	9.84

Table 1. 3 continued

Secchi (cm):

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1980	22.5	24.37	22.11	18.41	14.51	14.88	16.15	22.15	25.6		25.67	26.95
1981	26.56	18.54	18.22	16.93	17.61	19.88	20.84	23.79	35.26	38.73	33.71	19.7
1982	22.19	26.21	20.41	19.67	20.86	15.68	14.84	15.75	18.37	20.36	19.43	25.74
1983	28.11	21.71	15.4	19.05	16.79	17.26	19	20.45	29.22	19	24.92	
1984	30.47	22.06	16.5	16	22.29	41.25		30.23	35.46	31.42	27.79	
1985		24.47	23.06	18	22.5		21.54	24.1	33.39	39.75	49.77	41
1986	21.6	16.41	17.78	18.79	15.6	15.82	19.13		20.58	24.19	24.36	29.13
1987	29.47	19.87	17.88	20.62	19.83	21.36	24.92	30.31	34.17	29.64	30.6	24.43
1988	30.2	20.43	18.38	25.8	19.92	28.45	22.76	25.53	29.81	31.29	29.79	28.1
1989		29.69	17.4	15	13.64	19.82		22.53	20.38		22.33	28.4
1990	25.38	21.06	20.89	15.5	21.18	14.94	19	18.76	25.08		27.71	28.12
1991	37.81	25.39	16.13	14	14	16.69	19.65	23.29	29.29	36.25	30.69	28.65
1992	27.12	24.82	19	16.24	17.41	21.13	22.12	21.24	28.47	34.47	26.44	26.65
1993	18.94	16.47	21	17.75	16	13.47	16.07	14.47	16.59	22.71	25.88	28
1994	25.29	19.3	18.29	23.94	17.7	23.43	18	25.33	22.57	23.67	21.62	26.33
1995	12.67	16.19	13.62	11.48	12.81	15.1	13.07	13.95	13.1	20.86	21.38	20.52
1996	16.95	15.52	16.67	16.95	17.33	15.48	23.19	22	26.52	34.9	27.24	24.81
1997	16.3	15.43	14.25	12.05	18.43	22.95	24.52	27.05	32.38	37.71	37.1	23.86
1998	27.38		24.48	20.52	14.5	17.76	14.57	16.43	13.86	17.9	20.29	21.52
1999	24.48	16.33	23	16.71	13.57	12.57	16.24	19.24	21.26	26.1	29.62	22.19
2000	25.14	21.33	18.48	15.1	15.04	15.81	24.57	25.95	31.81	26.1	33.05	30.95
2001	29.38	25.9	19.76	20.19	21.95	22.86	29.62	29.57	34.05	31.05	30.43	27.76
2002	22.57	21.57	22	20.86	23.57	25.76	27.67	37.19	35.76	33.68	32.05	23.81
2003	24.26	21.15	20.86	26.25	20.75	19.05	26.86	25.79	34.9	35.67	30.14	41.57
2004	27.43	19.85	17.95	20.10	21.20	26.85	29.71	32.43	37.10	38.86	34.65	39.37

Dissolved Oxygen (mg/l):

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
2000	7.98	10.42	7.69	7.51	7.09	7.04	7.64	8.06	7.12	7.68	8.21	8.23
2001	9.83	9.21	8.84	9.11	7.68	6.96	7.89	7.8	8.03	5.92	6.47	9.93
2002	9.33	8.45	8.88	7.7	6.81	6.96	7.31	6.7	6.45	6.55	8.2	9.21
2003	7.23	8.09	7.4	6.56	10.77	5.52	10.27	7.82	7.94	5.75	6.55	8.15
2004	8.06	8.88	7.53	8.38	7.91	7.41	7.61	7.89	7.29	6.33	6.57	9.79

Table 1. 4 Summary of Suisun Marsh data 1980-2004. 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	7.7	27.2
2003	31.1	11.6	0.1	53.8	1.1	3.3	17.2	7.6	27.4
2004	22.9	8.8	0.02	13.7	1.0	3.9	17.3	7.8	28.8

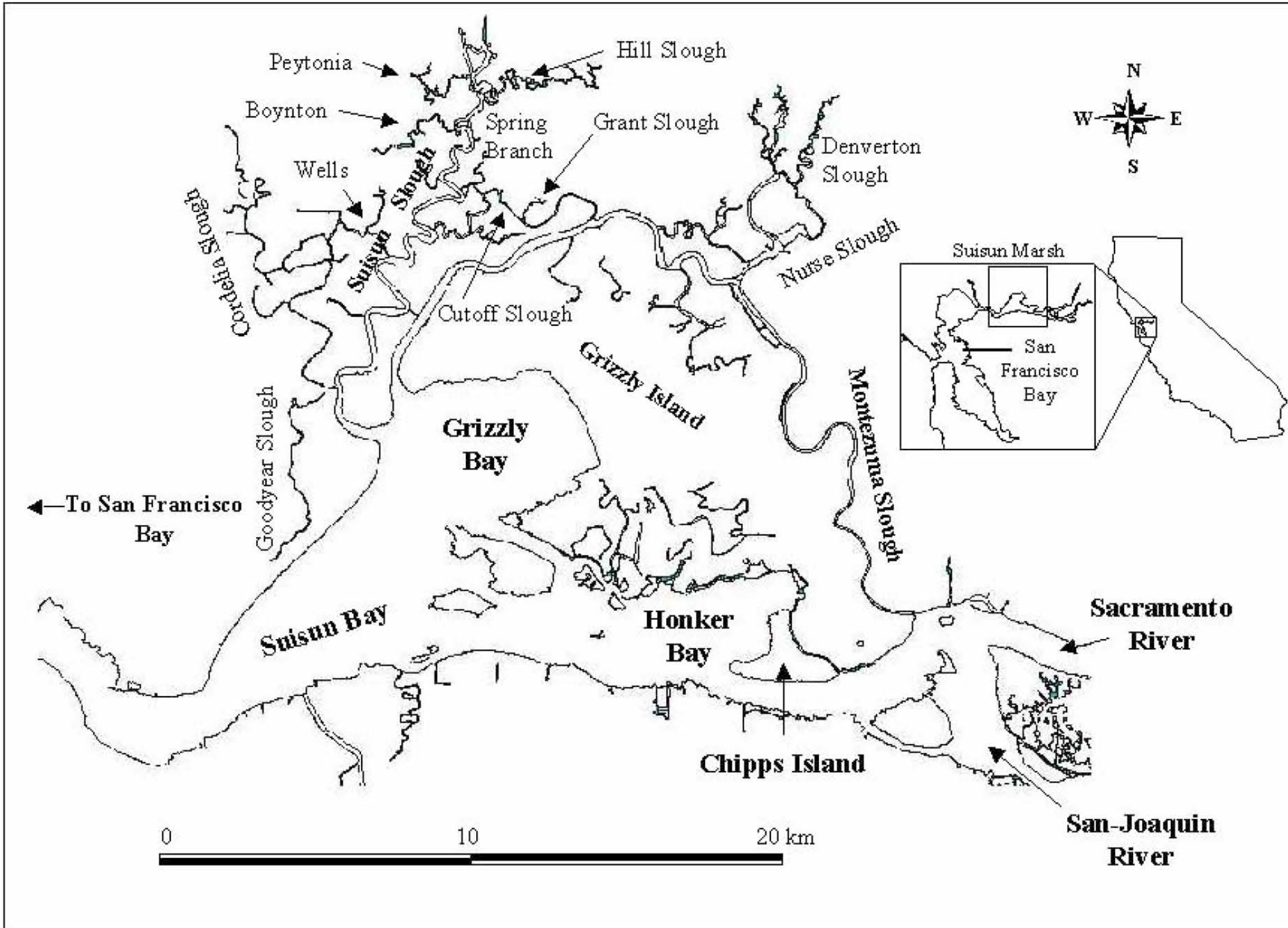
Table 1.5 Total catch per year for species collected in Suisun Marsh trawls January 1979 - December 2004. See Table 1.1 for species represented by abbreviations.

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	2003	2004
ASH	21	36	156	8	2	5	8	7	7	6	2	16	3	6		4	1	1	1			13	11	96	154	27
BB		3	3	2	1	4	4	2			1					1				1				1	1	0
BC		2	5	1	1		2	78	7	4							1	3	10	5	127	47	79	17	7	8
BF	2	9	2	4	1																					
BG		5	1	4	1			1									1					1	1		1	
BLB		2	1			11	17	4	1	1						1	4	8	5	17	21	24	15	31	3	9
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	157	86
DAB												1		2												
DS	17	168	230	33	11		1			1	1	1	5	3	7	16	2	12		2	26	16	33	12	11	7
FHM		6	2				6	1			1						1		1					2		2
GF	6	23	5	2		21	100	7	3	3	2			1	3	2			1	1	3	16	2	7	21	11
GS																		1		2						
GSF		1	1																1					2		
GSH									2	1															1	
HCH		13	24	8	6	6	19	2	10	9		3	1	1		1	2			1				2	1	1
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	22	3
KS		13	19		11	1		13	1	1	1						2	1		1	2	3	2			1
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	490	133
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	133	0
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					5	1
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	3564	2235
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	96	95
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	43	68
SG							2		82	282	1253	819	696	353	117	534	117	48	1202	133	384	140	659	515	170	691
SKG																					1		34	78	52	51
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	83	44
SP		2	3						1			11														
SPM	16	44	22	6	3	5	2	9	5	1							2			1		1		2	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	1009	657
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	36	23
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	111	473
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	107	70
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	1097	553
WAK																					1	5	1		1	2
WCF	1	4	4	6	132	32	24	14	6	8		6	2	1	3	6	51	190	79	276	232	331	109	204	121	107
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		2	
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	341	343
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**	**7841**	**5703**
# 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**	**252**	**252**
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**	**31.1**	**22.6**

Table 1. 6 Total catch per year for species collected in Suisun Marsh seine hauls from January 1995 - December 2004. See Table 1.1 for species represented by abbreviations.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
ASH			1				1	1	3	8
BC				6	2	3	3	2	1	
BF	5									
BG	1			1						
BLB					2	1				
BLP		1			1					
CC			1	1	4					
CP	3	7	33	33	74	7	8	4	5	7
DS	17	2	1	1	1	5	1	1	2	4
FHM	1	3	6	3	3				1	1
GF		1		1	4	3				3
GSH				1						
HCH	1			1	1					
ISS	1827	1991	4794	1091	1670	3052	4284	4033	6595	4721
KS	48	6	1	4	14	4	8	27	15	10
LFS	2				2	1	1			2
LMB				1						
MQF	18	19	35	22	30	2	1	1	6	9
PH		1	4		5	9	4	5	22	
RT		1			1		1	1		
RWK	6	1	1	1		1	3	2	4	5
SB	203	492	1906	90	376	481	506	566	725	439
SCP	38	21	16	8	6	25	1	1	5	5
SF	4	18	23	2		2		1	1	3
SG	170	43	274	106	33	64	122	204	68	97
SKR	3	6	8	1	5	2	1	3	3	2
SPM	11	2	9	7	1	1	3		1	1
ST	246	99	107	153	446	207	120	88	82	224
STAG	373	92	146	63	310	260	213	101	57	55
STBK	130	195	99	44	54	48	95	164	233	196
TFS	203	415	144	340	210	85	166	124	252	466
TP	95	41	27	100	13	19	17	26	64	9
WAK			1			3				
WCF		3	3	43	21	2	12	1	3	
YFG	2075	909	611	770	1977	2288	708	412	370	527
Total	5480	4369	8251	2894	5266	6575	6279	5768	8518	6794
Number o	72	84	84	74	84	84	84	80	84	84
Mean fish	76.1	52.0	98.2	39.1	62.7	78.3	74.8	72.1	101.4	80.9

Figures



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

Figure 1.1

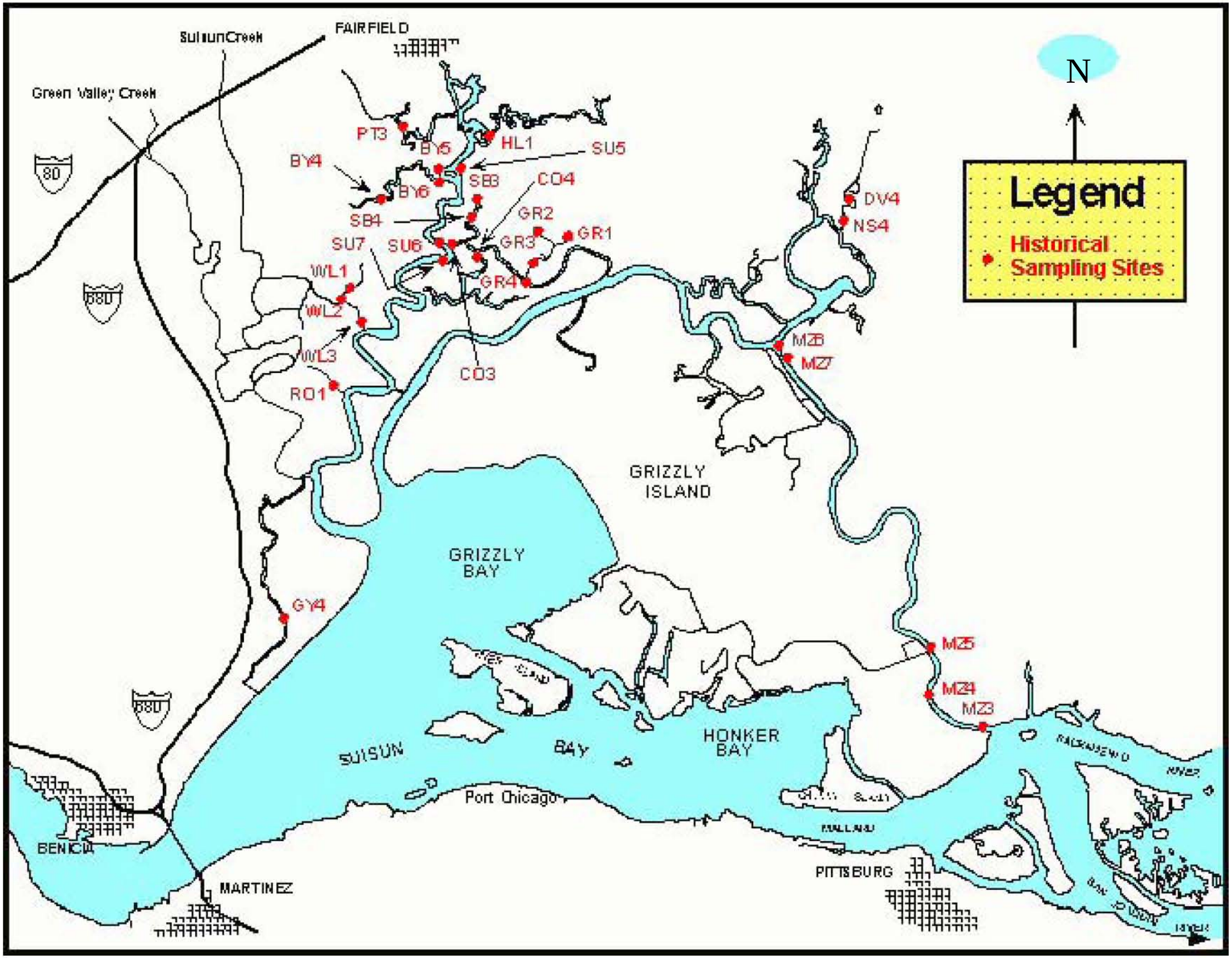

FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
N
Legend
Historical Sampling Sites
PT3
BY5
HL1
SU5
BY4
BY6
SB3
CO4
SB4
GR2
SU7
SU6
GR3
GR1
WL1
GR4
WL2
WL3
CO3
RO1
DV4
NS4
MZ6
MZ7
GRIZZLY ISLAND
GRIZZLY BAY
GY4
MZ5
MZ4
MZ3
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG

Figure 1.2

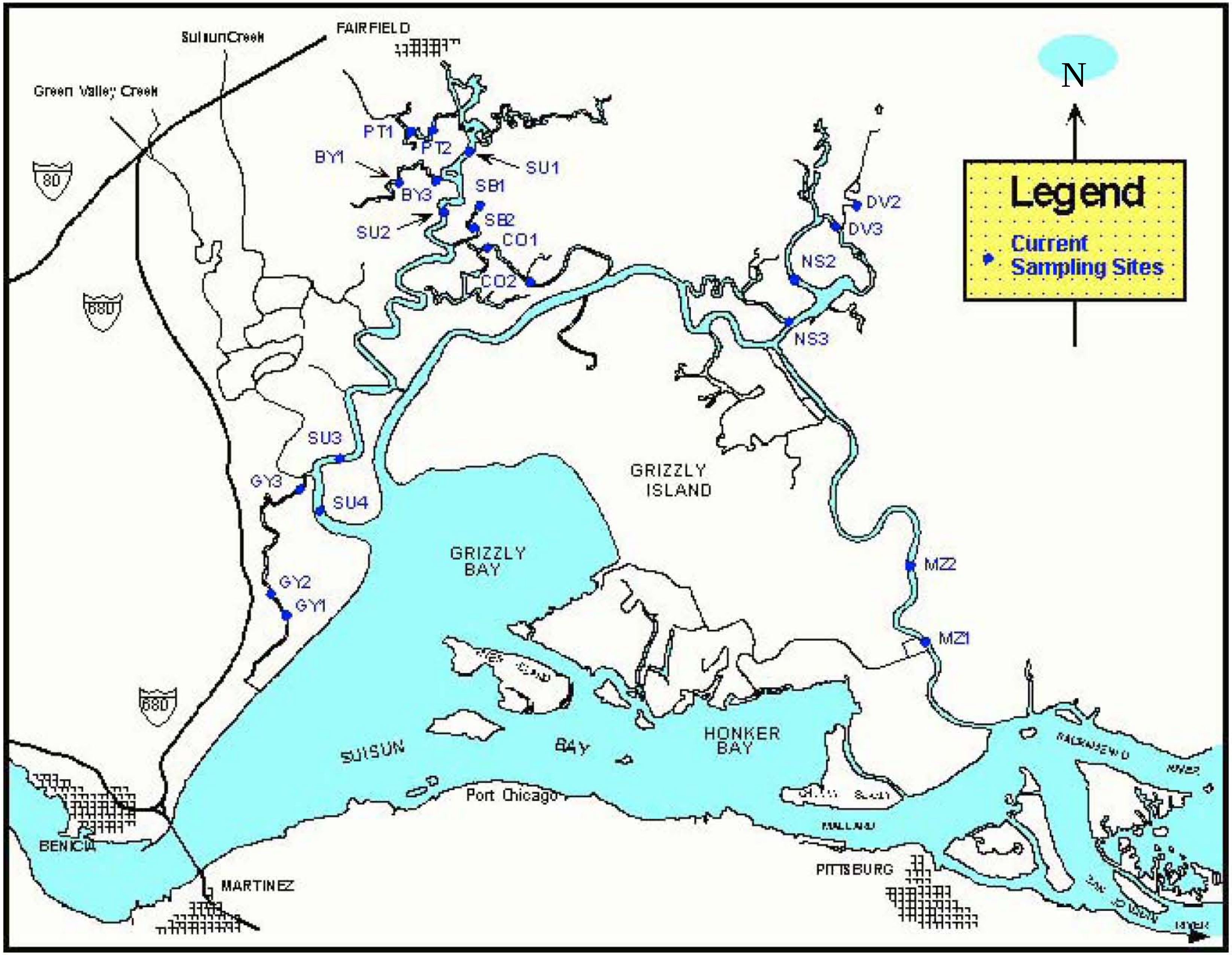
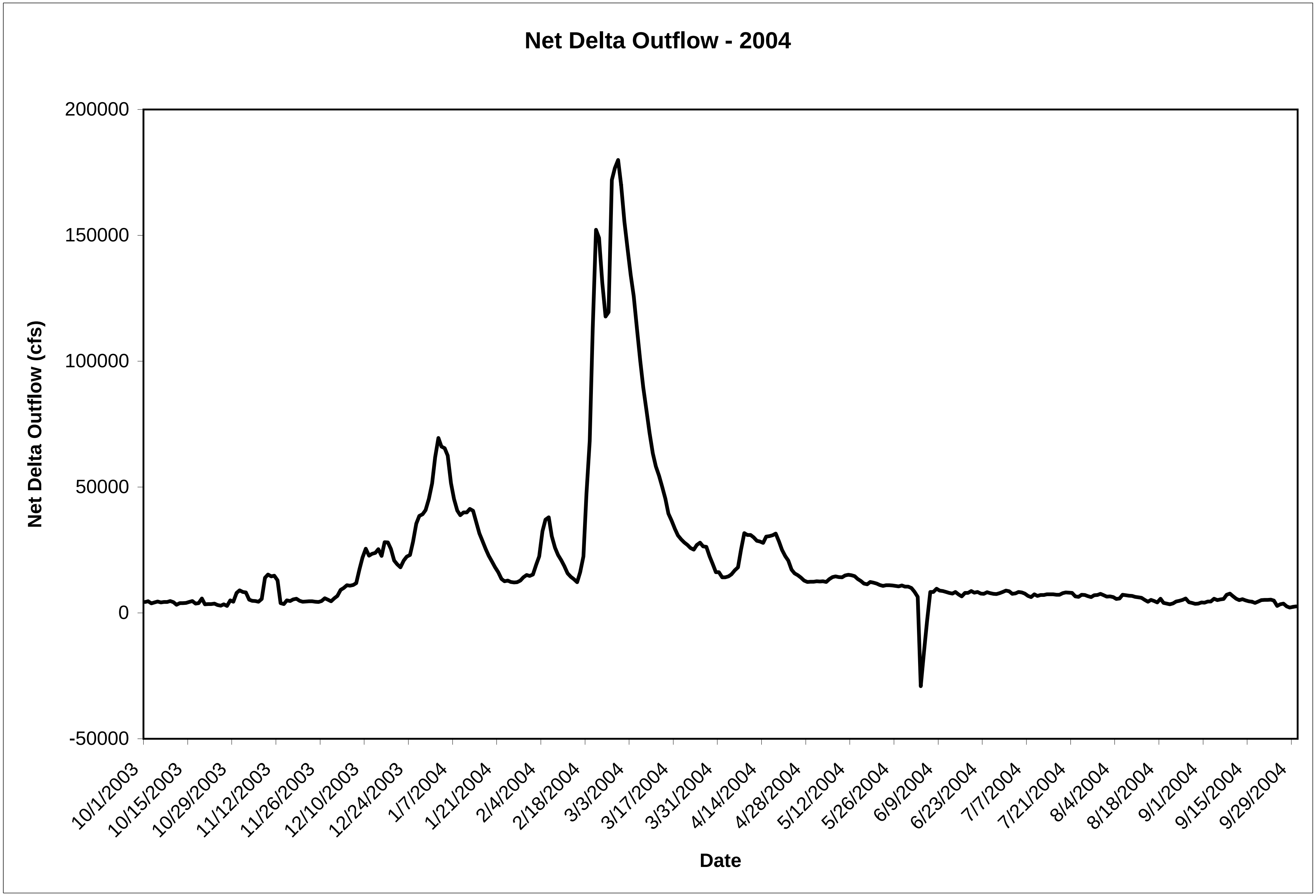

FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
680
PT1
PT2
BY1
SU1
BY3
SB1
SU2
SB2
CO1
CO2
NS2
NS3
DV2
DV3
N
Legend
Current Sampling Sites
SU3
GY3
SU4
GRIZZLY ISLAND
GRIZZLY BAY
GY2
GY1
MZ2
MZ1
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG

Figure 1.3



Net Delta Outflow - 2004
200000
150000
100000
50000
0
-50000
Net Delta Outflow (cfs)
10/1/2003
10/15/2003
10/29/2003
11/12/2003
11/26/2003
12/10/2003
12/24/2003
1/7/2004
1/21/2004
2/4/2004
2/18/2004
3/3/2004
3/17/2004
3/31/2004
4/14/2004
4/28/2004
5/12/2004
5/26/2004
6/9/2004
6/23/2004
7/7/2004
7/21/2004
8/4/2004
8/18/2004
9/1/2004
9/15/2004
9/29/2004
Date

Figure 1. 4

Native and introduced fish catch in Suisun Marsh (1980-2004)

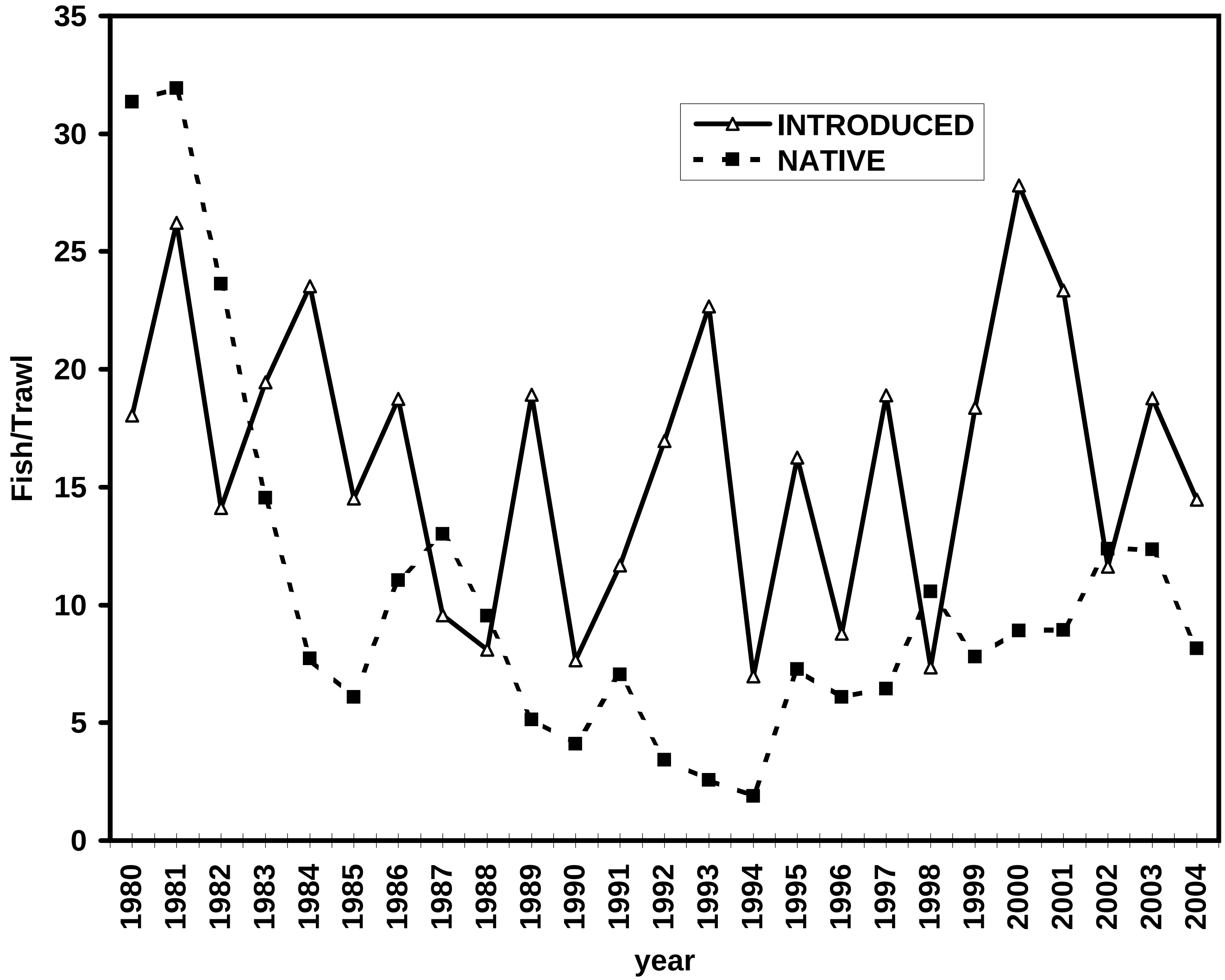


Figure 1.5

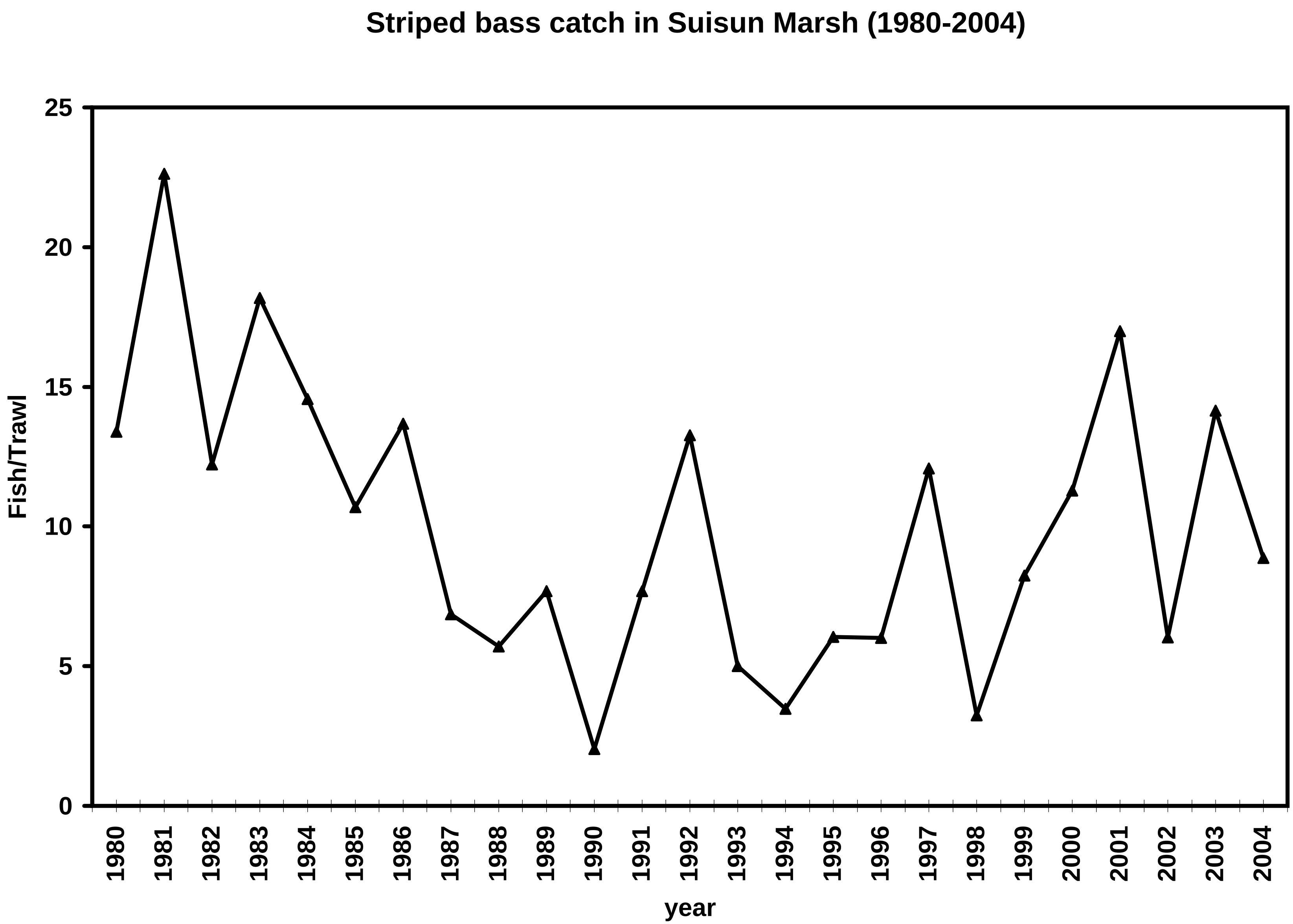
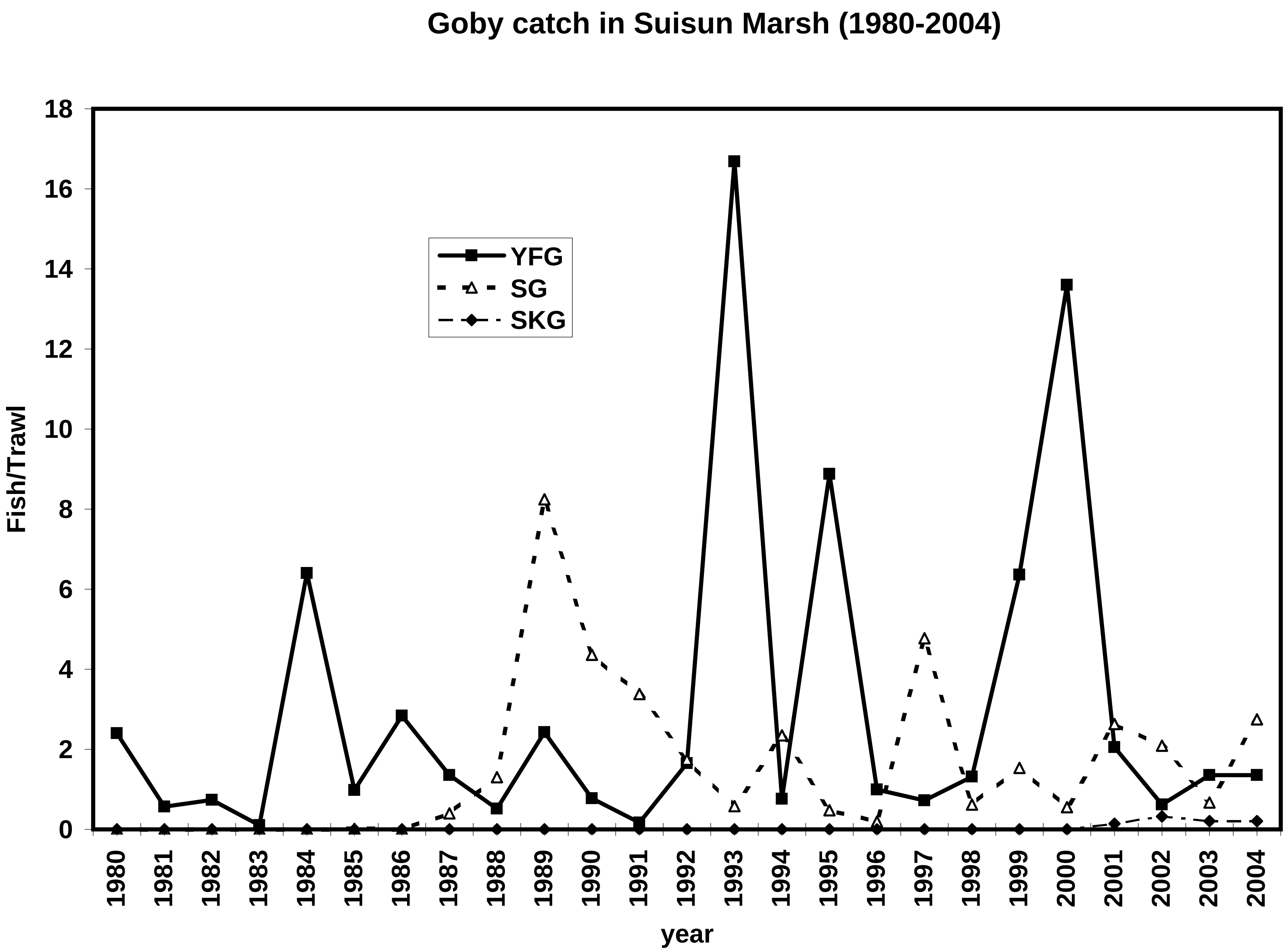

Striped bass catch in Suisun Marsh (1980-2004)
Fish/Trawl
25
20
15
10
5
0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Figure 1.6



Goby catch in Suisun Marsh (1980-2004)
YFG
SG
SKG
Fish/Trawl
0
2
4
6
8
10
12
14
16
18
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Figure 1.7

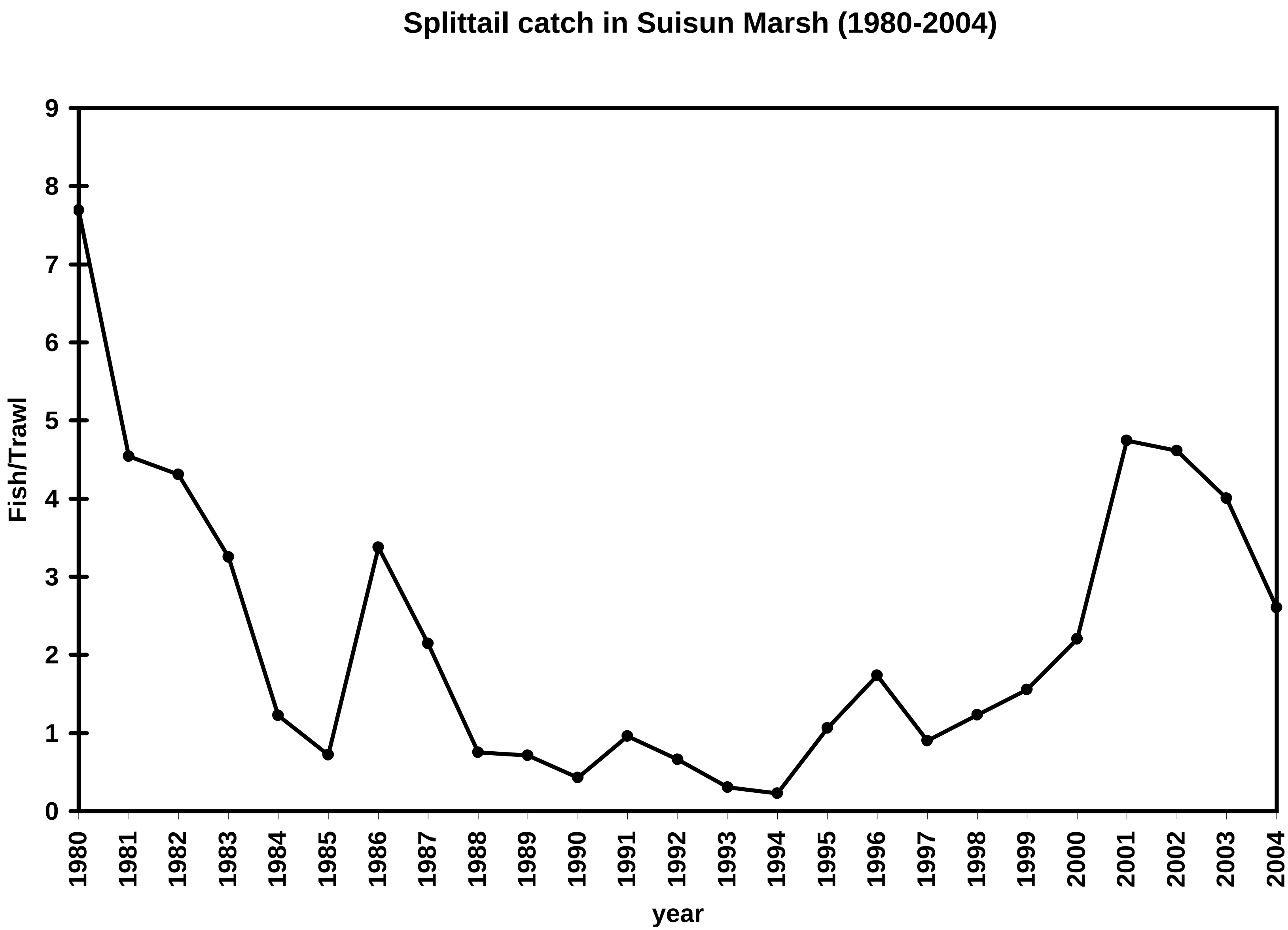
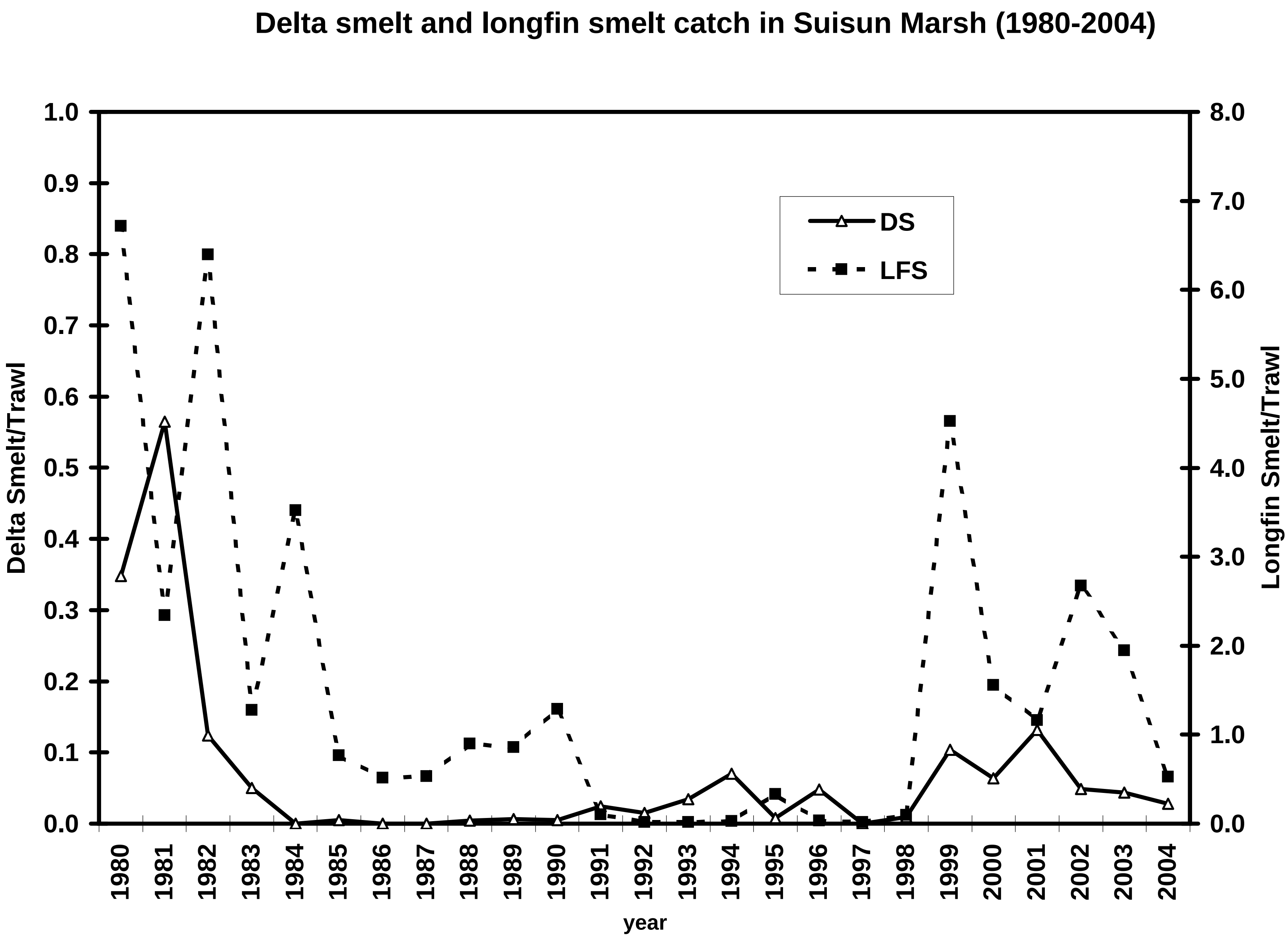

Splittail catch in Suisun Marsh (1980-2004)
Fish/Trawl
0
1
2
3
4
5
6
7
8
9
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Figure 1.8



Delta smelt and longfin smelt catch in Suisun Marsh (1980-2004)
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
DS
LFS
Delta Smelt/Trawl
Longfin Smelt/Trawl
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Figure 1.9

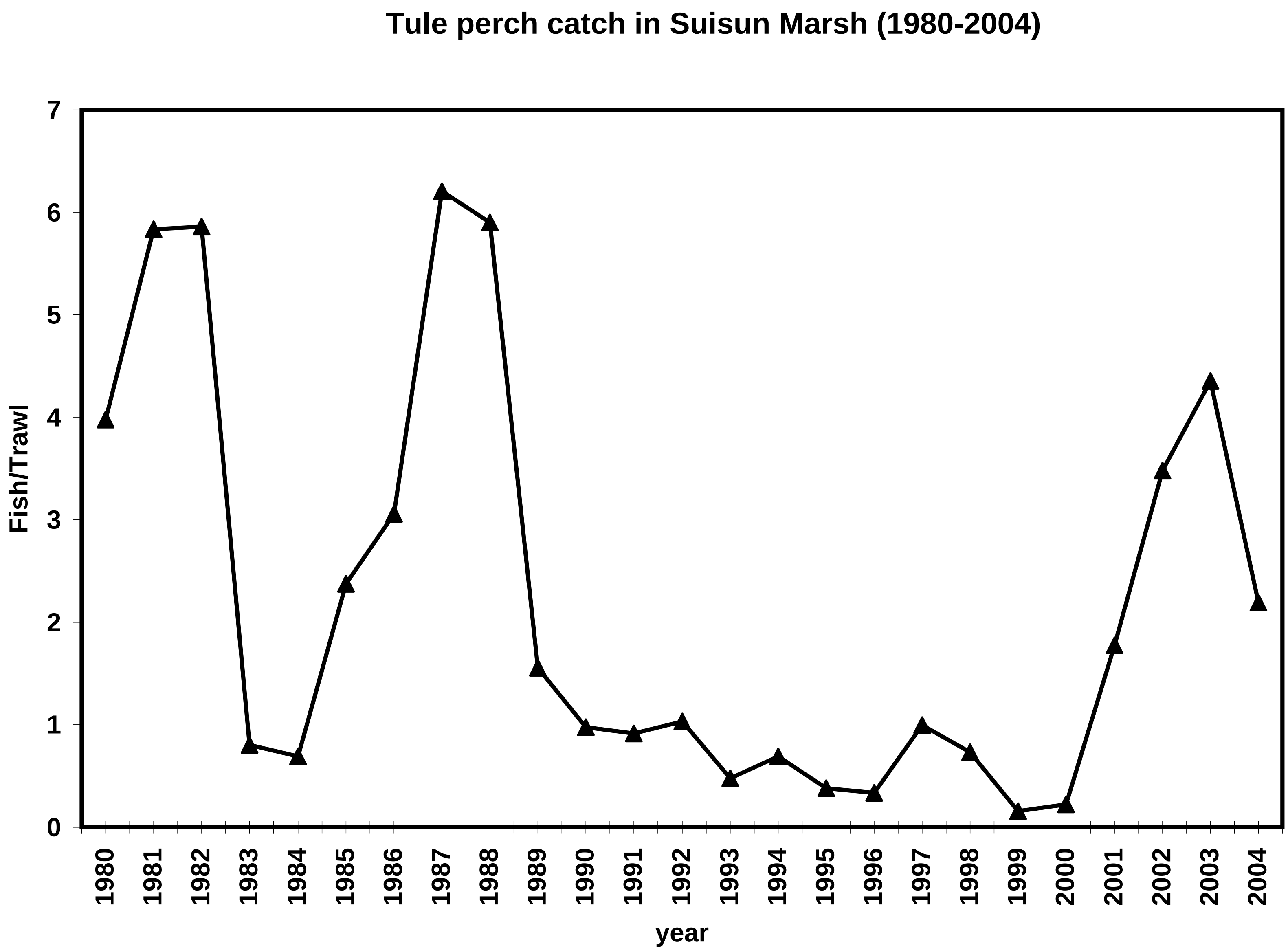

Tule perch catch in Suisun Marsh (1980-2004)
Fish/Trawl
0
1
2
3
4
5
6
7
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Figure 1.10

Sculpin and Sucker catch in Suisun Marsh (1980-2004)

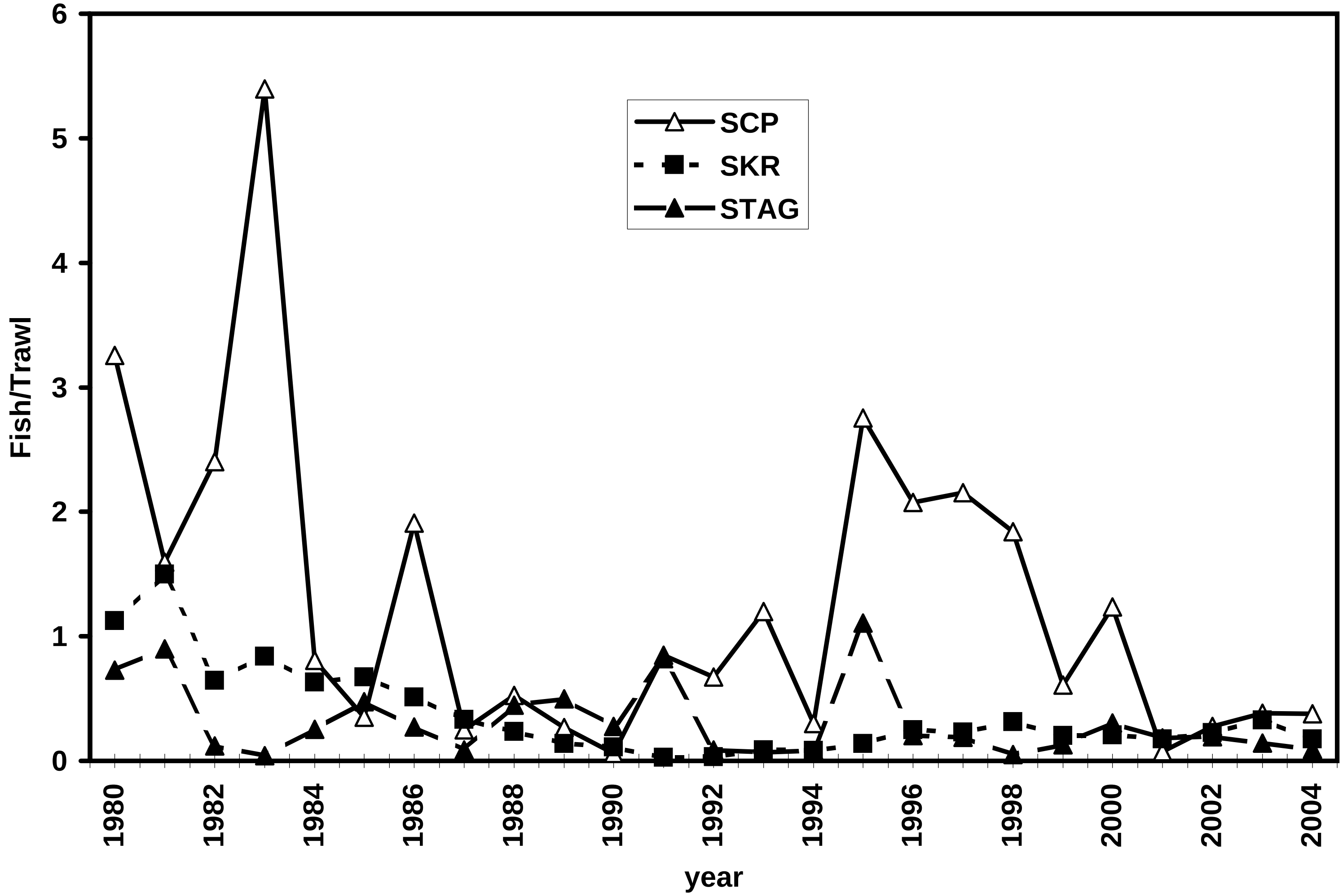


Figure 1.11

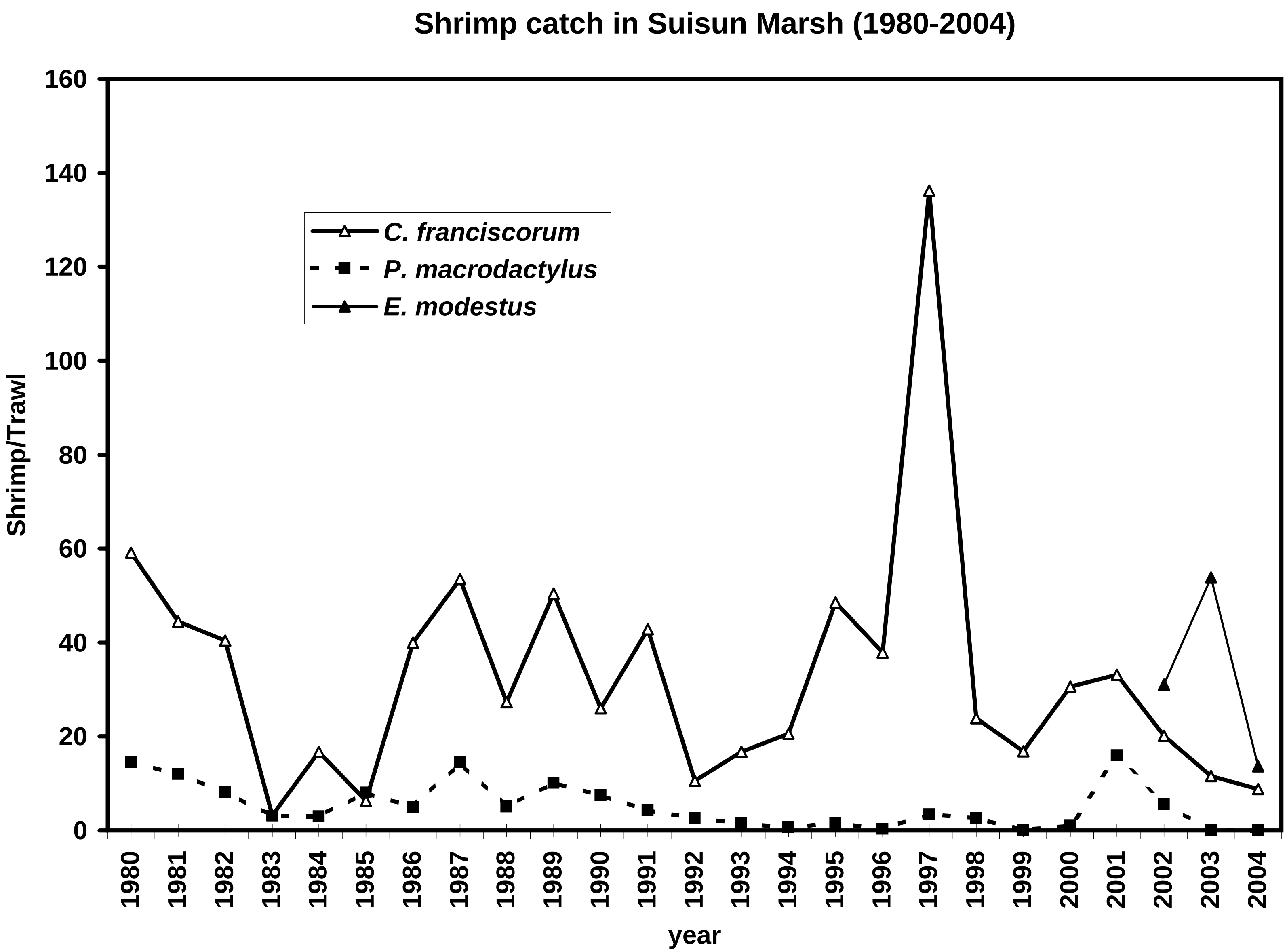
1995-2004 Average fish catch per trawl (all species) by slough listed in order of increasing abundance

Fish/Trawl

60.00
50.00
40.00
30.00
20.00
10.00
0.00

Montezuma
Boynton
Susuin Upper
Nurse
Cutoff
Peytonia
Denverton
Good Year
Spring Branch
Suisun Lower

Figure 1.12



Shrimp catch in Suisun Marsh (1980-2004)
C. franciscorum
P. macrodactylus
E. modestus
Shrimp/Trawl
0
20
40
60
80
100
120
140
160
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Figure 1.13

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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
2003	252	18.80	12.40	14.14	1.35	0.67	0.21	4.00	0.04	1.94	4.35	0.38	0.33	0.14	11.56	53.80	0.13
2004	252	14.73	8.16	8.87	1.36	2.74	0.20	2.61	0.03	0.53	2.19	0.38	0.17	0.09	8.80	13.65	0.02