Trends in Fish Populations of Suisun Marsh
January 2005 - December 2005

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Summary

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: juvenile and adult sampling and larval fish sampling. The larval fish sampling component was initiated in 1994 and discontinued after 2002. The larval fish sampling was conducted to gain a better understanding of larval fish use of Suisun Marsh. At present only 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 overbite clam, *Corbula 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, Stover et al. 2004) and a publication on trends in catch of larval fishes (Meng and Matern 2001) further documented overall changes in numbers of juveniles and adults of most fishes and have presented possible factors contributing to successful spawning and rearing of larval fishes within Suisun Marsh. Recent annual reports suggest that the numbers of native fishes overall have increased somewhat since their lows in the early 1990s but numbers have generally been lower than in the 1980s. 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, (3) documenting invasions of new species, and (4) monitoring species and community 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 2005 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 sloughs. Salinities within the marsh fluctuate by location, with sloughs in 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 fresh water (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.

Objective:

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, overbite clam, mitten crab, 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 alien species (Moyle et al. 1986, Meng et al. 1994, Matern, Moyle and Pierce 2002, Schroeter and Moyle 1994 – 2003, Stover et al. 2004). In general, abundance of the various species within the marsh has declined from the early sampling years (1980 - 1982), with upswings in abundance during wet time periods. This report presents the findings from the twenty-sixth year (2005) 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 Mallard 1 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), and water transparency (secchi depth in cm) were recorded .Dissolved oxygen (mg/l and %saturation) first sampled in 2000, were also 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 likely composed a large percentage of the 2001 and early 2002 (January and February) of the shrimp catch recorded as *P. macrodactylus*. 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. The jellyfish, *Maeotias marginata*, were also counted when present.

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

Results and Discussion

Environmental parameters:

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 2005 outflow was similar to 2003 in that there were no large peak events, usually occurring in January or February in most years, rather a continuous series of smaller increased outflow events (DWR-Dayflow; Figure 1.4 a). This resulted in an extended period of time at which X2, the distance upstream of the Golden Gate of the 2 psu near bottom salinity, was located in or adjacent to Suisun Bay and Suisun Marsh through June 2005 (Figure 1.4b). There was an increase in X2 position to a location upstream of Chipps Island by July, 2005 and upstream of the confluence of the Sacramento and San Joaquin River by Middle of August, 2005. The amount of outflow at any given time largely determines the X2 position and the salinity found within the waters of Suisun Marsh. Less outflow and a resulting higher X2 position in the critical rearing months (Spring and early Summer) in Suisun Bay and Suisun Marsh considerably influence the presence and abundance of various species in Suisun Marsh. The rate at which X2 moves upstream after outflow is curtailed or negated by export at the water projects is likely to have a large influence on salinity limited species, such as delta smelt, in that they are less likely to be able to ride the low salinity front as it gets pushed upstream. The dramatic shift in X2 position in June 2004 likely had a similar negative impact on salinity-limited species. In June 2004, Delta outflow was considerably altered by the Jones Tract levee failure which resulted in 3 days of negative outflow past Chipps Island (-3,300 to -29,000 cfs). This resulted in a dramatic change in X2 position of 5 kilometers in one day (June 2 to June 3, 2004) and 12 kilometers in 4 days time (June 2 to June 5, 2004). This was a shift from the X2 location at Chipps Island to well into the Sacramento and San Joaquin River.

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 ‰ (17 of the 26 years sampled) with salinities exceeding 9 ‰ in 6 of those years. In general, average salinities are usually < than 7 ppt (Table 1.4).

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 high outflow and reduced salinities, followed by increased salinities through December. Very dry periods with little outflow often result in dramatic increases in salinity beginning in May and June.

The 2005 water year resulted in salinities remaining fairly low through August, but then increasing to just below 5 ‰ in September. The monthly average high salinity (7 ‰) was recorded in November 2005. The 2004 water year resulted in an average salinity of 4 ‰, and 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).

In summary, the salinity conditions in Suisun Marsh since 2000 are similar to those observed during drought conditions and are largely influenced by low outflow and high export conditions especially in the fall months. The spring and early summer conditions are generally characterized as low salinity- high outflow conditions which are more indicative of wet water years. Whereas, late summer and fall conditions are more indicative of high salinity-low outflow dry water years. Over the last five years, the combination of low salinity spring and early summer conditions and high salinity late summer to fall conditions have likely influenced the aquatic community that now resides within Suisun Marsh. Nonmigratory freshwater species are at a physiological disadvantage under the current conditions (e.g., hitch, Sacramento sucker, pikeminnow), while nonmigratory midrange salinity species are at an advantage if salinities do not surpass their physiological tolerances (e.g., tule perch, white catfish, black bullhead, black crappie). Spring rearing migratory species that utilize low salinity waters (< 5 ‰), would be at an advantage in Suisun Marsh if they could migrate out of the area when salinities increase in the summer to fall time period (delta smelt). Migratory species that utilize midrange salinities would be expected to do fairly well under the current salinity conditions. These species include the Sacramento splittail striped bass, longfin smelt, threadfin shad, American shad and Pacific herring. High salinity (marine) species, either migratory or resident, would not be expected in large abundance in Suisun Marsh under the current conditions, given the fresh late winter, spring, and early summer conditions and the midrange salinity conditions in the fall.

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 significantly affects the use of the marsh by traditionally more cold water species including salmonids, osmerids, and most marine species. In 2005, average monthly water temperatures were above the 26 year average for all months except January, March and September. Some months were particularly warm, such as February (average = 12.4°C; 5th highest on record), July (average = 23.4 °C; 4th highest on record), October (average = 19.1 °C; 5th highest on record), and November (average = 16.3 °C; 2nd highest on record). In general, the 2002 – 2005 time period can be classified as warm, which fits in well with other low outflow and drought years over the monitoring period (1980-2005).

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 six years (2001-2005) have consistently yielded high secchi depth readings. The six years with the highest yearly averages in order were 2004, 1985, 2005, 2003, 2002, and 2001(tied with 1984). The months with greatest transparency or secchi depth readings are typically in the fall when the turbidity maximum (associated with X2 and the low salinity zone) gets pushed upstream. The higher salinity bay water that intrudes is considerably clearer. If high turbidity and low transparency are limiting phytoplankton production by limiting light availability, we would expect to see a corresponding increase in phytoplankton production in the fall months when transparency increases. No such investigation has been conducted, but our separate CALFED funded study will elucidate this relationship for the 2004 – 2005 time period. 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 greater turbidity under reduced light transparency conditions (high outflow / runoff) may result in greater availability of nutrients for phytoplankton and ultimately 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 discharge from a diked marsh, which discolored water and resulted in the mortality of fish. In this report we have included the average monthly and yearly dissolved oxygen concentrations for the 2000 - 2005 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, but 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 (DO) 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 fish mortality or absence of native species that are intolerant of low DO. The 2005 sampling period yielded the lowest average DO concentrations in February (7.2 mg/l), May – August (6.3, 5.8, and 5.5 mg/l, respectively) and again in November (6.4 mg/l) and December (7.5 mg/l). The low DO concentrations in June and July were particularly noteworthy because it is uncommon for the June discharge event to produce such a large and extended DO sag.

General trends in fish abundance:

As in 2004, alien fishes outnumbered native fishes in 2005. The difference in abundance between the two groups grew larger in 2005, due to a considerable downward trend in native fishes and a rebound in alien fish abundance. Throughout the twenty-six 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 product of recruitment success 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.

Up until 2005, 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). However, the catch of yellowfin goby has significantly declined since 2000 and the catch of shimofuri goby has fluctuated between moderate to low catches. In 2005, yellowfin, shimofuri and shokihaze goby comprised less than 9% of the total catch of alien species. Striped bass comprised the largest percentage (65%) of the alien species catch. Catch of black crappie and white catfish both increased dramatically in 2005 and they comprised a considerable portion of the alien species catch (both 9%). Increases in abundance of American shad and common carp also contributed to the increase in alien fish abundance in 2005.

In 2005, we observed our second consecutive year of native fish declines following a considerable increase in abundance since 1994 (Figure 1.5; Table 1.5). The decline in native fish abundance was largely due to a decline in tule perch and splittail, the two most abundant native fishes in the marsh, but also, to the decline in abundance of longfin smelt in 2004 and 2005. In addition, Pacific herring also were absent in 2004 and 2005, following a low abundance in 2003.

Delta smelt and longfin smelt:

Catch of delta smelt (DS) has declined since the early 1980s with fewer than 40 individuals captured in any given year. Delta smelt abundance increased somewhat between 1999 and 2001 and to a lesser extent between 2002 and 2004 (Figure 1.9). However, in 2005 no delta smelt were captured by otter trawl and only 2 individuals were captured by beach seine. The absence of delta smelt in the marsh otter trawl catch in 2005 is similar to their abundance during the drought years of

1984 – 1993. The rapidly increasing summer salinities and the high fall salinities likely exclude delta smelt from the many diverse sloughs and channels found within Suisun Marsh, given their preference for salinities at or below 5 ppt.

Catch of longfin smelt in 2005 was the lowest since 1998 and the 8th lowest catch since 1980 (Figure 1.9; Table 1.5). Very few post-larvae and juvenile longfin smelt, usually the most abundant age class, were captured in the marsh in 2005, suggesting that either there was little spawning in 2005 or spawning occurred in habitats outside of Suisun Marsh (e.g. upstream in the Sacramento and San Joaquin Rivers). This downward trend follows trends observed in other sampling surveys (Fall Midwater Trawl; Bay Study). The reason for the decline of longfin smelt in Suisun Marsh in 2004 and 2005 is unclear. Reduced outflow and the resulting salinities likely influences this species use of Suisun Marsh, but unlike delta smelt, their physiological tolerances and salinity preferences match those found in Suisun Marsh in both years.

Striped bass:

Striped bass catch in 2005 (12.8 striped bass/trawl; Table 1.5; Figure 1.6) was the 9th highest since 1980 and the 5th highest since 1986. The catch in 2005 reversed a one year decline observed in 2004 when 8.9 striped bass/trawl were captured. Striped bass comprised 50% of the total catch in 2005 and comprised 65% of the alien species catch. Several age classes were represented with young-of-year again dominating the total catch. Striped bass were also captured in high abundance in our beach seine sampling, with 2005 yielding the 2nd highest catch (1231 individuals) since 1995.

The abundance of striped bass has fluctuated considerably in the marsh since 1980 with very low abundances observed in 1990, 1994, 1998, and 2002 followed by dramatic increases in 1991-1992, 1997, 1999 – 2001, 2003 and again in 2005. 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, fewer 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, given our observations that they feed heavily on mysid shrimp and amphipods as young-of-year.

Splittail:

The otter trawl catch of Sacramento splittail increased slightly in 2005 with an average catch / trawl of 3.0 individuals (total catch = 763 individuals; Table 1.5; Figure 1.8). The 2005 catch was the 9th highest since 1980 and the 5th highest since 1986. The last 6 years of sampling (2000-2005) have yielded numbers of splittail comparable to the early sampling years of 1980-1983, suggesting that conditions in the estuary and specifically, within Suisun Marsh remain favorable for this species. The late summer and fall high salinities are not sufficiently high to exclude them from Suisun Marsh where they are likely taking advantage of ample prey resources (CALFED Invertebrate Study, unpublished results). Suitable spawning conditions which have occurred over several of the last 6 years of sampling likely have contributed to the splittail's recent high abundance. Splittail catch by beach seine decreased slightly in 2005 to a total of 111 individuals.

Splittail 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 (20%), Spring Branch (18%), Peytonia (16%), and lower Suisun Slough (14%). 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. This pattern continued in 2005 with a majority of splittail captured in Spring Branch Slough.

Chinook salmon:

No chinook salmon were captured by otter trawl in 2005 and only 4 were captured by beach seine. Our catch of chinook salmon is typically quite low and only exceptionally fresh conditions result in larger numbers of chinook salmon utilizing Suisun Marsh. All chinook salmon captured from 1995 through 2005 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. Juvenile chinook salmon have never been captured when water temperatures exceed 17 °C in Suisun Marsh. The 17 °C threshold was surpassed as early as April in 2005, thus there was a significantly reduced rearing window present in the marsh.

Gobies:

Three alien species of goby have been consistently collected in Suisun Marsh since 2001, the shokihaze, shimofuri, and yellowfin goby. The catch of these three gobies has been consistently low over the last 5 years (Table 1.5; Figure 1.7) suggesting that either the environmental changes present in the system over this time period (i.e., fresh spring, high salinity late summer and fall) are no longer conducive to producing their high abundance or biotic changes to the system are exerting a large influence on their abundance. Environmental conditions in 1999 and 2000, two very high abundance years for yellowfin goby, appear to be similar to those observed in the time period between 2001 and 2005, yet there has been a significant decrease in their catch. Thus, environmental conditions alone may not explain the recent declines. Shimofuri goby abundance has also remained relatively low but variable during this time period. One biotic change that has occurred in the system is the large increase in abundance of the jellyfish, *Maeotias marginata* (Figure 1.14 a). The abundance of *M. marginata* has increased 373 % since 2000 and they are now consistently captured every year and in large abundance as opposed to the 1980-2000 period, when they were only captured occasionally. The timing of the bloom of *M. marginata* (July-November) corresponds well with the larval production period of both yellowfin and shimofuri goby, thus predation on the larval and juvenile life stages may be, in part, responsible for the observed declines. Our diet work is not completed, but we have already documented that *M. marginata* can and do feed upon larval gobies in July and August in Suisun Marsh.

Overall, the catch of shokihaze goby in Suisun Marsh has remained consistent but low. The 2005 abundance was the second highest capture since they were first detected in the marsh in 1999, but only a total of 54 individuals were captured. It is difficult to predict their future trend in abundance in Suisun Marsh, although their continued low abundance for the last 6 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 in 2005 was 199 individuals or 0.79 individuals / trawl. 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 in 2005 was 657 individuals. The 2004 catch was 527 individuals and the 2003 beach seine catch was 370 individuals, 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. Historical peaks and dips in abundance of YFG in Suisun Marsh have been short-lived, typically lasting one to three years. The current low abundance of yellowfin goby has lasted for over five years.

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 2005 was 176 individuals or 0.7 individuals / trawl (Table 1.5; Figure 1.7). The shimofuri goby catch has fluctuated considerably since its introduction in 1985, likely driven by population cycles and environmental variation. More recently, the increased abundance of jellyfish during the shimofuri goby spawning period may be reducing the larval and post larvae survival and ultimately the abundance of shimofuri goby.

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. However, the recent decline in yellowfin goby abundance with a corresponding low shimofuri goby abundance is not consistent with an assumption of biotic suppression by yellowfin goby. Other biotic interactions, such as predation by *M. marginata* may be constraining the abundance of shimofuri goby and yellowfin goby over the last five years.

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, 2004, and 2005 prickly sculpin catch was low with only 96, 95, and 94 individuals captured, respectively, in otter trawls and 5 individual captured by beach seine in 2003 and 2004 and 14 individuals in 2005. The low numbers of prickly sculpin observed between 2003 and 2005 is a considerable decline from the 1995-1998 time period as well as the 2000 catch. Moderate outflow in the dry water years of 2001 through 2005 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 decreases 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 2005, the pattern (low abundance with moderate to high outflow) re-emerged, with catches falling in the wake of heavy outflow. A total of 13 staghorn sculpin were collected by otter trawl and 32 individuals by beach seine in 2005 (Figure 1.11). In the past three years we have seen staghorn sculpin declines in both the beach seine and the otter trawl catches, but only 2003 was a high outflow year. The beach seine catches in 2003, 2004 and 2005 were the three lowest catches since 1995 (57, 56 and 32 individuals respectively). The otter trawl catches were also low in 2003 (36 individuals), 2004 (23 individuals) and 2005 (13 individuals) being the 8th and 5th and 2nd lowest catches since 1980. The majority of staghorn sculpin caught in 2004 and 2005 were less than 40 mm SL but in 2003 the majority of individuals 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). A total of 61 individuals were captured by otter trawl in 2005 and 3 were captured by beach seine. Despite a relative low overall abundance, the 2003-2005 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 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; Figure 1.10). 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 otter trawls peaked from 1981 to 1982, 1987 to 1988 and again between 2001 and 2005. Despite the declines observed in 2004 and 2005, tule perch abundance remains high and the multiple age classes present in the population suggest that continued high abundance is possible if conditions remain favorable for growth. It is interesting to note that the outflow in the 2001 – 2005 time period has been relatively low, similar to 1981 and 1987 and 1988. The moderate to high salinity conditions in each of these relatively low outflow years are likely contributing to this species success, which is unusual given this species high population abundance in freshwater creeks and rivers upstream of Suisun Marsh. There is likely a secondary influence independent of salinity, which is resulting in greater abundance during moderate outflow conditions. Possible factors may be greater abundance of invertebrates resulting from increased productivity when the low salinity zone is located adjacent to or just upstream of Suisun Bay. Another possibility, that is less likely, is that the population of tule perch found within Suisun Marsh may be better adapted to moderate salinity conditions as opposed to upstream low salinity populations.

Tule perch have clearly demonstrated that they can quickly increase in abundance given suitable environmental conditions. Although the reason for the resurgence in abundance between 2001 and 2005 is unknown, it may well be associated with improved 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). The lower abundance in 2005 may be linked to the corresponding low DO conditions in Suisun Marsh in that year. Areas with continued low dissolved oxygen conditions (Peytonia, Boynton and Goodyear sloughs), remain largely devoid of tule perch, but areas such as Spring Branch and Cutoff Slough, which are generally high in DO, maintain the largest numbers of tule perch. 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.

American shad and threadfin shad:

Threadfin shad and American shad are usually uncommon or are captured in low abundance in Suisun Marsh. Both species are pelagic planktivores that, have been found by other sampling programs to have declined in the San Francisco Estuary beginning in 2001. Our sampling gear does not specifically target pelagic species such as threadfin shad or American shad, but the Suisun Marsh trends in catch are still a useful indicator of relative abundance and species use in the system. American shad were fairly abundant in 2005 with 121 individuals captured by otter trawl (0.5 individuals /trawl; Table 1.5; Figure 1.12) and 76 individuals captured by beach seine (Table 1.6). The 2005 catch of American shad represents the third highest catch by otter trawl and the highest catch by beach seine. This was an improved catch from 2004 when only 27 individuals (0.1 individuals / trawl) were captured by otter trawl, but is similar to our 2002 (96 individuals; 0.4 individuals / trawl) and 2003 catch (154 individuals; 0.6 individuals / trawl), which were the third and first highest catches, respectively, since 1980. Except for the moderate decline observed in 2004, which was still the 5th highest catch between 1980 and 2005, there is no indication that American shad are in decline in Suisun Marsh. In fact one can infer the opposite conclusion that between 2002 and 2005 there was a significant and unprecedented use of the marsh by American shad. This suggests that this species either did well in the marsh in this time period because of suitable prey resources, or that the poor environmental (e.g. salinity) and or biological conditions (prey availability) elsewhere in the estuary resulted in a larger movement of American shad into Suisun Marsh.

Our otter trawl catch of threadfin shad has remained at similar levels since 1998 (Table 1.5; Figure 1.12). In 2005, our otter trawl catch was 59 individuals or 0.2 individuals / trawl. This was a slight decline from 2004 in which we captured 70 individuals or 0.3 individuals / trawl. The 2004 and 2005 otter trawl abundances were lower than those in 2002 and 2003, but they still represented the 9th and 10th highest catch in Suisun Marsh since 1980 and the 5th and 6th highest catch since 1985. As is the case for the American shad, there is no indication that threadfin shad are in significant decline in Suisun Marsh. In fact, threadfin shad abundance over the last 7-10 years has, on average, been increasing in Suisun Marsh. The catch in 2004 and 2005 do indicate a moderate decline from the high levels in 2002 and 2003, but the 2004 and 2005 catch rates are still well above the average catch rate of threadfin shad in Suisun Marsh. Our high beach seine catch in the last three years provides further evidence of a stable and perhaps increasing population of threadfin shad in Suisun Marsh (Table 1.6; Figure 1.12). The 2005 threadfin shad catch by beach seine was the third highest since 1995 (368 individuals; 4.5 individuals/seine haul) and our 2004 threadfin shad beach seine catch, was the highest catch since 1995 (466 individuals; 5.8 individuals/seine haul). Together our two sampling methodologies have not detected a decline in threadfin shad abundance in the marsh, which runs counter to observations in other habitats of the San Francisco Estuary. Threadfin shad, like American shad are likely benefiting from the favorable environmental (salinity and temperature) and biological conditions (prey availability) within Suisun Marsh over the last 5 years.

Uncommon species:

Representative members of the family Centrarchidae (mostly alien species in California) are typically rare in Suisun Marsh (Table 1.5). A single bluegill was captured by otter trawl in Suisun

Marsh in 2005 with no green sunfish captured. The black crappie is the most abundant centrarchid in Suisun Marsh, with high catches typically occurring in years with moderate to high precipitation and outflow. Black crappie had an exceptional year in 2005 with 468 individuals captured by trawl (1.86 individuals / trawl) comprising 7.3 % of the total Suisun Marsh fish catch. This is the highest catch of black crappie since sampling began in 1980. A majority of individuals captured in 2005 are young-of-year. Beach seine catch of black crappie in 2005 was also the highest recorded since 1995, but the overall abundance in the beach seine catch was still relatively low (13 individuals). This species did particularly well in 2005, due to the favorable spawning conditions (fresh / low salinity spring conditions). It is interesting to note that spawning conditions, and of course presence of spawning adults, is likely a major limiting factor for black crappie in Suisun Marsh, given that they have demonstrated an ability to maintain their high abundance under the high salinity fall conditions of 2005. If the current environmental conditions repeat themselves in the coming years and this cohort of black crappie survive to reach spawning age, we could see black crappie become a more dominant component of the Suisun Marsh fish fauna. Moyle (2002) indicates that black crappie can tolerate salinities up to 10 ppt, thus would likely do well in certain locations in the marsh where salinities rarely exceed that concentration. Spring Branch and Cutoff Slough and the Denverton Slough area generally have the greatest black crappie abundance and are also the areas with the lowest consistent salinities. It will be interesting to see if the 2005 cohort of black crappie will survive to reach reproductive age in 2006 and 2007. If black crappie maintain their current high abundance, they may adversely affect several native species that utilize the same habitats including tule perch, splittail, and Sacramento sucker through competition for resources and direct predation. Striped bass may also be adversely affected by high black crappie abundance due to the vulnerability of its young of year, which are found in very high densities within those same low salinity sloughs.

Three species in the family Ictaluridae are commonly captured in Suisun Marsh, but like centrarchids, their catch is generally limited and is usually restricted to sloughs where salinity remains low. However, in 2005 a total of 459 white catfish (1.8 white catfish / trawl) were captured by otter trawl comprising 7.2 % of the total Suisun Marsh fish catch. This was the highest annual catch of white catfish on record. Black bullhead were not as abundant, with only 11 individuals captured by otter trawl. Two channel catfish were also captured in 2005. White 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.

Another planktivore species worth noting is the Pacific herring, which was not captured in 2004 and only a single individual was captured in 2005 (Table 1.5). In 2003, herring numbers were the highest on record (133 individuals). The fresh spring and early summer months of 2004 and 2005 likely limited the use of the marsh by the Pacific herring.

The catch of other rare species was limited in 2005 with only a single hitch being captured.

Species collected in beach seines:

Fish catch by seine has fluctuated considerably between 1995 and 2005 ranging between 2000 and 9000 individuals captured. The mean number of fish per seine haul over this time period was 75.9 individuals. In 2005, 8016 individuals were caught by seine or 99 fish/seine. This is the second highest catch since we began sampling in 1995 when Denverton Seining Beach was added to the regular sampling. 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 2005 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 2005 (5086 individuals) and comprised 63 % of the total catch. Striped bass, yellowfin goby and threadfin shad were the next three most abundant species (1231, 657, and 388 individuals, respectively), together comprising 28 % of the total seine catch. The threadfin shad catch for 2005 was the third largest catch by beach seine since 1995. Although yellowfin goby still make up a large percentage of the total fish catch by seine, their numbers have remained relatively low over the last four 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 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 2005 (1.1) 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. We have completed our processing and identification of mysid shrimp collected between 1999 and 2002 (UC Davis Larval Fish Survey) and are also analyzing data from 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), 2004 (8.8 individuals / trawl) and 2005 (8.4 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 and Figure 1.13) may also be playing a role in the recent decline. Other alien species within the genus *Crangon* have 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* abundance has shifted over the course of this study with consistent higher abundances reported between 1980 and 1992 than during the 1993 – 2005 time period. In the latter time period, there were two observable increases in abundance in 1998 and 1999 and again in 2001 and 2002. It is important to note that the high catch of *P. macrodactylus* in 2001 and 2002 may be a result of incorrect identification and taxonomic confusion with *Exopalaemon modestus* (see below). For all other years between 1993 and 2005, the catch of *P. macrodactylus* has been at or below 1 individual / trawl. The catch in 2005 was 0.19 individuals / trawl, the third lowest catch ever recorded. Because *P. macrodactylus* feeds in part on mysid shrimps, their decline in Suisun Marsh may be related to the recent low abundance of mysids (Jim Orsi, DFG, pers. commun.). Competition with *E. modestus*, at least since 2002, may also be contributing to their recent low abundance.

E. modestus is now common in the freshwater portions of the San Francisco Estuary and Delta. It was first positively identified in Suisun Marsh in February 2002 but was likely present in the Fall of 2001. At the time of its discovery in Suisun Marsh, over 90% of the shrimp identified as *P. macrodactylus* were in fact *E. modestus.* The catch of *E. modestus* has fluctuated considerably since we began recording its abundance in 2002, with its greatest abundance in the two years following its introduction. The catch of *E. modestus* has declined somewhat in 2004 and 2005 with an average catch rate of 13.7 and 21.8 individuals / trawl, respectively. *E. modestus* is well established in Suisun Marsh with multiple size classes and ovigerous shrimp found throughout the marsh. The consequences of this new invasion on the preexisting aquatic biota are not known; however, if *E. modestus* has predaceous tendencies 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. A preliminary analysis of diet revealed that there was a considerable quantity of crustacean body parts including statoblasts from mysid shrimp. Ostracods were also found in low number. Thus it can be expected that *E. modestus* are impacting prey resources used by fish, but they are also serving as a source of food, at least for juvenile and adult striped bass. It is unknown if *E. modestus* preys on larval fishes.

Another introduced species occurring in the marsh is the overbite clam, C*orbula 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. In 2005, there was a significant reduction in overbite clam abundance with only 6699 individuals captured, but total abundance remains high, at least locally (Figure 1.14 b). The individuals captured continue to be larger than in past years with an average size greater than 10 mm. The decline in 2005 is likely due to the lower salinity conditions in the spring and early summer of that year. *C. amurensis* are likely limited by low salinity and if the duration of exposure to fresh water is too great, then mortality will result.

The catch of mitten crabs in Suisun Marsh has fluctuated considerably since 1996, but has been in continuous decline since 1999. No mitten crabs were captured in 2005.

Summary / Conclusions

Fish catch in Suisun Marsh has fluctuated considerably since sampling began in 1979. Both native and introduced species abundance originally declined following highs in the early 1980s and both introduced and native species increased in abundance through 2003. Alien species have continued to increase in abundance in 2004 and 2005, but native species declined. In the last few years the dominant alien species have shifted somewhat with fewer gobies being captured since 2001 and more catfish and crappie being captured in 2005. Striped bass remain the most abundant species in our Suisun Marsh otter trawl catch, despite the significant decline observed by other sampling programs in the S.F. Estuary. Similarly, the Suisun Marsh fish study has also failed to detect a significant decline in abundance of American shad and threadfin shad with both species doing relatively well over the last 4 -8 years (2002-2005 for American shad and 1998-2005 for threadfin shad).

Historically abundant native species, including longfin smelt, splittail and tule perch, have also fluctuated considerably in abundance with their abundance remaining low until 1999 when all three species increased in abundance. The continued high catch of splittail and tule perch in Suisun Marsh during recent years is encouraging, because historically these two species comprised the largest percentage of the native species catch in Suisun Marsh. Multiple age classes of both species indicate a healthy population structure. Although splittail and tule perch abundance did decline somewhat in 2004 and 2005, their catches are still high. Longfin and delta smelt trends are similar to splittail and tule perch in that they both declined from historic highs in the early 1980s and then rebounded in abundance between 1999 and 2003. However, both smelt species declined in 2004 and 2005 to very low abundances. The decline of delta smelt and longfin smelt in 2004 and 2005 fits in well with observations of system-wide decline observed by other sampling programs in the S.F. Estuary. It is interesting to note that the decline of the two smelt species in Suisun Marsh occurred at a later date (nearly 2 years) than the declines observed elsewhere. Another interesting observation is that threadfin shad, splittail, and tule perch all declined somewhat in 2004 and 2005, from their 2002 and 2003 high abundances. This may indicate that conditions did change in the last two years even though catch rates for all three species in 2004 and 2005 were still considered at or above average.

Other native species once abundant in the early sampling years (Sacramento sucker, and prickly sculpin), have largely failed to recover or have only had moderate increases in abundance in recent years. All three species have had low population abundances between 2001 and 2005. The absence or very low abundance of low salinity native fishes (hitch, Sacramento blackfish, pikeminnow, prickly sculpin, and Sacramento sucker) is likely due to increased salinity and poor water quality conditions in the marsh over the last 20 years, especially in the fall months.

Other factors responsible for native species decline likely include the impacts brought upon by the introduction of numerous fish and invertebrate species into the San Francisco Estuary. The continued increase in number of alien species and the expansion of their range within the S.F. Estuary will likely further affect native species. For example the recent invasion of the large shrimp, *E. 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. In addition, the large and increasing blooms of the jellyfish, *M. marginata,* in the marsh (Figure 1.14 a) and surrounding bays and downstream river habitats are likely further reducing prey availability for pelagic and benthic fishes. This species has demonstrated the capacity to feed directly on fish larvae and postlarvae and large numbers of zooplankton even at remarkably small sizes (< 3 mm bell diameters). The status and impact of *M. marginata* is currently being investigated as part of a dissertation chapter which will be completed by summer 2006. Another introduced species, *Corbula amurensis,* the overbite clam, is increasing in size and abundance in Suisun Marsh especially between 2000 and 2005 (Figure 1.14 b) as well as in the surrounding bays and river habitats. This species is likely further reducing the primary and secondary productivity of this estuarine system through its filter feeding. A lack of thorough understanding as to how these alien species are affecting the aquatic community in Suisun Marsh (and elsewhere in the estuary) 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. Continued monitoring of the fish populations in Suisun Marsh will also enable further evaluations of factors contributing to native and alien species declines. This monitoring is particularly valuable because the trends in the marsh are somewhat different from those in other parts of the estuary, which presumably reflects a combination of differences in environmental conditions and the sampling programs.

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	*Ameiurus melas*	BLB
black crappie	*Pomoxis nigromaculatus*	BC
bluegill	*Lepomis macrochirus*	BG
brown bullhead	*Ameiurus 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
2005	1.24	1.63	0.9	1.46	0.97	0.78	2.41	3.07	4.95	5.38	7.01	5.56

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
2005	8.24	12.44	14.22	18.4	19.88	22.04	23.4	21.97	20.05	19.06	16.29	10.08

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
2005	28.95	25.21	25.8	24	18.9	22.05	22.6	24.65	32.86	35.05	39.48	38.29

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
2005	8.63	7.16	NA	7.07	6.33	5.77	5.45	6.37	6.76	7.61	6.4	7.5

Table 1. 4 Summary of Suisun Marsh data 1980-2003. 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	0.85	13.7	1.0	3.9	17.3	7.8	28.8
2005	25.4	8.4	0.19	21.8	1.1	3.0	17.2	6.8	28.2

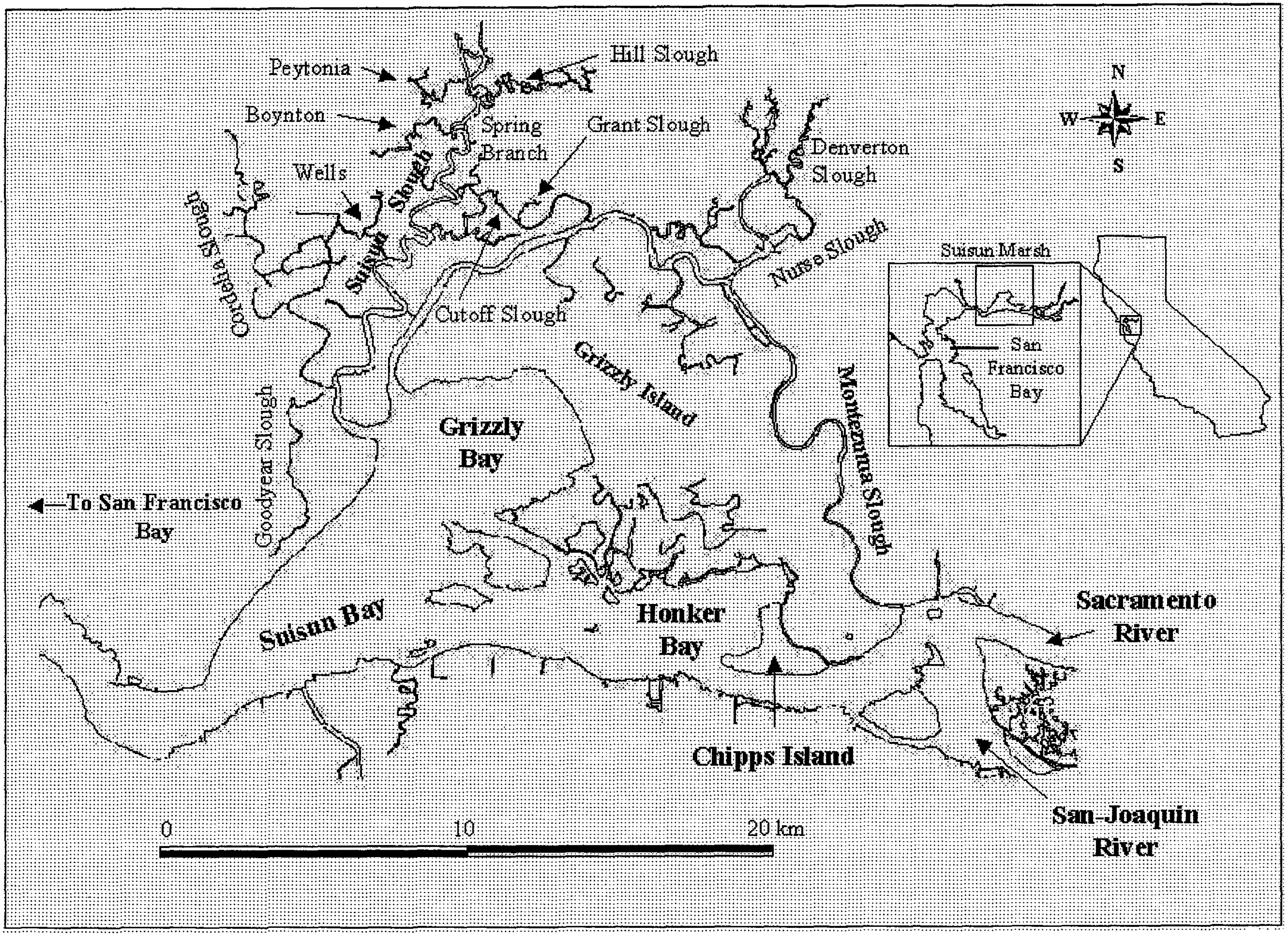
Table 1.5 Total catch per year for species collected in Suisun Marsh trawls January 1979 - December 2005. See Table 1.1 for species represented by abbreviations.

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	2005
ASH	21	36	156	8	2	5	8	7	7	6	2	16	3	6		4	1	1	1			13	11	96	154	27	121
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	468
BF	2	9	2	4	1																						
BG		5	1	4	1			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	11
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			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	154
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	21
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	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	21
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	32
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	1
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	3230
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	94
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	18
SG							2		82	282	1253	819	696	353	117	534	117	48	1202	133	384	140	659	515	170	691	176
SKG																					1		34	78	52	51	54
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	61
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	763
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	13
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	72
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	59
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	368
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	459
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	199
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	6399
#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	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	25.4

Table 1. 6 Total catch per year for species collected in Suisun Marsh seine hauls from January 1995 - December 2005. See Table 1.1 for species represented by abbreviations.

	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
ASH			1				1	1	3	8	76
BC				6	2	3	3	2	1		13
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	9
DS	17	2	1	1	1	5	1	1	2	4	2
FHM	1	3	6	3	3				1	1	1
GF		1		1	4	3				3	10
GSH				1							
HCH	1			1	1						1
ISS	1827	1991	4794	1091	1670	3052	4284	4033	6595	4721	5086
KS	48	6	1	4	14	4	8	27	15	10	4
LFS	2				2	1	1			2	
LMB				1							
MQF	18	19	35	22	30	2	1	1	6	9	16
PH		1	4		5	9	4	5	22		1
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	1231
SCP	38	21	16	8	6	25	1	1	5	5	14
SF	4	18	23	2		2		1	1	3	4
SG	170	43	274	106	33	64	122	204	68	97	161
SKG											2
SKR	3	6	8	1	5	2	1	3	3	2	3
SPM	11	2	9	7	1	1	3		1	1	2
ST	246	99	107	153	446	207	120	88	82	224	111
STAG	373	92	146	63	310	260	213	101	57	55	32
STBK	130	195	99	44	54	48	95	164	233	196	121
TFS	203	415	144	340	210	85	166	124	252	466	388
TP	95	41	27	100	13	19	17	26	64	9	64
WAK			1			3					
WCF		3	3	43	21	2	12	1	3		5
YFG	2075	909	611	770	1977	2288	708	412	370	527	657
Total	5480	4369	8251	2894	5266	6575	6279	5768	8518	6794	8014
Number of siene hauls	72	84	84	74	84	84	84	80	84	84	81
Mean fish per haul	76.1	52.0	98.2	39.1	62.7	78.3	74.8	72.1	101.4	80.9	98.9

Figures



Peytonia
Hill Slough
Boynton
Spring Branch
Grant Slough
Wells
Suisun Slough
Cordelia Slough
Denverton Slough
Nurse Slough
Cutoff Slough
Grizzly Island
Suisun Marsh
San Francisco Bay
Montezuma Slough
Goodyear Slough
Grizzly Bay
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

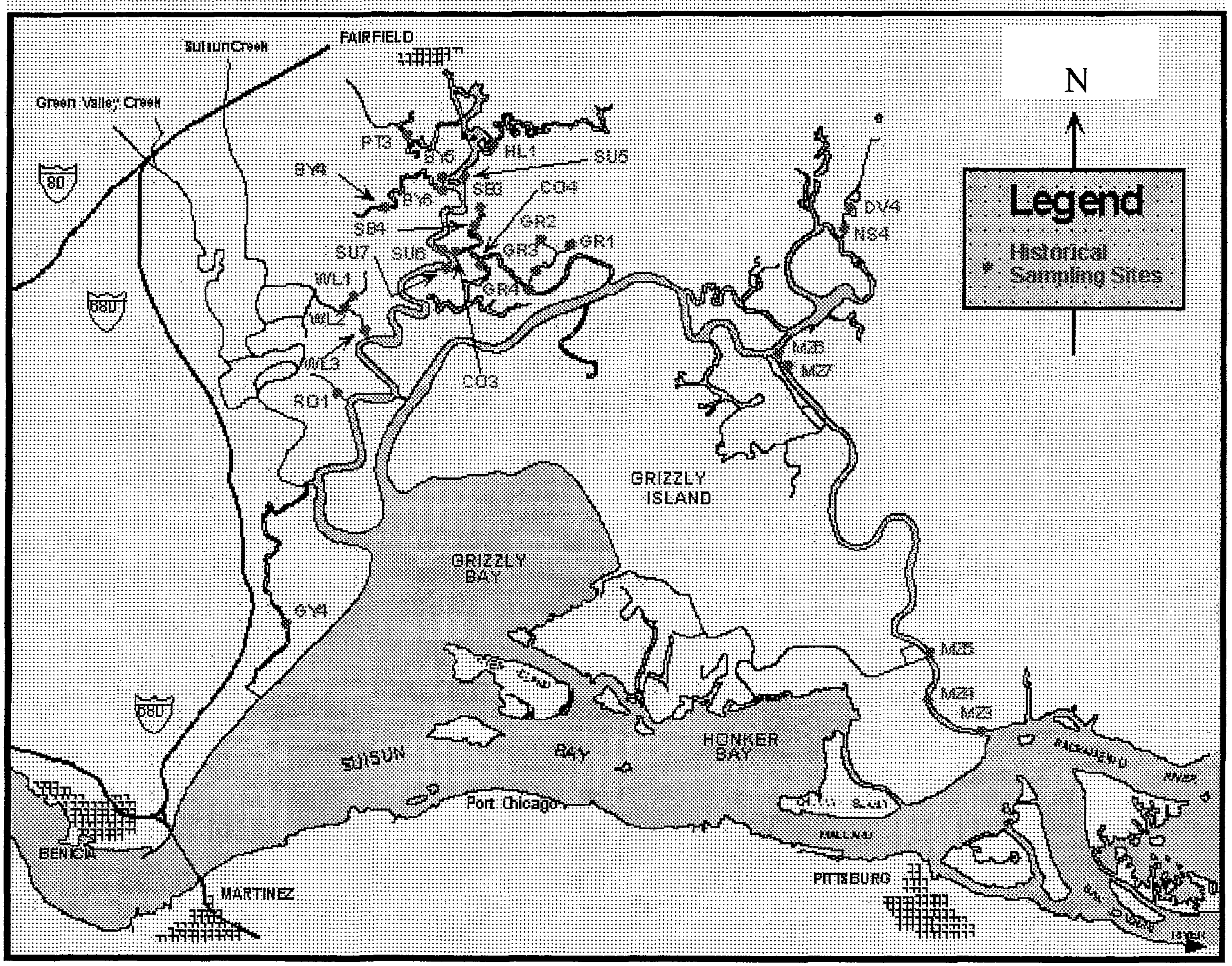

N
Legend
Historical Sampling Sites
FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
PT3
BY4
BY6
HL1
SU5
SB3
CO4
SB4
GR2
GR3
GR1
SU7
SU6
WL1
GR4
WL2
WL3
CO3
RD1
DV4
NS4
MZ6
MZ7
GRIZZLY ISLAND
GRIZZLY BAY
GY4
MZ5
MZ4
MZ3
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG

Figure 1.2

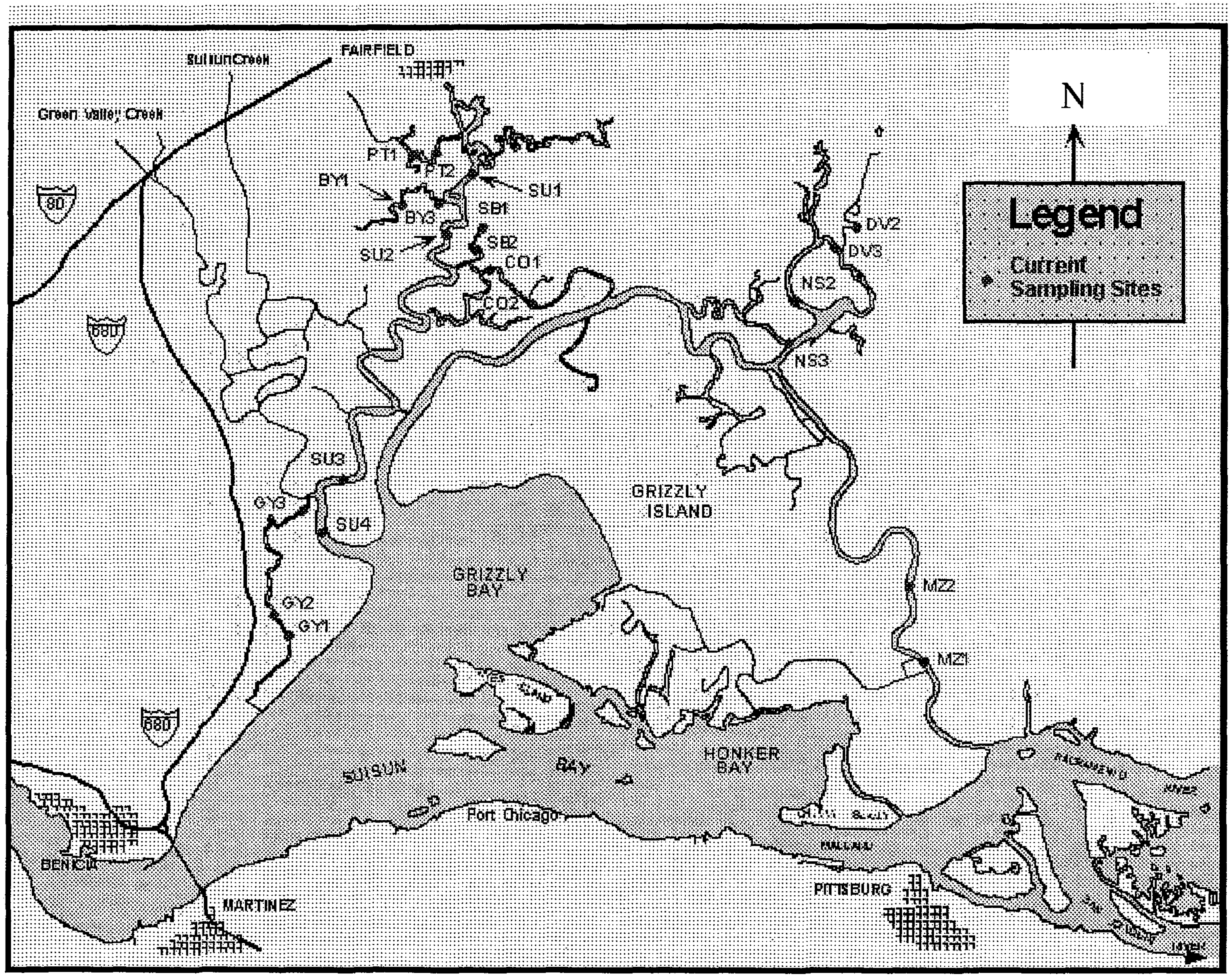

FAIRFIELD
Suisun Creek
Green Valley Creek
80
680
680
N
Legend
Current Sampling Sites
PT1
PT2
BY1
BY3
SU1
SB1
SB2
SU2
CO1
CO2
DV2
DV3
NS2
NS3
SU3
SU4
GY3
GY2
GY1
GRIZZLY ISLAND
GRIZZLY BAY
MZ2
MZ1
SUISUN
BAY
HONKER BAY
Port Chicago
BENICIA
MARTINEZ
PITTSBURG

Figure 1. 3

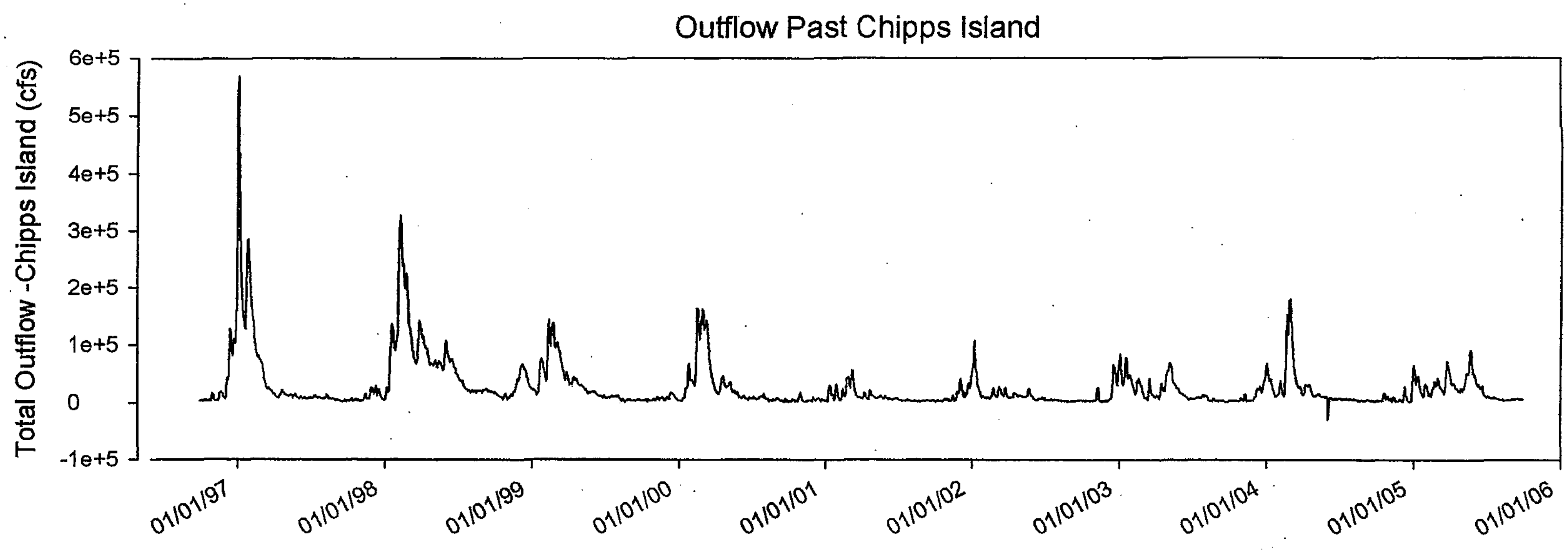


Figure 1.4 a

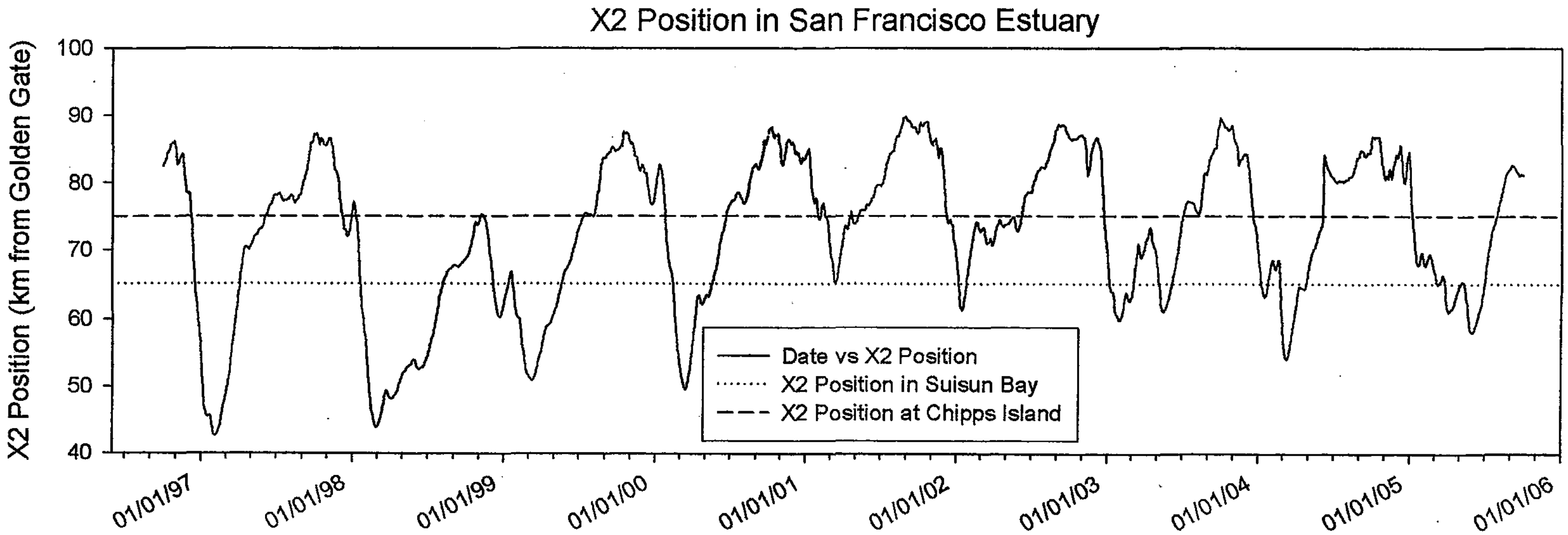


Figure 1.4 b

Native and introduced fish catch in Suisun Marsh (1980-2005)

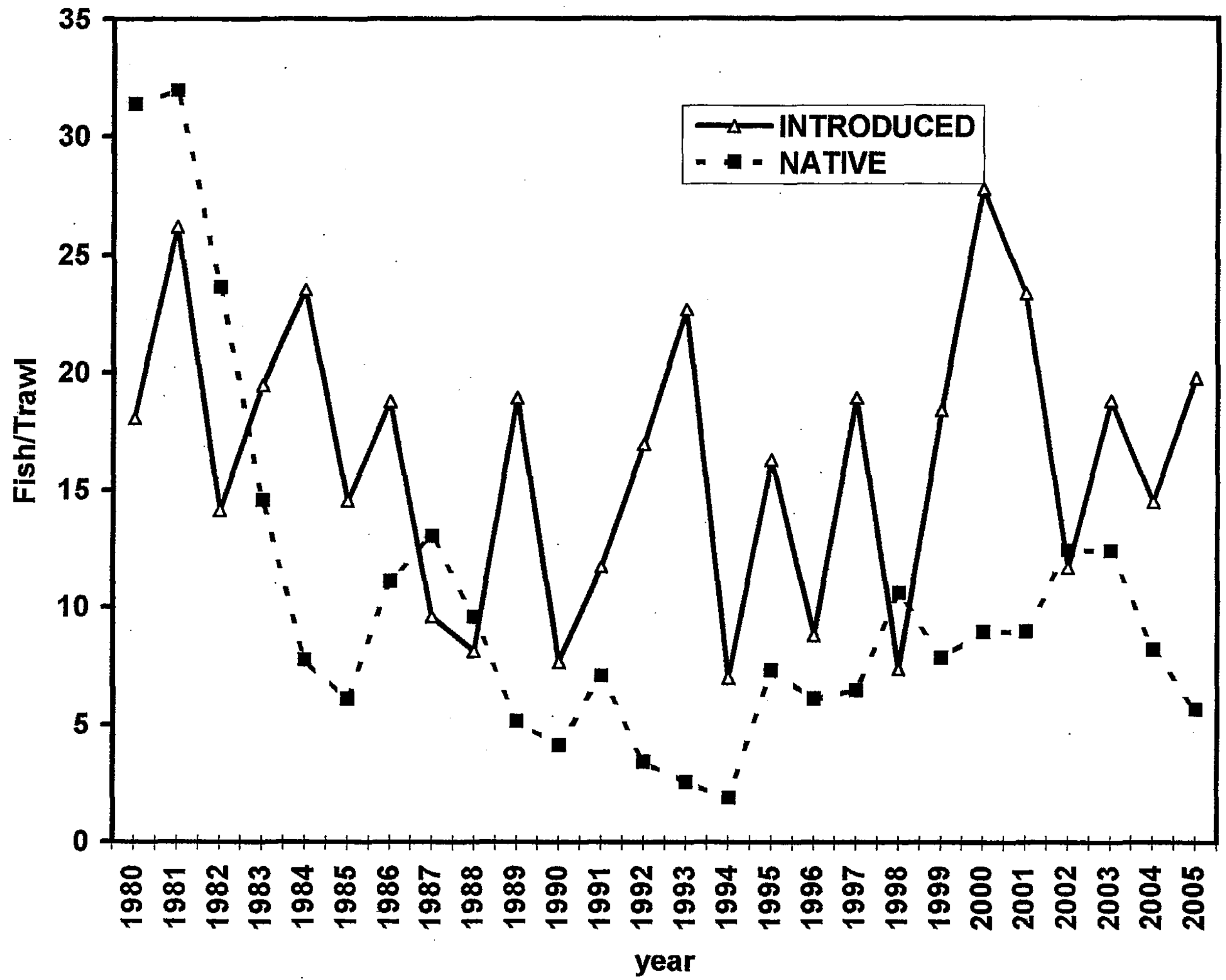


Figure 1.5

Striped bass catch in Suisun Marsh (1980-2005)

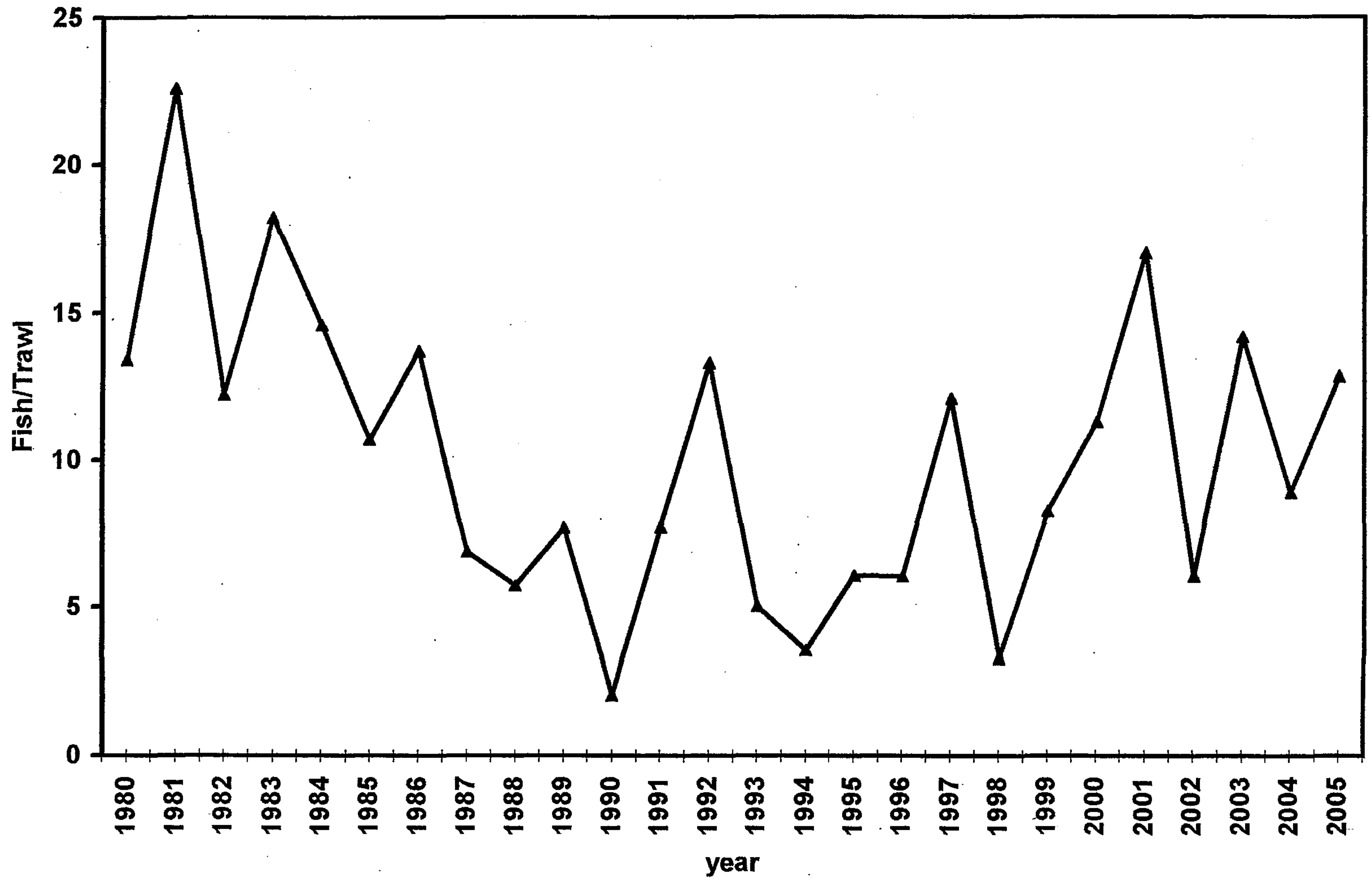


Figure 1.6

Goby catch in Suisun Marsh (1980-2005)

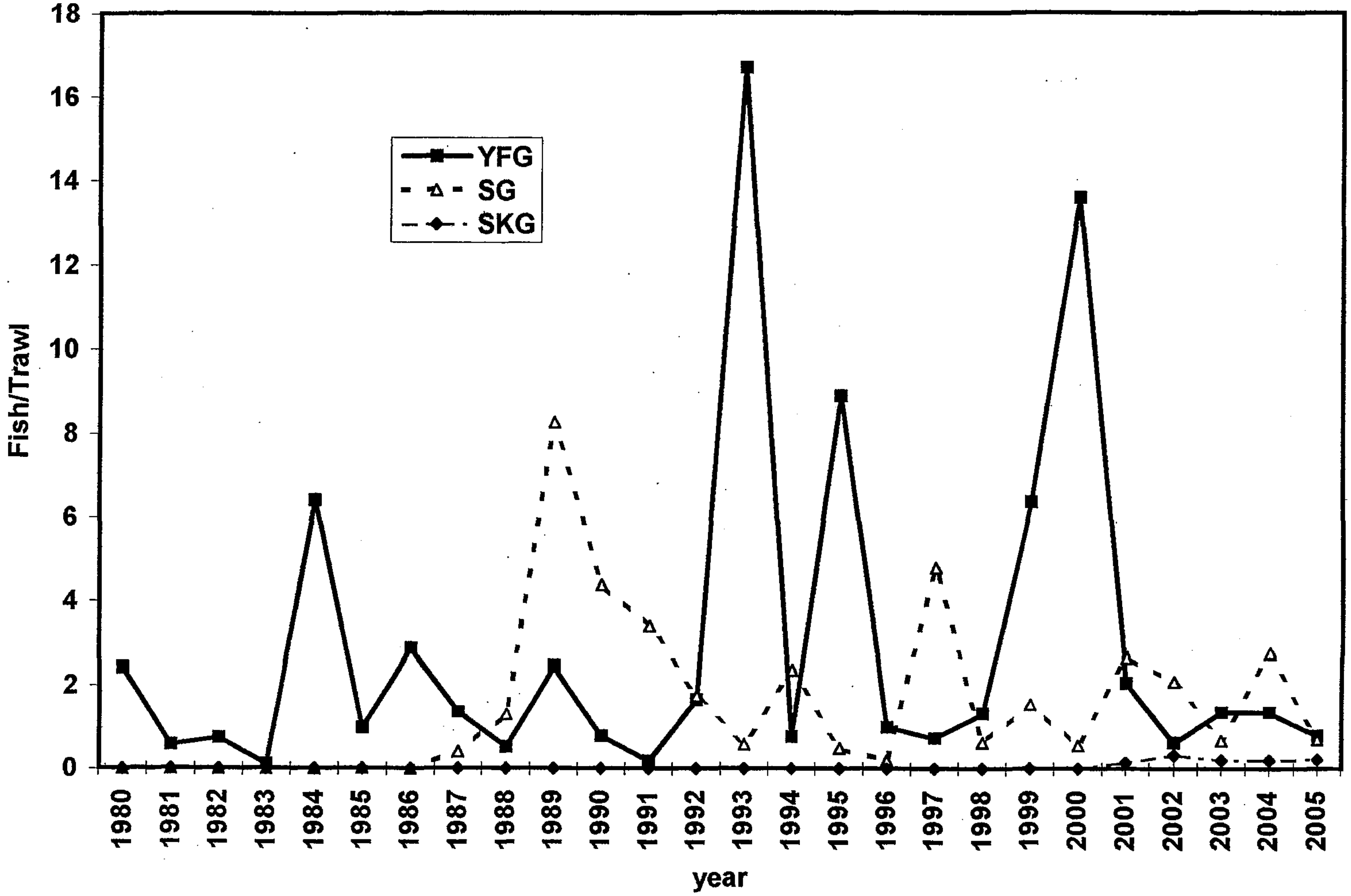


Figure 1.7

Splittail catch in Suisun Marsh (1980-2005)

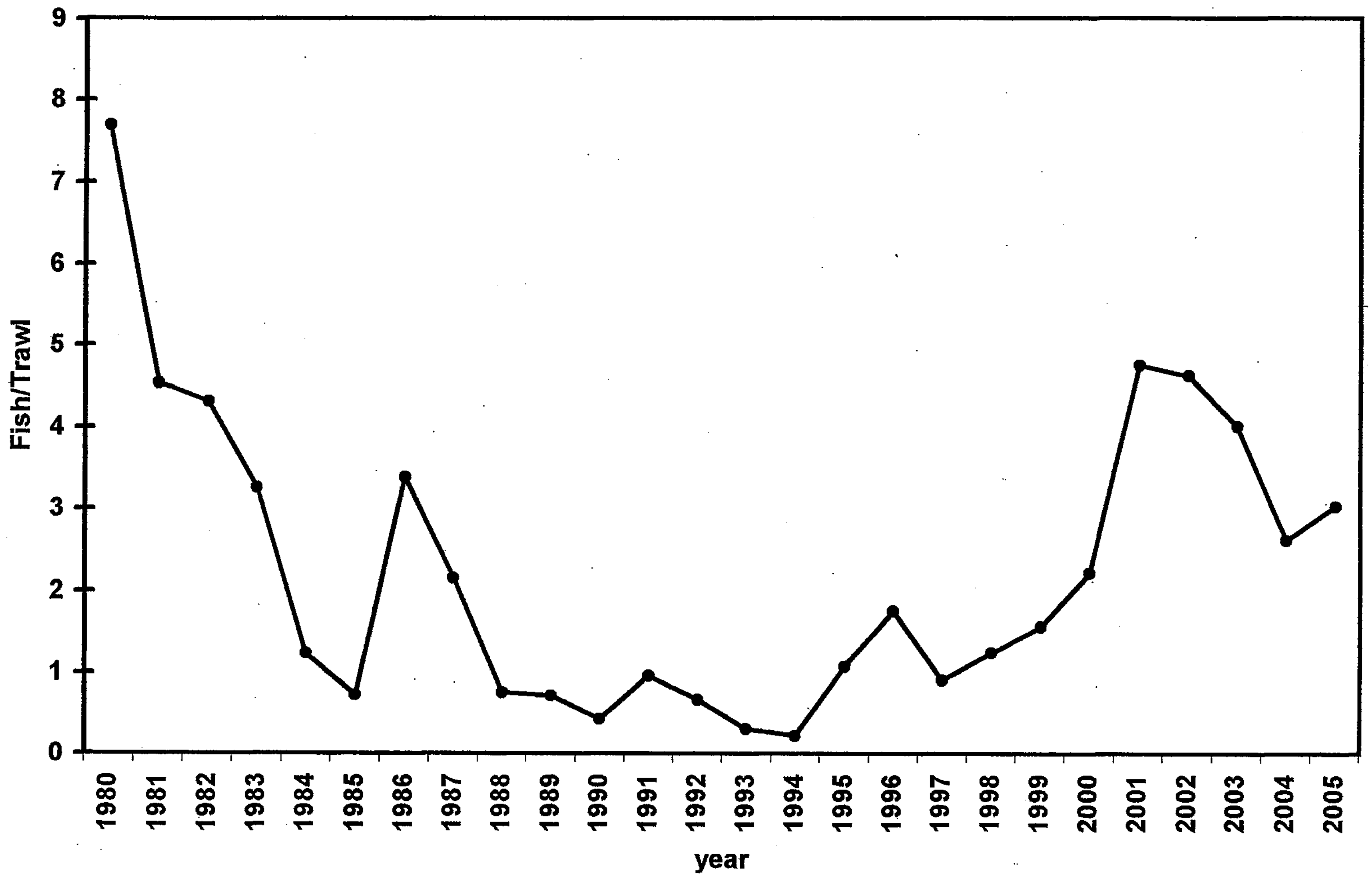


Figure 1.8

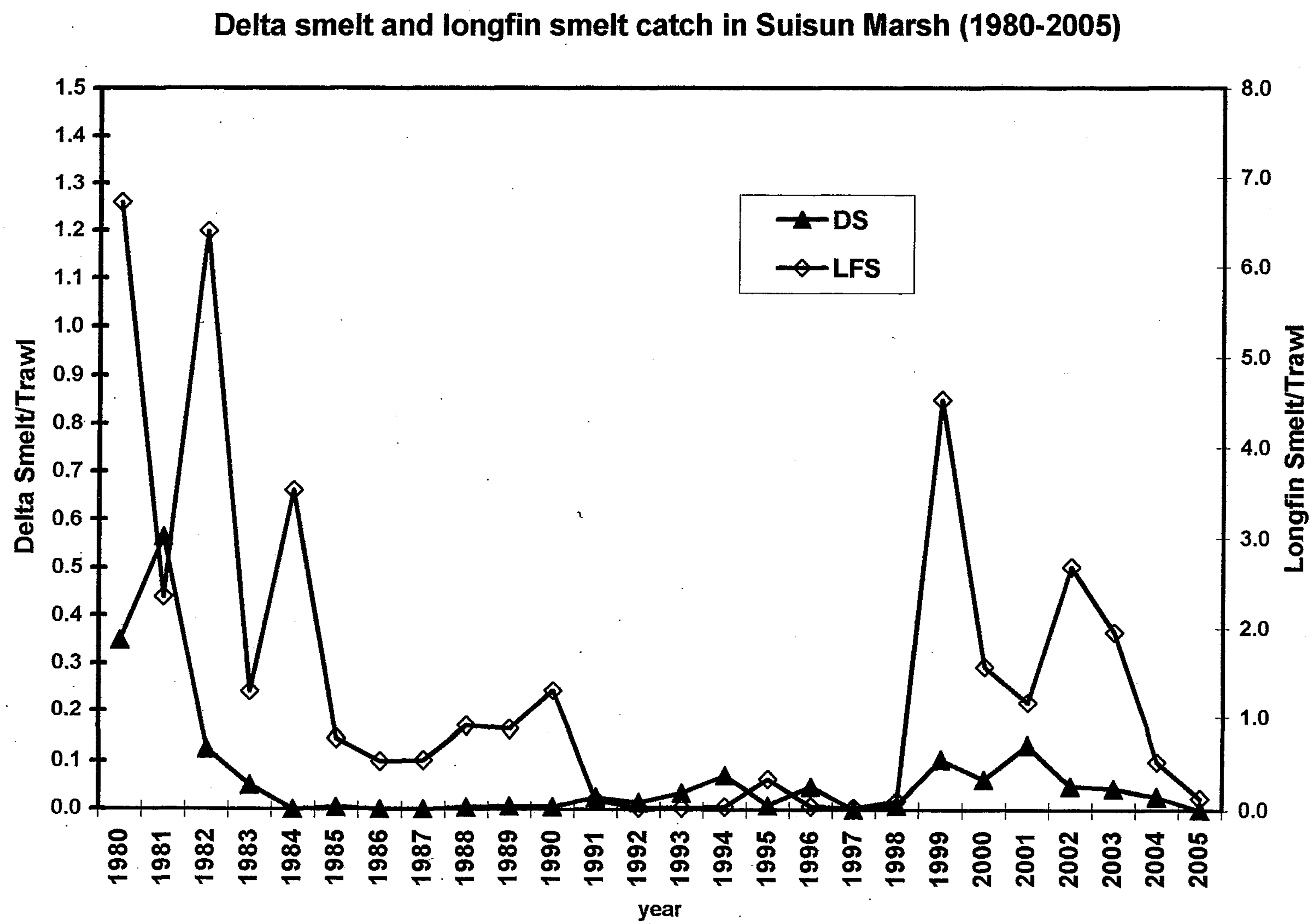

Delta smelt and longfin smelt catch in Suisun Marsh (1980-2005)
Delta Smelt/Trawl
Longfin Smelt/Trawl
year
DS
LFS
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005

Figure 1.9

Tule perch catch in Suisun Marsh (1980-2005)

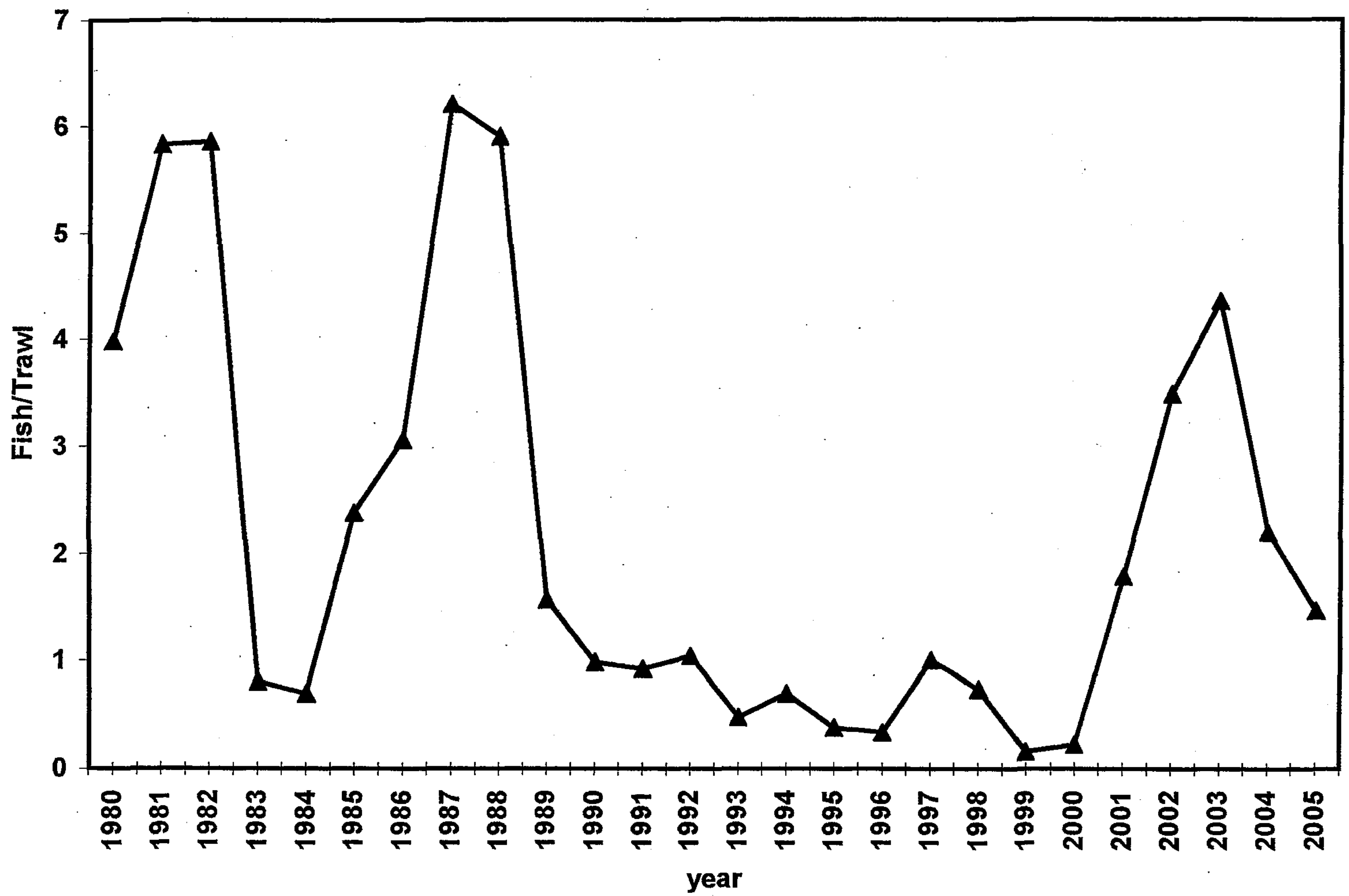


Figure 1.10

Sculpin and Sucker catch in Suisun Marsh (1980-2005)

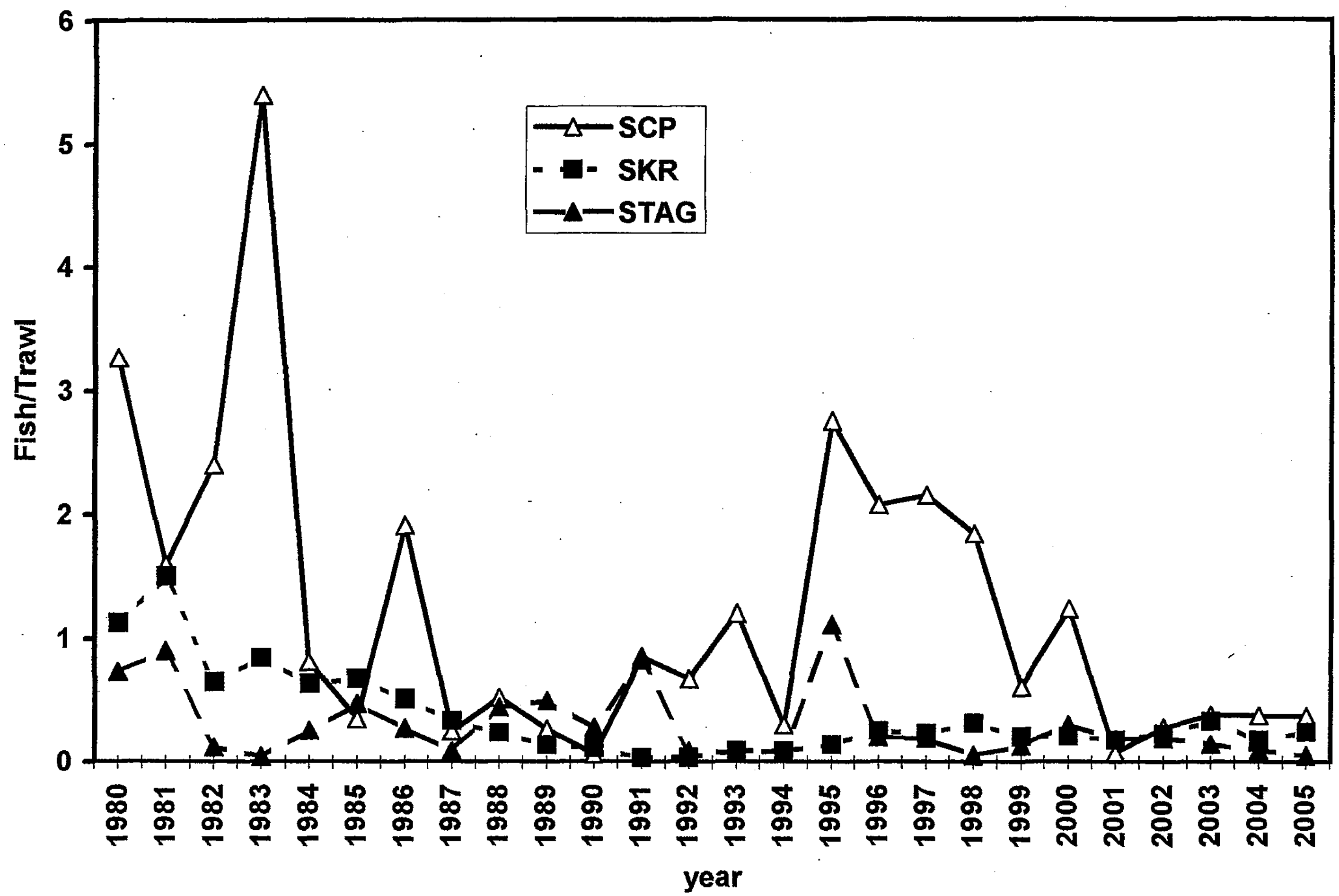


Figure 1.11

Threadfin shad and American shad catch in Suisun Marsh (1980-2005)

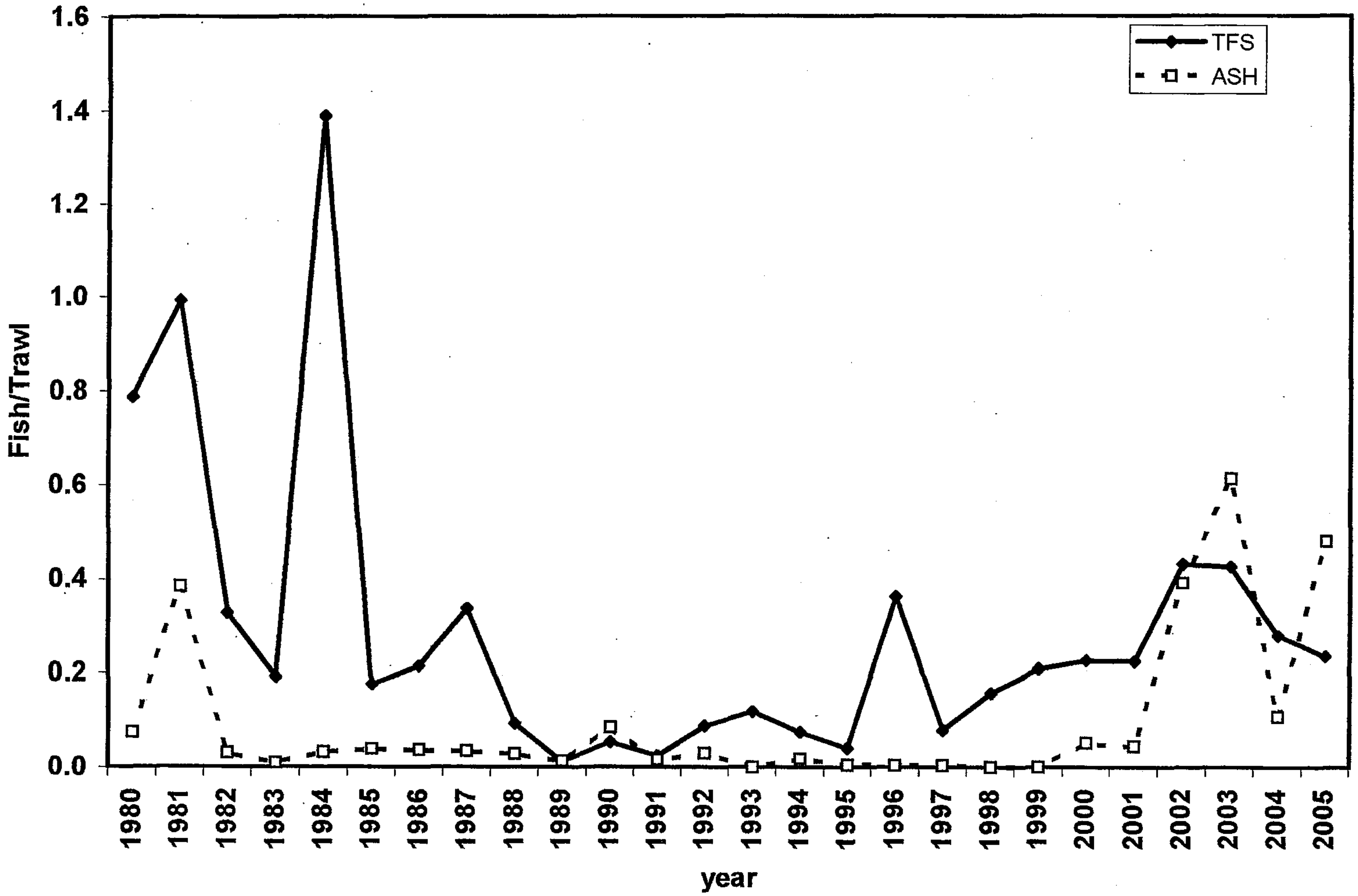


Figure 1.12

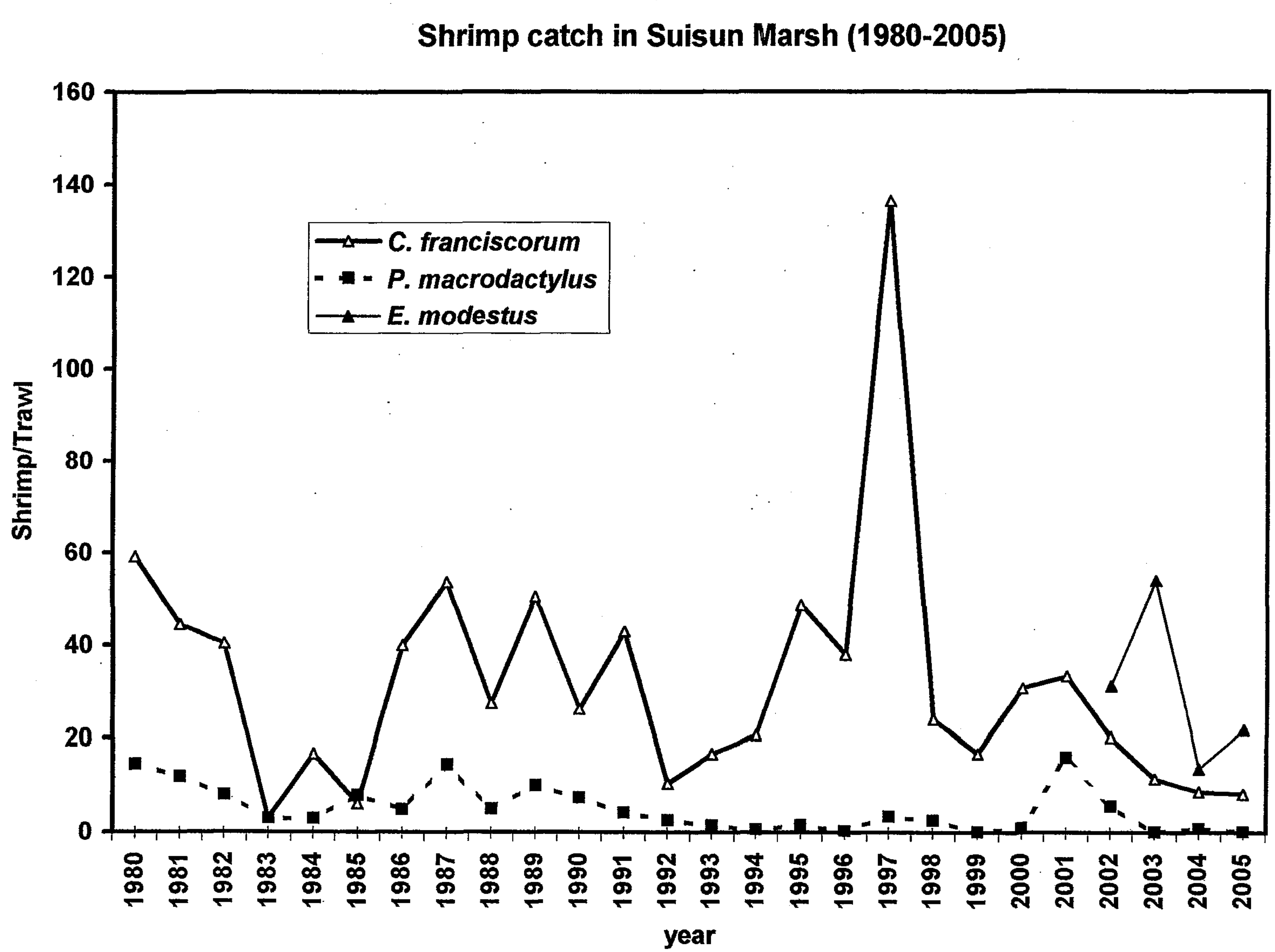

Shrimp catch in Suisun Marsh (1980-2005)
C. franciscorum
P. macrodactylus
E. modestus
Shrimp/Trawl
0
20
40
60
80
100
120
140
160
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
year

Figure 1.13

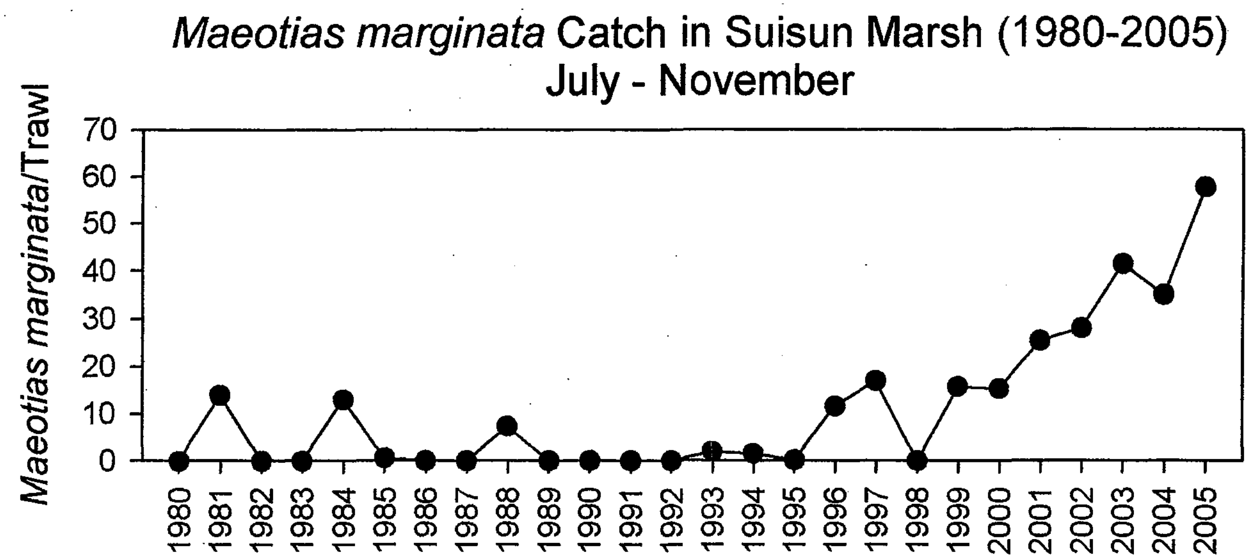


Figure 1.14 a

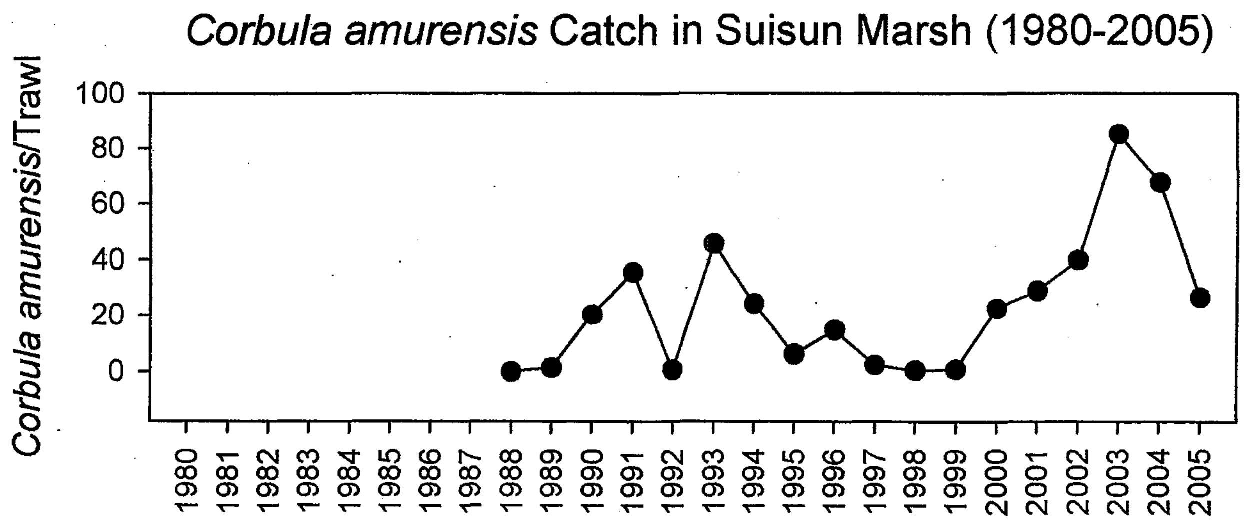


Figure 1.14 b

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Appendix Mean catch per trawl for several categories of fish and invertebrate species captured in Suisun Marsl

yr	trawls	intros	natives	SB	YFG	SG	SKG	ST	DS	LFS	TP	SCP	SKR	STAG	TFS	ASH	Cra	Exo	Pal
		Figure 1.5		Fig. 1.6	Figure 1.7			Fig 1.8	Figure 1.9		Fig. 1.10	Figure 1.11			Figure 1.12		Fig. 1.13		
1980	483	18.03	31.36	13.40	2.40			7.69	0.35	6.72	3.98	3.25	1.13	0.73	0.79	0.07	59.10	14.54	
1981	407	26.21	31.94	22.63	0.57			4.54	0.57	2.34	5.84	1.60	1.50	0.90	0.99	0.38	44.54	11.95	
1982	266	14.12	23.64	12.23	0.74			4.31	0.12	6.39	5.86	2.40	0.65	0.12	0.33	0.03	40.41	8.16	
1983	218	19.45	14.55	18.17	0.11			3.25	0.05	1.28	0.80	5.39	0.84	0.04	0.19	0.01	3.25	3.08	
1984	157	23.52	7.72	14.57	6.39			1.22	0.00	3.52	0.69	0.81	0.63	0.25	1.39	0.03	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	0.18	0.04	6.27	8.09	
1986	197	18.76	11.05	13.68	2.84			3.38	0.00	0.52	3.06	1.91	0.51	0.27	0.21	0.04	40.03	4.92	
1987	206	9.56	13.00	6.86	1.35	0.40		2.15	0.00	0.53	6.20	0.25	0.33	0.09	0.33	0.03	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	0.09	0.03	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	0.01	0.01	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	0.05	0.09	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	0.02	0.01	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	0.09	0.03	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	0.12	0.00	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	0.07	0.02	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	0.04	0.00	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	0.36	0.00	37.92	0.28	
1997	252	18.90	6.44	12.08	0.72	4.77		0.90	0.00	0.02	1.00	2.15	0.23	0.19	0.08	0.00	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	0.16	0.00	23.90	2.65	
1999	251	18.36	7.80	8.24	6.36	1.54	0.00	1.55	0.10	4.52	0.16	0.61	0.20	0.13	0.21	0.00	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	0.23	0.05	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	0.22	0.04	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	0.43	0.39	20.16	5.59	31.04
2003	252	18.76	12.35	14.14	1.35	0.67	0.21	4.00	0.04	1.94	4.35	0.38	0.33	0.14	0.42	0.61	11.56	0.13	53.80
2004	252	14.47	8.16	8.87	1.36	2.74	0.20	2.61	0.03	0.53	2.19	0.38	0.17	0.09	0.28	0.11	8.84	0.85	13.65
2005	252	19.75	5.65	12.82	0.79	0.70	0.21	3.03	0.00	0.13	1.46	0.37	0.24	0.05	0.23	0.48	8.37	0.19	21.79