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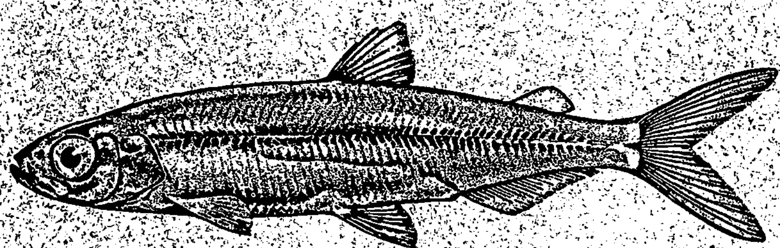
State of California
THE RESOURCES AGENCY
Department of Fish and Game
Bay-Delta and Special Water Projects Division

Written Testimony

Delta Smelt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June 1992

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WRITTEN TESTIMONY
DELTA SMELT PROJECT

The life history of delta smelt.

Description

The delta smelt, Hypomesus transpacificus, is a small, slender-bodied fish, with a typical adult size of 2-3 inches (55-70mm standard length) although some may reach lengths up to 5 inches (130mm) (Stevens, et.al., 1990). Live delta smelt have a steel blue sheen on the lateral sides and appear somewhat translucent. Like other members of the family Osmeridae, the delta smelt has an adipose fin. Other related smelt species found in the Sacramento-San Joaquin Estuary include the longfin smelt, Spirinchus thaleichthys, and the wakasagi, Hypomesus nipponensis.

Taxonomy

Delta smelt were at one time thought to be a widely distributed population of the pond smelt, Hypomesus olidus. Distribution is said to have ranged from as far south as San Francisco of the North American side of the Pacific, as far south as Japan on the Asiatic side of the Pacific, and into the Arctic Ocean in the north. In 1961, pond smelt were separated into two separate species; H. olidus was used for the present day H. transpacificus, and a new name, H. sakhalinus was designated for the Asiatic species. It was later determined that H. olidus was not present in California waters, but the name, H. olidus, was retained for the pond smelt which ranges from Alaska to Japan in the northern Pacific. Two additional subspecies were described, H. transpacificus transpacificus, found on the eastern side of the Pacific, and H. transpacificus nipponensis, found on the western side of the pacific. The two subspecies have since been split into two distinct species H. transpacificus and H. nipponensis with the common names delta smelt and wakasagi.

In 1959, when the Delta smelt and wakasagi were considered to be a single species (H. olidus), California Department of Fish and Game (CDFG) introduced wakasagi into several freshwater reservoirs in the state to supply forage for trout. The six original reservoirs in which wakasagi eggs were planted include: Dodge Reservoir, Lassen County; Dwinnell Reservoir (also known as Shastina Reservoir), Siskiyou County; Freshwater Lagoon, Humbolt County; Spaulding Reservoir, Nevada County; Jenkinson Lake, El Dorado County; and Big Bear Lake, San Bernardino County. The original plan was for "experimental introduction" into these six reservoirs and if they became established they could be transferred elsewhere. Later, if the fish were determined to be undesirable, they were to have been chemically treated. Additional transfers have since taken place and wakasagi are currently abundant in Folsom and Oroville reservoirs.

Age and Growth

Delta smelt are fast growing and shortlived although little is known about their early development and most of the information is derived from other closely related species such as wakasagi. The majority of growth is within the first 7 to 9 months of life when the fish grow to about 50-70mm after which growth slows presumably to allow for reproductive development (Figure 1). Most smelt die after spawning in the early spring although a few survive to a second year. It is not known whether those fish which survive to a second year are able to spawn again in the second year. Delta smelt can grow to lengths up to 130 mm (FL).

Diet

Delta smelt feed entirely on zooplankton. At larval stages, gut samples indicate that the diet consists of small copepods. As Delta smelt grow larger the primary dietary objects are calanoid copepods (Table 1). In 1974 samples, Eurytemora affinis was the primary prey item with mysid shrimp, Neomysis mercedis second. In 1988 samples, Pseudodiaptomus forbesi, an exotic species first observed in 1987, was the dominant prey item. Other prey items observed in gut samples include: Sinocalanus doerii, the amphipod, Corophium sp., and the cladocerans Bosmina sp. and Daphnia sp.

Reproduction

Spawning occurs from late winter to early summer. Ripe females can be collected from December to April with most collected from February to March. Peaks of larval abundances are usually in March, April, and May. Low abundances in some years provide evidence that nearly complete spawning failure sometimes occur.

Delta smelt spawn in freshwater or in slightly brackish water in or above the entrapment zone. Possible spawning locations include dead-end sloughs, close to inshore of the Delta, edges of rivers, or river areas under tidal influence with moderate to fast flows. Water temperature at spawning has been reported to be about 7°-15°C (≈45°-59°F), however, this range is inconsistent with temperatures during the peak larval abundance period, April-June which typically range from 15°-23°C (≈59°-73°F) (Sweetnam and Stevens, 1991). In 1990, post-hatch larvae (5.0 mm TL, total length) were collected at water temperatures as high as 22.8°C (73°F). Considering an egg incubation period of 7-14 days, the water temperature during spawning would have ranged from 20.8°-21.7°C (69.5°-71°F) at the same location.

Female Delta smelt mature at 55-70 mm and fecundity ranges from 1247 to 2590 eggs for females 59 to 70 mm (SL, standard length). No relationship between fecundity and length has been observed and eggs develop synchronously. Spawning probably occurs in the water column above vegetation or in open water above sandy or rocky substrates with adequate flows. As smelt eggs descend through the water column the outside adhesive layer of the chorion folds back and attaches to the substrate. Delta smelt eggs likely attach to rocks, gravel, tules, cattails, tree roots, and emergent vegetation. Hatching occurs within 14 days.

After hatching, the larvae are negatively buoyant but as the air bladder begins to develop, the larvae float and drift with the currents downstream to the entrapment zone or to other areas of the Estuary depending on flow conditions (e.g., outflow, exports, agricultural diversions, etc.). In the entrapment zone, the mixing effect allows the larvae to remain instead of being swept into salt water. This zone also traps large numbers of zooplankton on which they are able to feed, and its location is important to the young of many fish species, hence the term "nursery area". Recently, the entrapment zone has been confined to small channel areas of the Delta due to low inflows and high water exports. Larval growth is rapid and juveniles may reach lengths of 40-50 mm (FL) by August.

Delta smelt distribution and essential habitat.

Delta smelt are found only in the Sacramento-San Joaquin Estuary. They have been found as far upstream in the Sacramento River as the mouth of the American River and Mossdale on the San Joaquin River. Their normal downstream limit appears to be western Suisun Bay although during episodes of high outflow they can be washed into San Pablo Bay and San Francisco bays. Surveys by the Delta Outflow/San Francisco Bay Study, which has sampled fish in the Estuary from South Bay and the Golden Gate Bridge to the western Delta since 1980, indicate that delta smelt thin out in San Pablo Bay and are virtually non-existent in San Francisco Bay (Table 2).

Delta smelt usually inhabit salinity ranges of less than 2‰ (parts per thousand) although they are rarely found at salinities greater than 10‰. Summer townet and fall midwater trawl surveys conducted by the Department indicate that delta smelt are most frequently caught where specific conductance ranges from 500 to 8000 microsiemens (approximately 0.28‰ to 4.59‰ salinity)(Tables 3 and 4). These surveys demonstrate that the geographical distribution of delta smelt during the summer and fall is strongly influenced by delta outflow. As flows increase and saltwater is repelled, more of the population occurs in Suisun and San Pablo bays and less occurs in the Delta (Figures 2 and 3). There is reason to believe that delta smelt benefit from being transported to Suisun Bay. Historically, when delta smelt were more abundant a large proportion of the population was found in Suisun Bay and the surrounding areas. In winter and spring, as the spawning period approaches, adult delta smelt disperse widely into freshwater, as far upstream in the Delta as Mossdale on the San Joaquin River and the mouth of the American River on the Sacramento River.

Delta smelt live principally in the upper portion of the water column. During a 1963-1964 survey of delta fish populations a 10 foot by 10 foot surface trawl captured 1960 delta smelt while a 15 foot by 5 foot otter trawl only captured 461 delta smelt. These results were obtained despite the otter trawl constituting 60 percent of the surveys effort of about 1800 tows.

Status of the delta smelt population.

Information from seven independent data sets has demonstrated a dramatic decline of the delta smelt population and low population levels since 1983 (Figure 4). A rough estimate in CDFG's 1990 Status Report to the Fish and Game Commission placed the delta smelt population at several hundred thousand fish in 1985 although netting efficiency studies in 1991 indicate that abundance probably was actually about twice that level. Irregardless, based on September-December midwater trawl survey data, the 1985 population represents an 80% drop in abundance since 1983 compared to the average from 1967 to 1982 and a 90% decline from the peak level observed in 1980. Subsequent to the CDFG's status report to the Fish and Game Commission, the 1989 fall index has been reevaluated and corrected from 364 to 366 (Figure 5). The 1990 fall index has also been reevaluated and corrected to a value of 360 from 427. The 1991 fall index value was 689 which represents an increase from the 1983-1990 lows.

In contrast, the 1991 summer index (2.0) indicates that the population remains at a low level (Figure 6). The mean catch-per-trawl in the Delta Outflow/San Francisco Bay Study has also remained low since 1987 (Figure 7). The remaining four data sets also failed to show increased abundance in 1991. Hence, of the seven independent data sets which were initially used to document the decline, only the fall midwater trawl has shown any sign of an increase in abundance.

Although the recent increase in the fall abundance index suggests an increase in smelt abundance, it also continues to show reason for concern in that the smelt population has been concentrated in a single area: the lower Sacramento River between Collinsville and Rio Vista (Figure 8). Historically, when the population was at higher levels, the population was more widely distributed throughout the Estuary, suggesting that more suitable habitat was available to delta smelt in those years.

Also, the trend of low frequencies of occurrence of delta smelt in trawl tows which began in the early 1980s continued in 1991. The percentage of tows which captured delta smelt in the summer townet survey and the percentage of stations in which delta smelt were captured in the fall midwater trawl survey both show a striking decline from 1980 to 1983 (Figure 9). From 1959 to 1982, 43% of the tows in the summer townet survey caught delta smelt, from 1983 to 1991 only 16% caught delta smelt. In 1991 alone, only 8.2% of the tows caught delta smelt. For the fall midwater trawl survey, 25% of the tows caught delta smelt from 1967 to 1982, 11% after 1982.

The mean catch in tows with delta smelt has declined for the townet survey, but has not declined for the midwater trawl survey. This fact allows some insight as to how the patchiness of the population increases as the smelt grow older (Figure 10). The summer population is more dispersed than in the fall and the average densities are less than they were formerly. In the fall, there are now fewer aggregations, but those present are similar in density and/or size to the ones in the past which probably reflects an increased tendency to school as the smelt grow older. The reduced fall population is reflected in the decreased number of schools.

The timing of the decline observed in the early 1980s varies somewhat depending on which abundance measure is used. The summer and fall trawl surveys provide the best geographical coverage of the delta smelt population; thus they provide the best basis for evaluating population trends. Information from the other data sources confirms the general downward trend in abundance and allows additional insight into distributional patterns not covered by the summer and fall surveys.

Looking at the decline by geographical areas (Figures 11 and 12), it is apparent that the delta smelt decline began earlier in the south and east Delta than in the rest of the Estuary. An earlier decline in these areas is consistent with the decline suggested by the fish salvage data from the water project diversions in the south Delta (Figure 4).

Net efficiency evaluation.

In August, 1991, a net evaluation study of the standard midwater trawl used in the CDFG Fall Midwater Trawl Survey was initiated. A 1/8-inch mesh bobbinnet cover was placed over the standard 1/2-inch stretch-mesh codend of the net to capture fishes that escaped through the standard codend net. Because of high variances between catches, additional sampling is planned in order to fully evaluate net efficiency. However, preliminary results suggest that the standard midwater trawl was only 30% as effective at capturing delta smelt and about 80% as effective at capturing striped bass as the bobbinnet cover (Figure 13a,b). There was a difference in the maximum size of escapement between the two species, presumably due to differences in body shape or behavior. Additional sampling in January, 1992 suggests that as the mean size of the delta smelt captured increases, the efficiency of the standard midwater trawl net also increases (Figure 14). The standard net was about 55%

effective at capturing delta smelt (Figure 14b) and 100% effective at capturing striped bass (not shown). In comparing net efficiencies between delta smelt and striped bass, it appears that the standard midwater trawl was about 2.6 times more effective at capturing striped bass than delta smelt in August, 1991 and about 1.8 times more effective in January, 1992.

Thus, losses of small fish through the mesh of the standard midwater trawl would have effected actual abundance estimates for delta smelt based on comparisons of delta smelt catches with striped bass catches and striped bass abundance estimates (Stevens, et.al., 1990). It must be emphasized, however, that these results do not affect the interpretation of temporal trends observed in the fall midwater trawl abundance index. These results only indicate that the proportion of the delta smelt population caught by the midwater trawl is less than the proportion of the striped bass population caught and that the magnitude of both past and present abundance is somewhat greater than suggested by the extrapolations from catches in our standard midwater trawl.

Factors potentially responsible for the delta smelt decline.

Through regression analyses we evaluated the impacts of spawner-recruit relationships, delta outflows, water diversions, food abundance, reverse flows, water temperature, and water transparency on population abundance. This approach did not give a good explanation of the population decline. However, this does not mean that these factors are not important. It is possible that one or more factors were not measured with sufficient reliability for us to detect effects, or that some untested factor acts in concert with the measured factors to drive the smelt population.

Based on several life history characteristics, we can identify several factors which are potential threats to the delta smelt's continued existence. These factors include:

A. Food supply

Zooplankton abundance in the Estuary has been monitored by the Department's Zooplankton monitoring survey since 1972. This survey demonstrates that the densities of Eurytemora affinis, the most common copepod in the delta smelt's diet were relatively stable prior to 1988. However, in 1988, a major decline in the population occurred over much of the delta smelt's range (Figure 15). This decline coincided with the accidental introduction of the clam, Potomocorbula amurensis, but it was well after the decline in delta smelt abundance. Nevertheless, the recent decline in this major diet component must still be considered as a potential threat to the delta smelt's recovery unless other food resources compensate or E. affinis recovers to its former abundance.

B. Low Spawning Stock

Our evaluation of factors regulating delta smelt abundance failed to show that spawning stock abundance had a major influence on year class success. Nevertheless, the relatively low fecundity of this species and their planktonic larvae, which undoubtedly incur high rates of mortality, means that annual reproduction must be accomplished by fairly large numbers of fish if the population is to perpetuate itself. Thus while the stock abundance may not have been an important factor in the past, present or future low stock levels may inhibit the potential for population recovery.

C. Entrainment in Water Diversions

Delta smelt larvae are lost to entrainment in water diversions of the CVP, SWP, Delta agriculture, the Pacific Gas and Electric Company (PGE) and other industry using water from the Estuary.

Substantial entrainment losses of larvae occur at the CVP and SWP despite their intakes being located at the southern edge of the Delta miles from the current primary spawning and nursery areas. These losses occur due to the magnitude of the water project diversions, their impact on Delta flow patterns, and the tendency for young delta smelt to be transported and dispersed by river and estuarine currents. At high export rates, water is drawn up the San Joaquin River reversing its normal flow pattern. Moyle and Herbold (1989) found that high frequencies of reverse flows in the San Joaquin River during spring were always associated with low abundances of delta smelt in Suisun Bay in the fall while low frequencies of reverse flows sometimes were associated with high abundances of delta smelt. There has also been a trend of increasing reverse flows in the San Joaquin River, especially during the spawning months (Moyle, et.al., 1992).

Entrainment of delta smelt is greatest during spring and summer (Figure 16). This pattern reflects the late winter-spring spawning season and growth and mortality of young fish. During April and May, abundance of young smelt at the SWP and CVP diversions probably is greater than shown because the smelt are so small that they pass through the screens and are not salvaged for the first month or two of life. Also, smaller smelt are not readably identifiable as smelt by the technicians responsible for sampling of salvaged fish.

The intra-year salvage pattern in 1977-1978 was a notable exception to the pattern. Through much of 1977, water exports were reduced, due to a major drought, and while a delta smelt peak occurred in July, the greatest entrainment and salvage of the 1977 year class occurred from December 1977 through February 1978 when water exports increased after the drought broke (Table 5). In fact, the salvage of 134,000 delta smelt at the SWP in January

1978 almost equaled the total for all of 1977 (146,000) and exceeds the annual totals for all subsequent years.

Survival of delta smelt which have been salvaged appears to be low due to stress related mortality due to handling and trucking. In fact, survival of delta smelt retained at the Byron growout facility was reported to be 0% in 1989 (total of 2590 delta smelt; Odenweller, 1990).

D. Flows out of optimal range

The years of the smelt decline are not only characterized as dry years, but also by unusually wet years with exceptionally high outflows. These periods of exceptionally high outflow may be detrimental to delta smelt because their larvae are planktonic and move with the currents. If flows are high numbers of larval smelt may be transported out of the Delta into San Pablo and San Francisco bays and have no means to move back upstream.

E. Toxic Substances

The effects of toxic substances including agricultural pesticides, heavy metals, and other products of our urbanized society on delta smelt have never been tested. Although the effects of these compounds on fishes are poorly understood, some of these compounds are found in the Estuary at levels that may inhibit their reproduction (Jung, et.al. 1984) or are sufficient to trigger health warnings regarding human consumption in other fish species. Although there is no direct evidence of delta smelt suffering direct mortality or stress from toxic substances, this factor obviously cannot be eliminated as a potential agent adversely affecting the delta smelt population.

F. Genetic Dilution

The closely related wakasagi was introduced in 1959 by the Department of Fish and Game into six California reservoirs. Since then, there have been subsequent introductions and they are presently common in Folsom and Oroville reservoirs. Although the current status of wakasagi in the Estuary is uncertain, the potential exists that this species may be able to hybridize with the delta smelt. Currently, it is not known whether the potential of hybridization exists, but the threat of loss of genetic integrity should be considered as a substantial threat to the delta smelt population. However, as this factor can be considered as a threat to the continued existence of delta smelt, it cannot be considered as a possible cause of the delta smelt decline.

G. Competition and Predation

Delta smelt evolved with native predators such as squawfish (Ptychocheilus grandis), Sacramento perch (Archoplites interruptus), and steelhead (Onchorhynchus mykiss); however, predation by these species, none of which are currently abundant in the Estuary, is unlikely to be responsible for the relatively recent decline observed in delta smelt. Striped bass which were introduced into the Estuary in 1879, have been the most abundant predator (adults and sub-adults) and competitor (young) in the portion of the Estuary inhabited by delta smelt, but striped bass have also suffered a serious decline which began in the early 1970s and preceded the decline in delta smelt. Other potential competitors or predators which include longfin smelt, threadfin shad, and white catfish, also show signs of population erosion approximately coinciding with , or in the case of white catfish, preceding the decline of delta smelt. In essence, there has not been a consistent increase in the abundance of any potential predator or competitor that could account for the decline in delta smelt.

The possibility that the effort to enhance the Sacramento-San Joaquin striped bass population through the stocking of hatchery-reared fish could cause excessive predation on delta smelt has recently been suggested as cause for the decline in delta smelt. Striped bass are highly pisciverous (eat other fish); however, comprehensive striped bass food habit studies in the 1960's indicated that, while delta smelt were occasionally consumed, they were not a significant prey of striped bass even in the 1960's when delta smelt and striped bass were both much more abundant. That and the small size of the present bass population, including stocked bass, make this an unlikely hypothesis.

Actions that have been taken to advance understanding of factors affecting delta smelt abundance.

The purpose of the delta smelt study is to monitor and investigate factors potentially affecting delta smelt population levels in order to insure their long-term survival and to address the management and recovery objectives set forth by the Fish and Game Commission. It is also intended to provide the U.S. Fish and Wildlife Service with information relevant to the proposed Federal listing of the delta smelt as a threatened species.

The study plan has been divided into ten different projects designed to increase understanding of specific aspects of delta smelt life history and to help evaluate potential threats to the population. The study design included input from a committee of representatives of the Department of Fish and Game (CDFG), Department of Water Resources (DWR), U.S. Bureau of Reclamation (USBR), U.S. Fish and Wildlife Service (USFWS), State Water Resources Control Board, outside contractors, and researchers from the University of California at Davis (UC Davis). The delta smelt study began full implementation in January 1992 (Figure 17).

PROJECTS WITHIN THE DELTA SMELT STUDY:

(1.) **Trawl and seine surveys of adult delta smelt distribution during late winter and spring to define spawning areas and requirements. Detect spawning with artificial substrate surveys to collect delta smelt eggs.**

(A.) **Midwater Trawl Surveys during the spawning season.**

This midwater trawl survey will identify adult delta smelt distribution and abundance during the spawning season. Single 12 minute stepped-oblique midwater trawl tows will be made monthly from September through April at approximately 95 sites throughout the Estuary (Figure 18). All fish species will be identified and measured; physical parameters will also be measured.

(B.) **Beach seines of adult delta smelt distribution and abundance in spawning period.**

The beach seine survey will identify adult delta smelt abundance and distribution in low velocity areas such as side channels, backwater locations, and dead-end sloughs during the spawning season. The beach seine survey will be done weekly from December through June. Sampling will occur at approximately 35 sites including Suisun Marsh, Cache Slough, Delta, and Sacramento River (Figure 19). This survey will be run in conjunction with the Interagency Ecological Study Program Salmon Fry survey possibly with several site additions.

(C.) **Use of artificial substrates to capture delta smelt eggs in order to identify specific spawning locations.**

Delta smelt eggs are demersal and attach to aquatic vegetation, hence, artificial egg collecting substrates will be used to specifically identify spawning locations. Placement of artificial substrates will occur in response to high abundances of adult delta smelt identified by the trawl and/or seine surveys, suitable habitat, and accessibility of locations.

(2.) **Development of objective procedures to separate (identify) this species from longfin smelt during early larval stages.**

Dr. Johnson Wang has developed a key based on taxonomic characteristics such as morphological differences of gas bladder formation and relationship of the gut to the gas bladder. This Interagency technical report (Number 28, dated August, 1991; Wang, 1991) is currently being used in the laboratory for smelt identification.

(3.) **Larval fish surveys to determine the timing, distribution, and abundance of delta smelt larvae and their food supply.**

This project will monitor larval delta smelt occurrence, distribution and abundance along with associated environmental conditions. Larval fish surveys are critical to identification of factors controlling survival and abundance of young smelt and their food supply.

A 505 μm nitex egg and larval net attached to a sled will be towed in a stepped-oblique fashion. A Clark-Bumpus net of 154 μm mesh attached to the upper frame of the net will be used to collect zooplankton samples. Single 10-minute tows will be made at approximately 80 stations throughout the Estuary (Figure 20). Sampling will start in February and continue through July and occur every fourth day, but during late March and April it will be every second day. Gut analysis will identify prey items and allow comparison with abundance of prey species in the Clark-Bumpus net and in the CDFG Zooplankton Survey.

(4.) **Cohort identification from otoliths.**

Identification of specific cohorts of delta smelt by examination of daily growth increments (circuli) of otoliths (ear bones) will be used in concert with larval and juvenile fish abundance data from Projects 1 and 3 and will furnish information on when and where the majority of the population was spawned. This information combined with environmental information such as food supply, water temperature, salinity, diversions, and other water quality and quantity factors will improve understanding of how environmental conditions impact delta smelt growth and survival.

(5.) **Condition measures to evaluate effects of toxicity and starvation on larval delta smelt.**

The purpose of this project is to use histological and morphometric methods to compare condition of larval delta smelt collected in the field with that of larvae held under various conditions in the laboratory. These analyses will allow evaluation of the extent to which delta smelt condition is affected by variations in their food supply, toxicity and parasites. This knowledge is important to an overall evaluation of factors responsible for the population decline and development of a recovery plan.

(6.) **Trawl and/or seine surveys to determine abundance, distribution, and preferred habitats of older juvenile delta smelt.**

Surveys of older juvenile delta smelt are needed to identify critical nursery habitats and other requirements. The proposed sampling would supplement current summer and fall surveys for young-of-the-year striped bass with additional stations added for delta smelt. New sampling gear and methods as well as modifications of current sampling gear are being considered.

(7.) **Estimation of larval delta smelt fish losses at the State and Federal water project diversions, and local agricultural diversions in the Delta.**

The significance of losses of larval smelt to water project diversions will be assessed through a combination of the estuary-wide larval fish survey and sampling by DWR in the south Delta using the same sampling methods. Sampling in 1992 will begin in mid-February. USBR has been attempting to continuously sample eggs and larvae at the Federal water project diversion and at several sites throughout the Estuary.

Presently, there is no sampling of larval fish losses to agricultural diversions. DWR is developing a protocol for this sampling.

(8.) **Continued monitoring of older juvenile and adult smelt salvage at the State and Federal water project diversions and reducing handling and trucking losses of delta smelt at these diversions.**

Fish screens at the State and Federal water project diversions prevent many older juvenile and adult delta smelt from entering the aqueducts and canals south of the Delta. However, some portion of the smelt that approach the screens pass through them. Many other smelt that enter the water project facilities probably die due to handling associated with the screening and trucking process. Studies aimed at reducing mortality could be done on delta smelt salvaged at the facility or maintained in the laboratory. Improved sampling procedures at the State and Federal diversions planned for 1992 should increase accuracy of estimates of delta smelt lost to these diversions.

(9.) **Electrophoretic analysis of delta smelt and related species.**

The purpose of this project is to document genetic differences between delta smelt (Hypomesus transpacificus), wakasagi (Hypomesus nipponensis), and longfin smelt (Spirinchus thaleichthys). Loss of genetic integrity is a threat to the delta smelt population.

(10.) Modeling of delta smelt Population Dynamics and Persistence.

This project will apply population dynamics techniques to compute extinction probabilities and evaluate how changes in the environment and water management might alter them. Data will be used from current studies to look for spatial relationships that will aid in predicting extinction probabilities. A population dynamics model will also be produced.

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Table 1. Items in the diet of delta smelt collected from the townet survey at station 519 (Honker Bay) on June 28 and July 13, 1974 (taken from Stevens, et.al., 1990).

Length group(mm)	Total fish	Number w/food	Cyclopidae	*Eurytemora*	*Diaptomus*	Harpacticoid copepod	Neomysis	Other copepod
20-24	2	1		2				
25-29	18	17		117	1	1		8
30-34	18	17	2	585			1	45
35-39	12	12	0	220			1	34

Table 2. Delta Outflow/San Francisco Bay Study catch of delta smelt by month and area, 1980-1988. Number of sampling sites in parentheses. (Taken from Stevens, et.al., 1990.)

Area	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
San Francisco Bay (16)	0	0	0	0	0	0	0	0	0	0	0	0	0
San Pablo Bay (8)	4	5	29	1	0	1	0	0	0	54	0	1	95
Carquinez Strait & Western Suisun Bay (6)	61	46	86	37	5	55	70	94	71	36	9	38	608
Eastern Suisun Bay (3)	18	24	15	10	5	8	16	37	54	68	40	12	307
Western Delta (2)	30	13	15	5	2	20	12	23	55	12	33	32	252
Total	113	88	145	53	12	84	98	154	180	170	82	83	1262

Table 3. Summer townet survey catch frequencies for delta smelt by specific conductance (EC) ranges, 1969-1988. [1/]

Numbers of Smelt Per Catch

EC (microsiemens)	0	1-4	5-9	10-14	15-19	20-49	50-99	>100	Total Samples	Number Catches >0	Percent with smelt
No Data	9	4	3	1	0	1	1	0	19	10	52.6
1-499	541	170	52	17	10	36	16	14	856	315	36.8
500-999	105	51	13	16	7	13	14	10	229	124	54.1
1000-1999	38	31	15	10	8	17	9	10	138	100	72.4
2000-3999	34	41	15	11	8	22	9	8	148	114	77.0
4000-5999	31	30	11	6	4	6	8	8	104	73	70.0
6000-7999	22	21	9	7	3	11	5	1	79	57	72.1
>8000	338	96	32	14	7	17	14	3	521	183	35.1
Total	1118	444	150	82	47	123	76	54	2094	976	46.6

1/ EC was not measured prior to 1969 even though the survey started in 1959.

Table 4. Fall midwater trawl frequencies for delta smelt by specific conductance (EC) ranges, 1967-1988.

Numbers of Smelt Per Catch

EC (microsiemens)	0	1-4	5-9	10-14	15-19	20-49	>50	Total Samples	Number Catches >0	Percent with smelt
No Data	9	0	0	0	0	0	0	9	0	0
1-499	1756	604	103	30	16	27	4	2540	784	30.8
500-999	311	137	35	21	7	12	5	528	217	41.1
1000-1999	224	128	43	18	10	18	2	443	219	49.4
2000-3999	269	141	44	30	9	14	5	512	243	47.4
4000-5999	244	97	45	9	10	12	1	418	174	46.1
6000-7999	202	67	23	10	5	9	1	317	115	36.3
>8000	4547	173	24	9	9	11	4	4777	230	4.8
Total	7562	1347	317	127	66	103	22	9544	1982	20.7

Table 5. Estimated salvage of delta smelt and water exports at the State Water Project diversion in the southern Delta, during 1977-1978.

	Month	Delta Smelt Salvage	Exports (thou. acre ft)
1977	Jan	6980	205
	Feb	2430	106
	Mar	1707	97
	Apr	2975	14
	May	3017	68
	Jun	3033	17
	Jul	43489	20
	Aug	6435	15
	Sep	17890	9
	Oct	2528	8
	Nov	350	51
	Dec	55101	224
1978	Jan	134089	365
	Feb	53960	343
	Mar	4217	108
	Apr	130	35
	May	3523	59
	Jun	36289	201
	Jul	1034	211
	Aug	2658	246
	Sep	244	211
	Oct	60	127
	Nov	473	131
	Dec	900	169

1/ EC was not measured prior to 1969 even though the survey started in 1959.

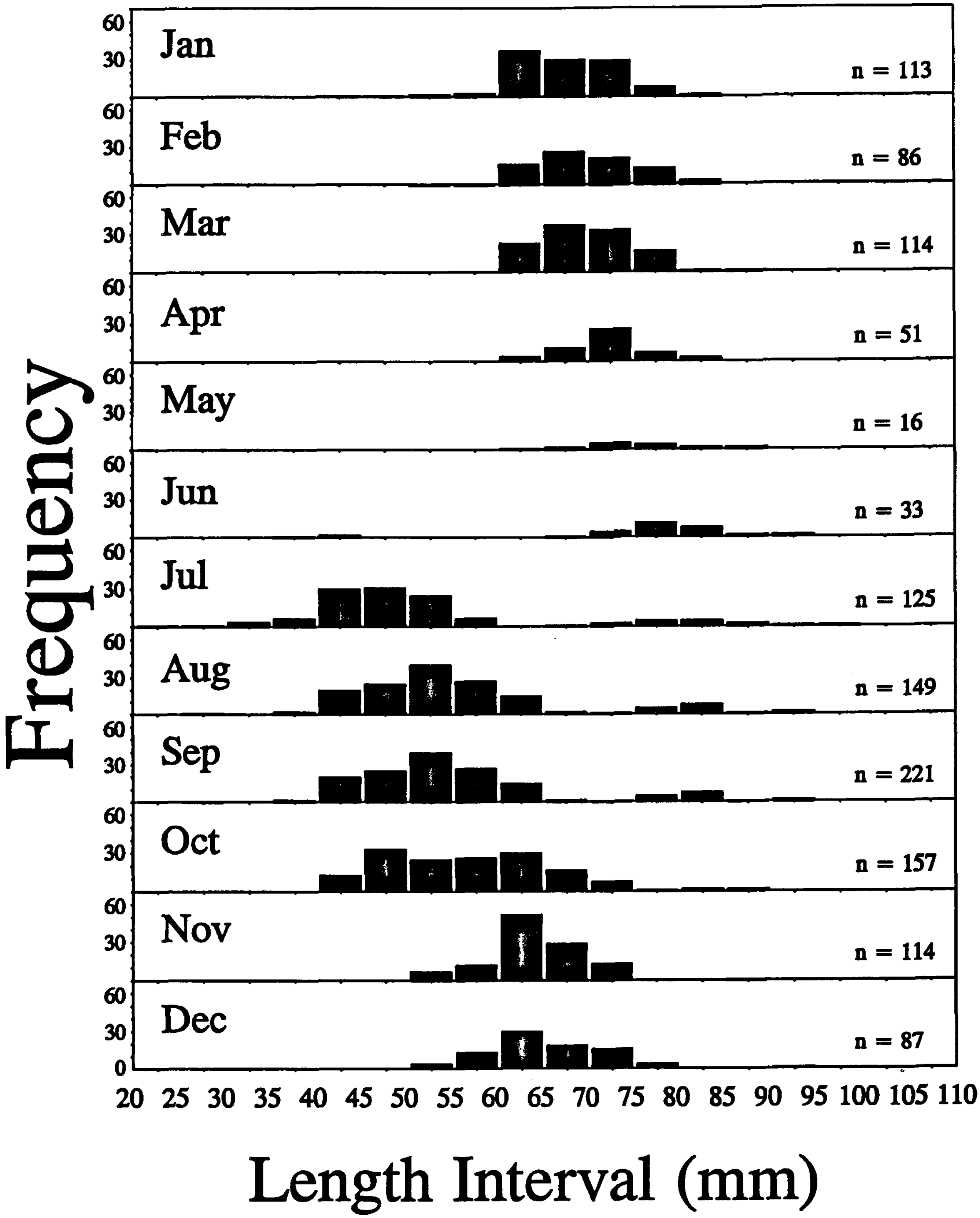

Figure 1. Length-frequency distribution of delta smelt by month collected by the Delta Outflow/ San Francisco Bay Study, 1980-1991.

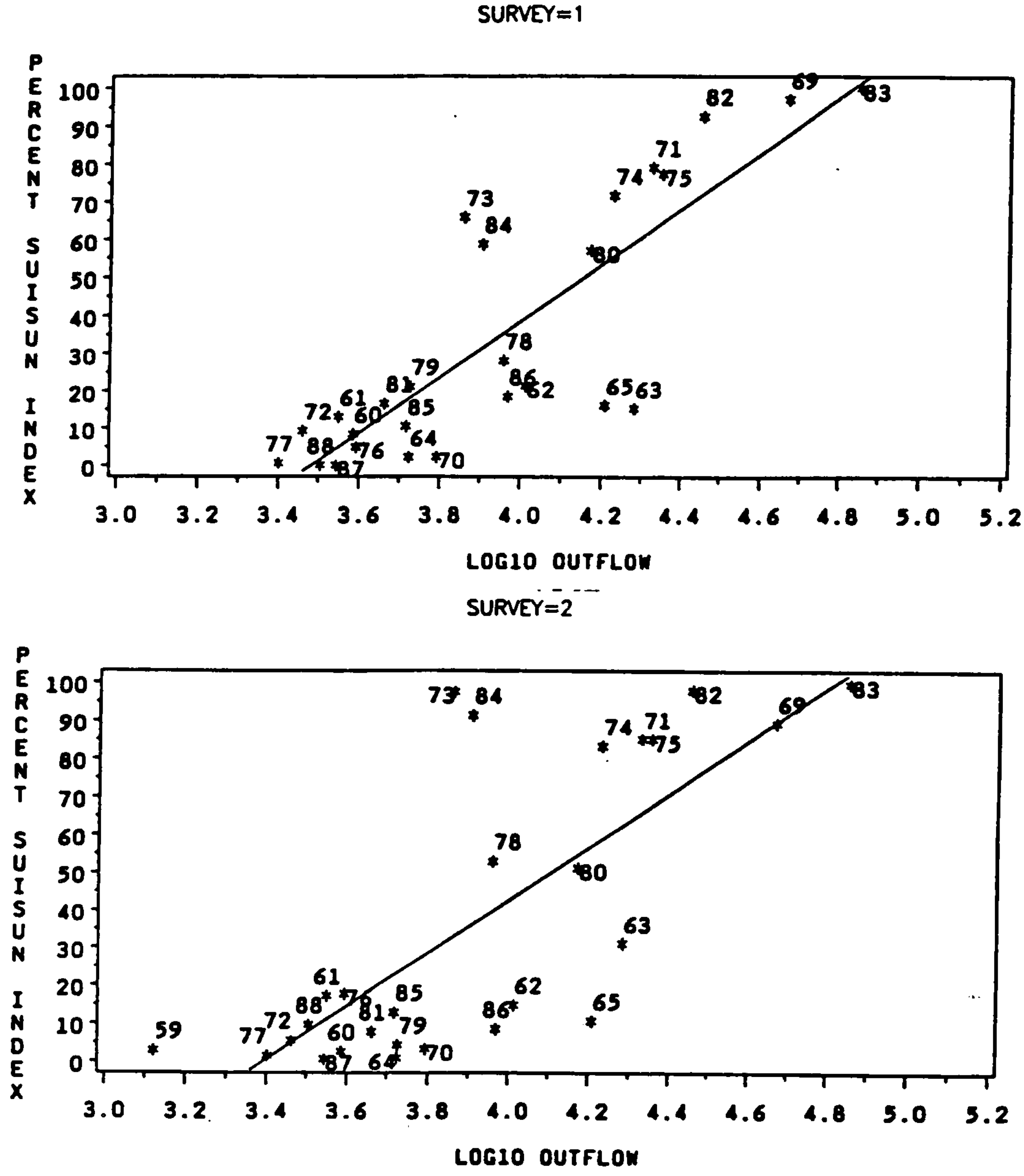

Figure 2. Relationship between the portion of the delta smelt population occurring west of the Delta and the log delta outflow during the survey period. Data are from the summer townet survey. For arcsine transformed percentages, $R^2 = 0.74$ for survey 1 and $R^2 = 0.55$ for survey 2.

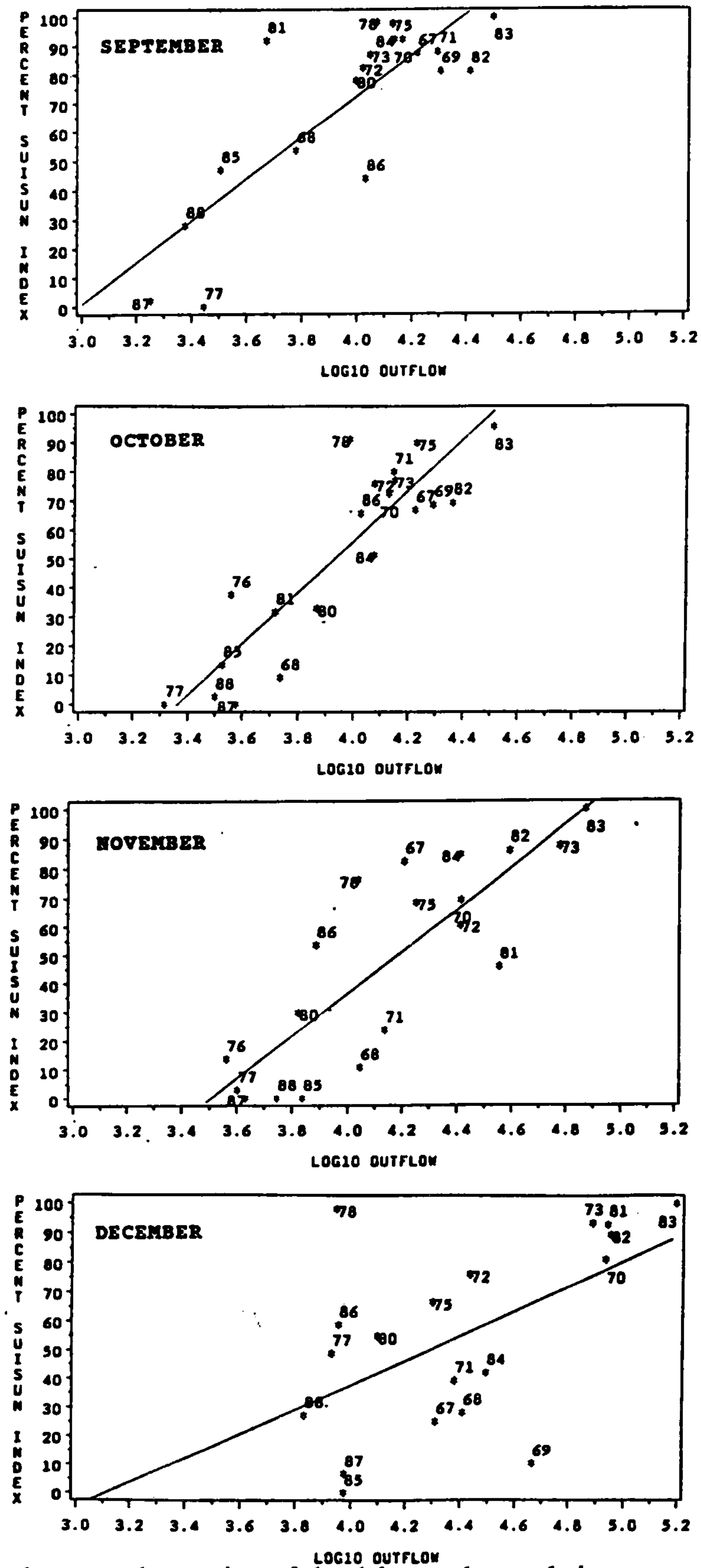

Figure 3. Relationship between the portion of the delta smelt population occurring west of the Delta and log Delta outflow during the survey month. Data are for the fall midwater trawl survey. For arcsine transformed percentages, $R^2 = 0.640$ for September, 0.763 for October, 0.708 for November, and 0.336 for December.

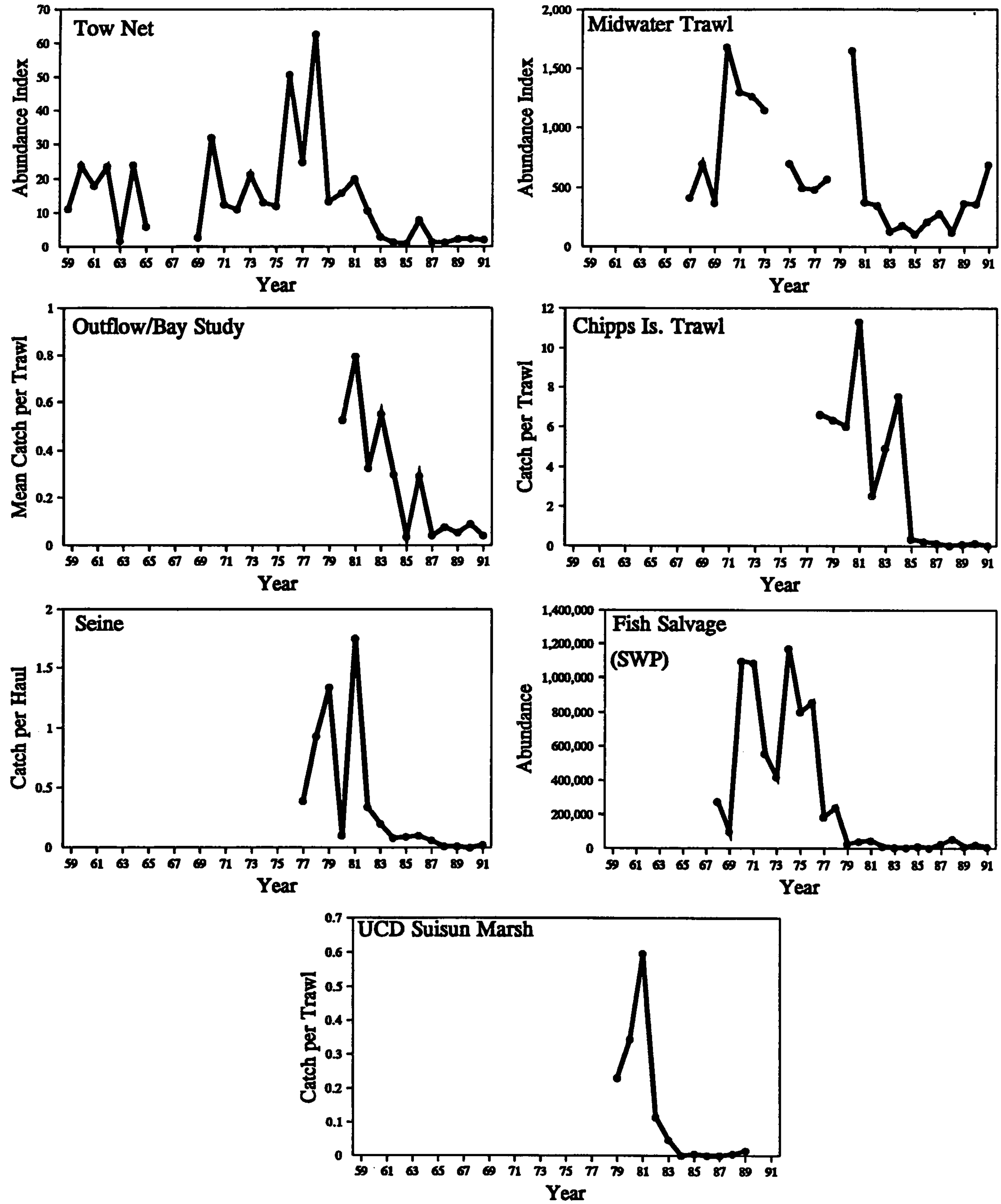

Figure 4. Trends in delta smelt as indexed by seven independent surveys (updated from Stevens, et.al., 1990, Figure 4).

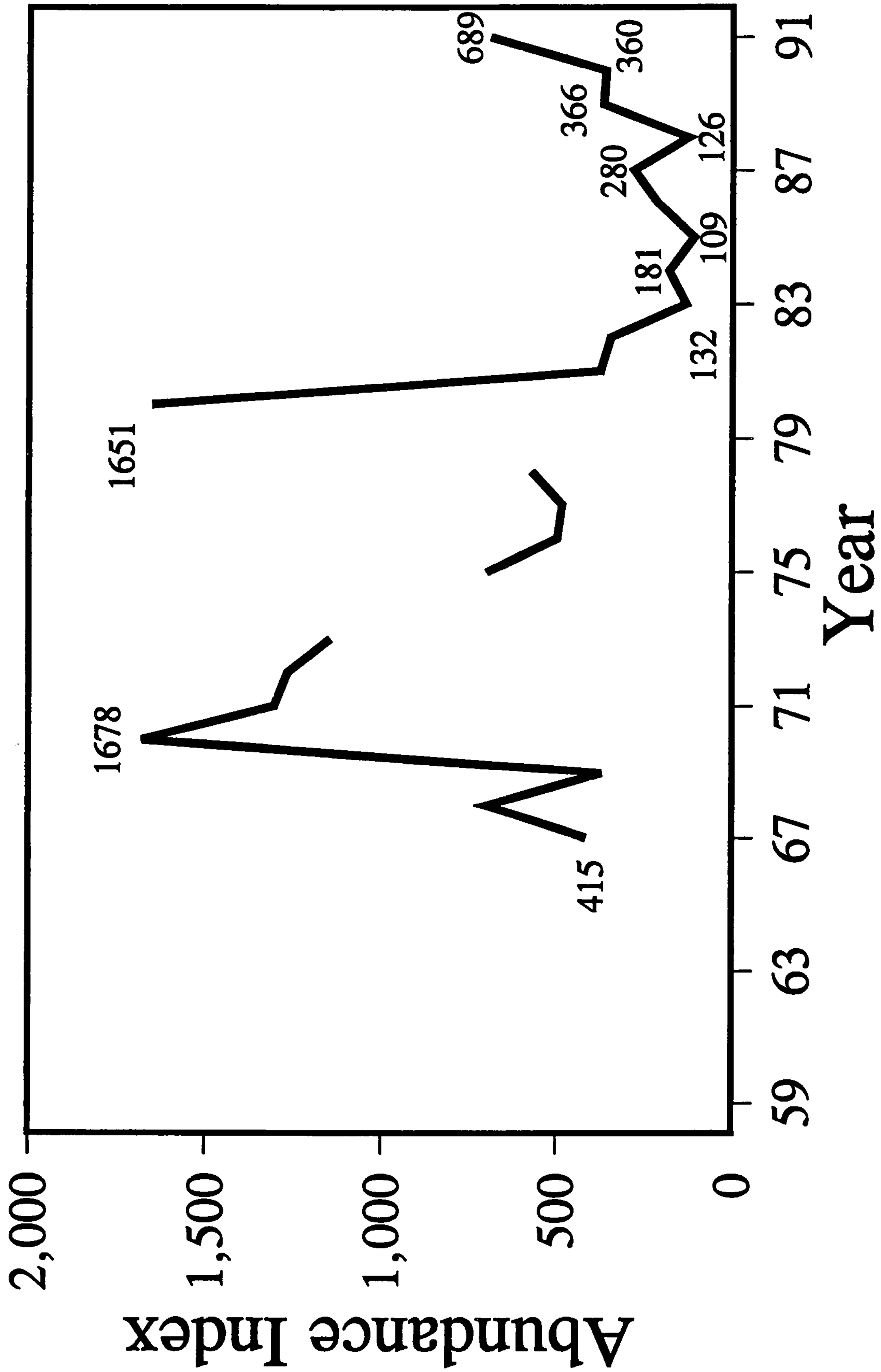

Figure 5. Fall midwater trawl abundance index for delta smelt for the years 1967-1973, 1975-1978, 1980-1991 in the Sacramento-San Joaquin Estuary.

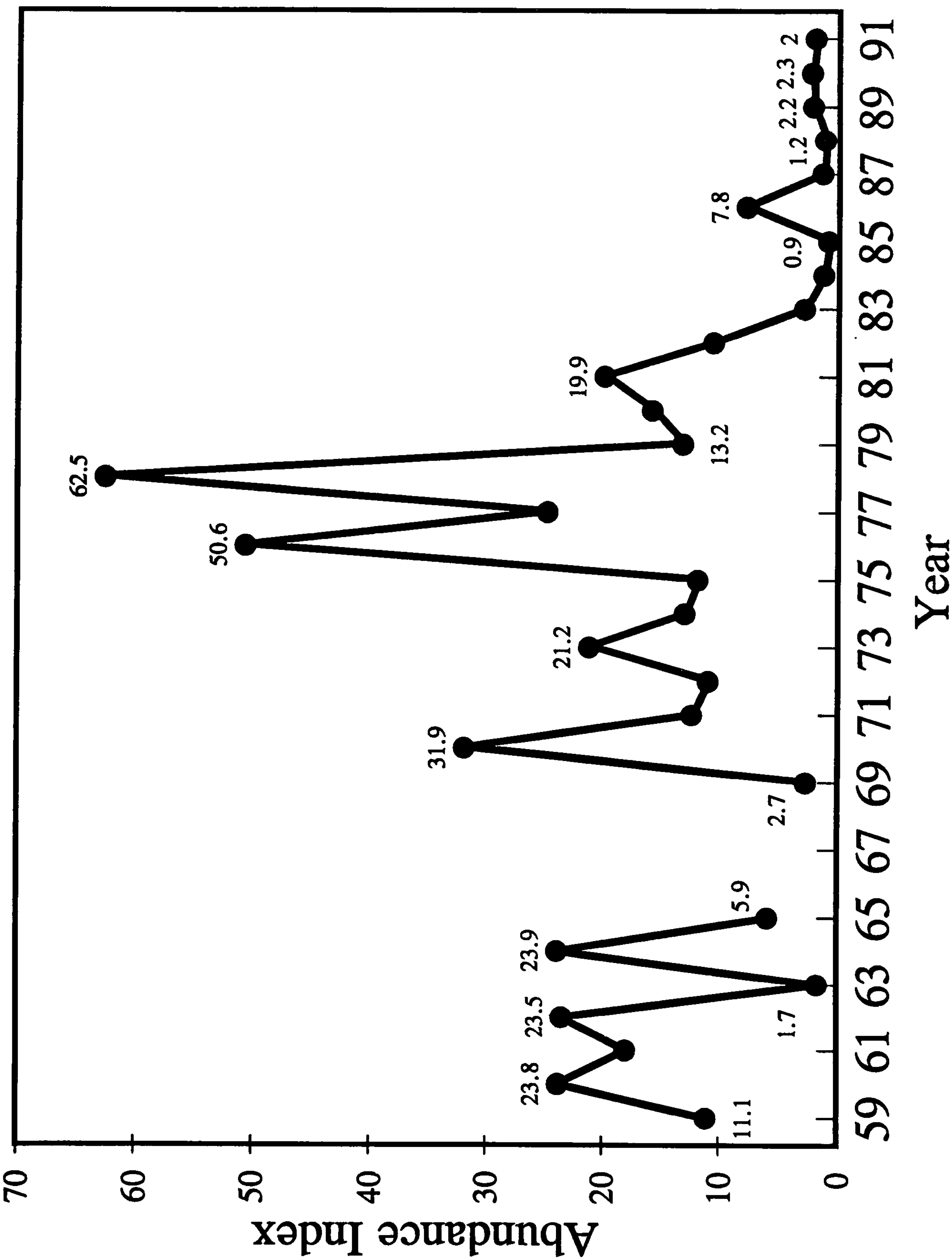

Figure 6. Summer townet abundance index for delta smelt in the Sacramento-San Joaquin Estuary for 1959-1965, 1969-1991. Only surveys 1 and 2 were used.

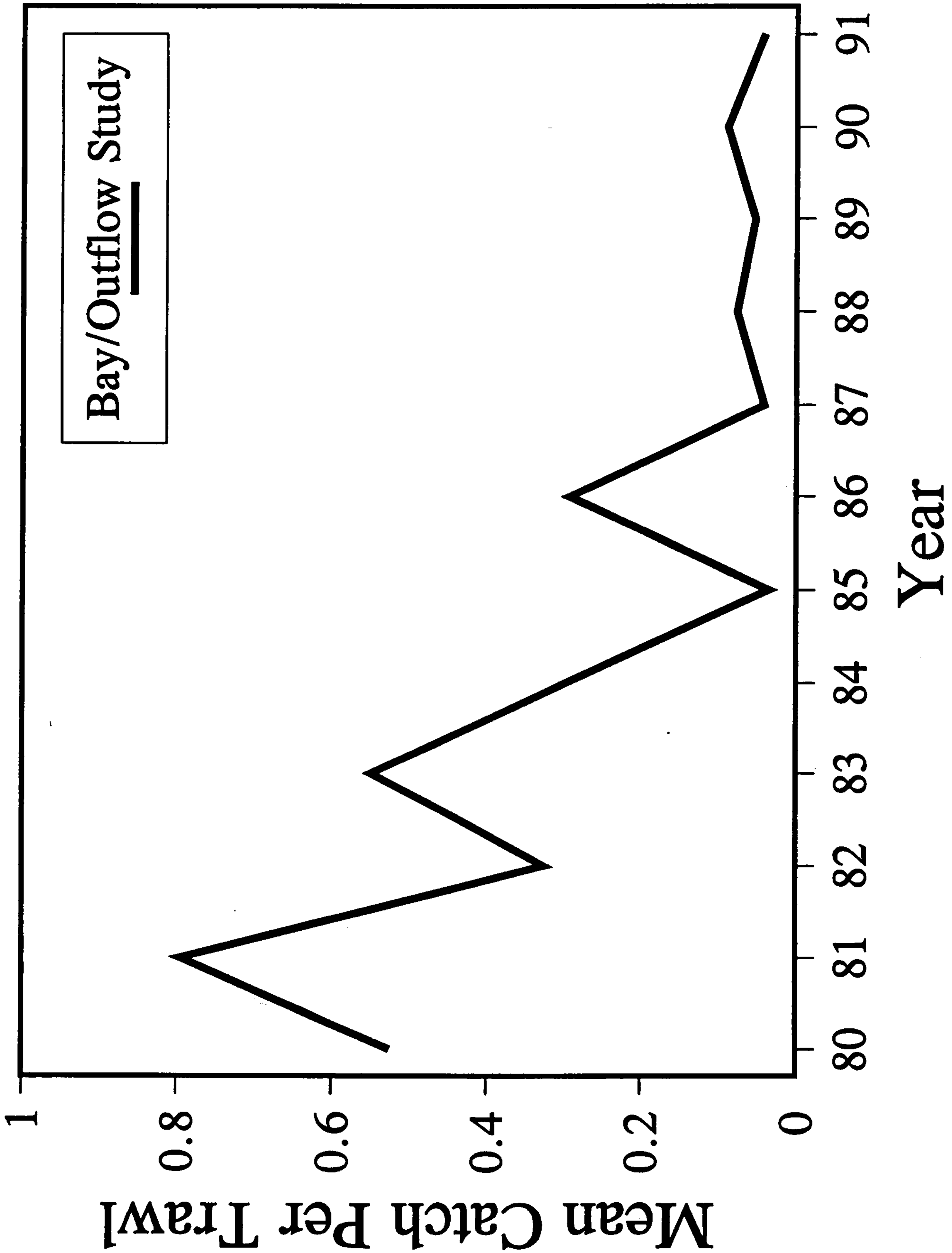

Figure 7. Mean-catch-per-trawl of delta smelt from the Delta Outflow/San francisco Bay Study 1980-1991.

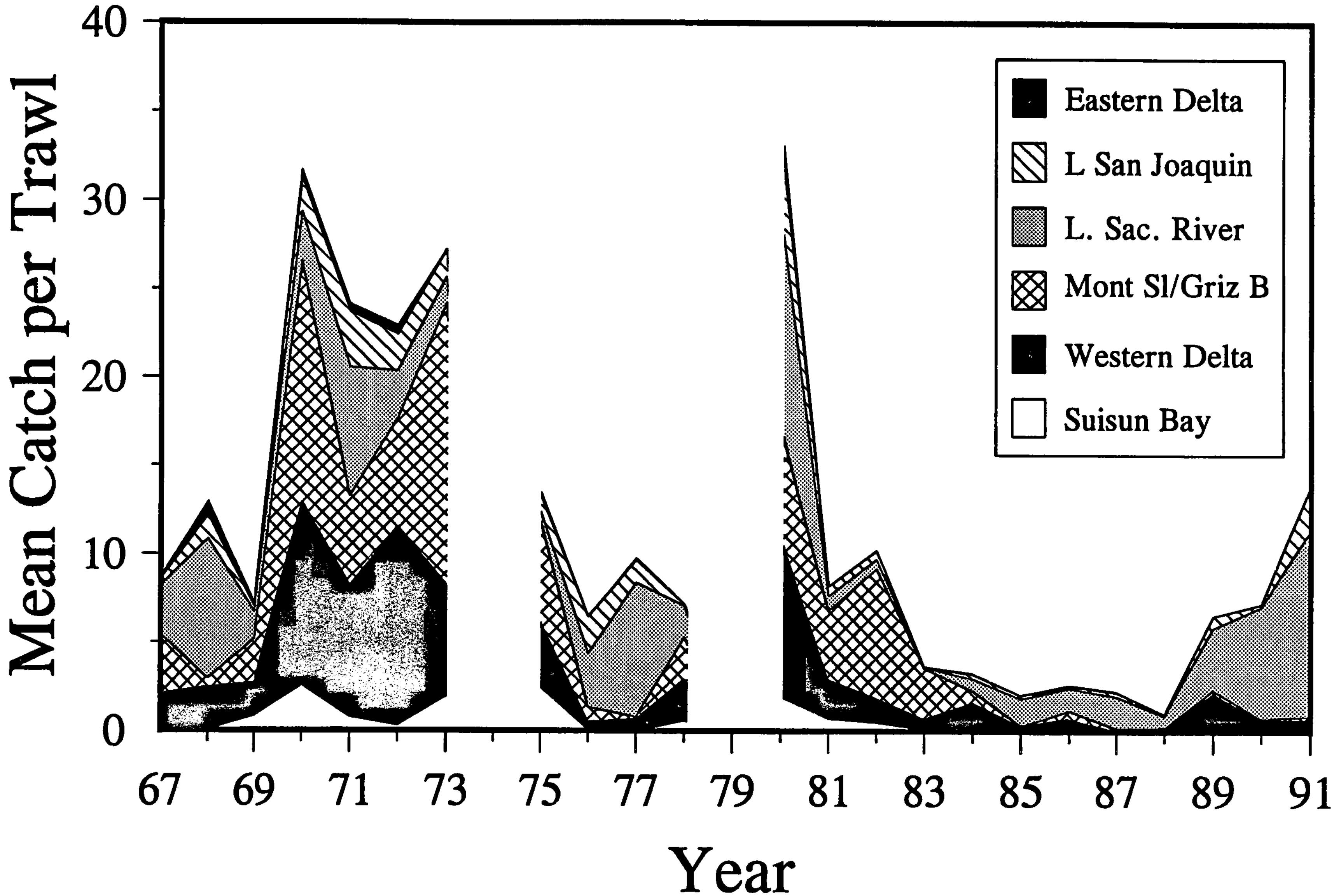

Figure 8. Mean catch per trawl from the fall midwater trawl survey for specific areas of the Sacramento-San Joaquin Estuary. Areas represent annual mean catch per trawl for specific areas in the Estuary.

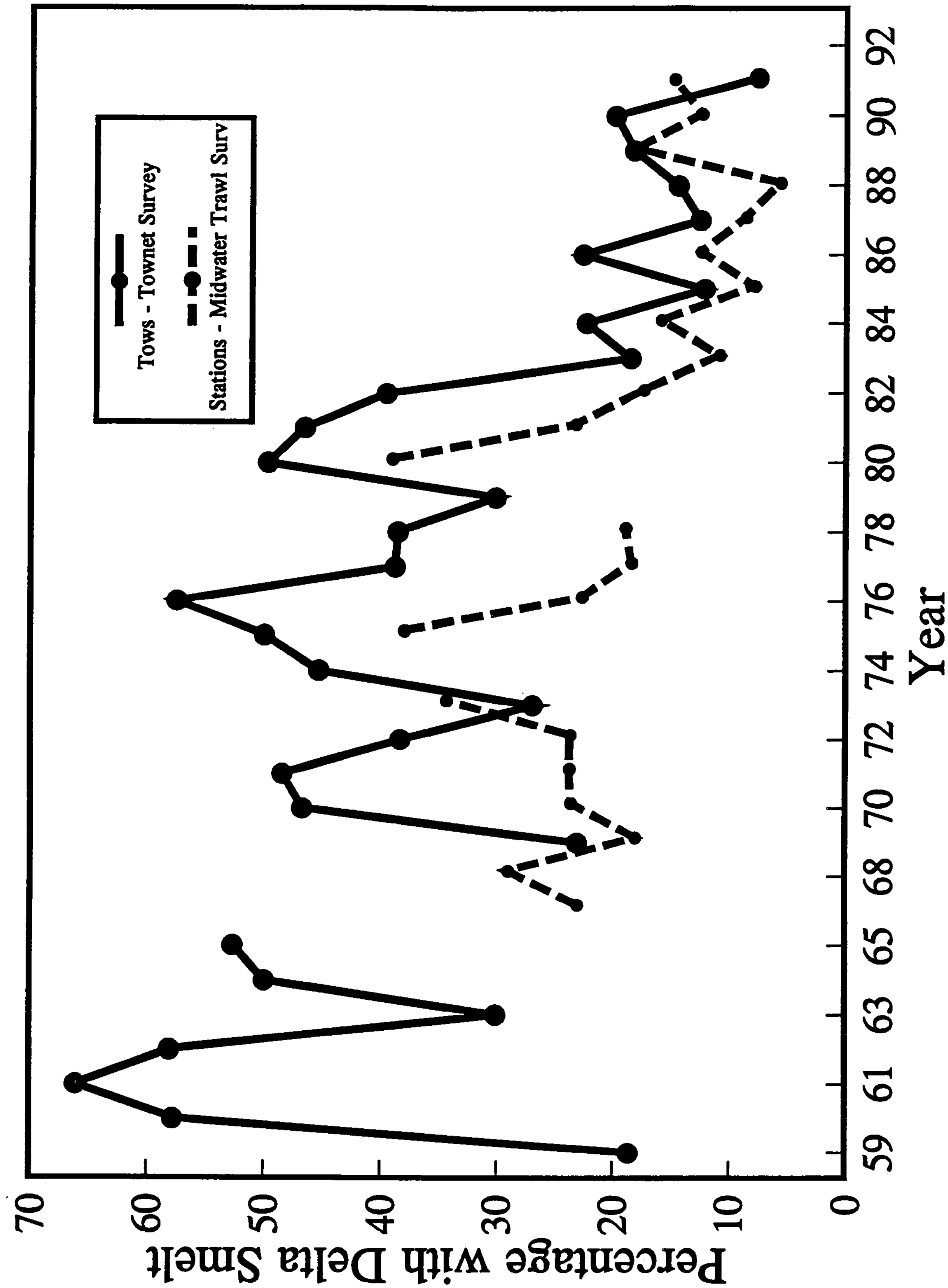

Figure 9. Percent catch of delta smelt in townet and midwater trawl surveys. Townet values represent percent occurrence in all tows in the 1st and 2nd surveys. Midwater trawl values represent percent occurrence at stations.

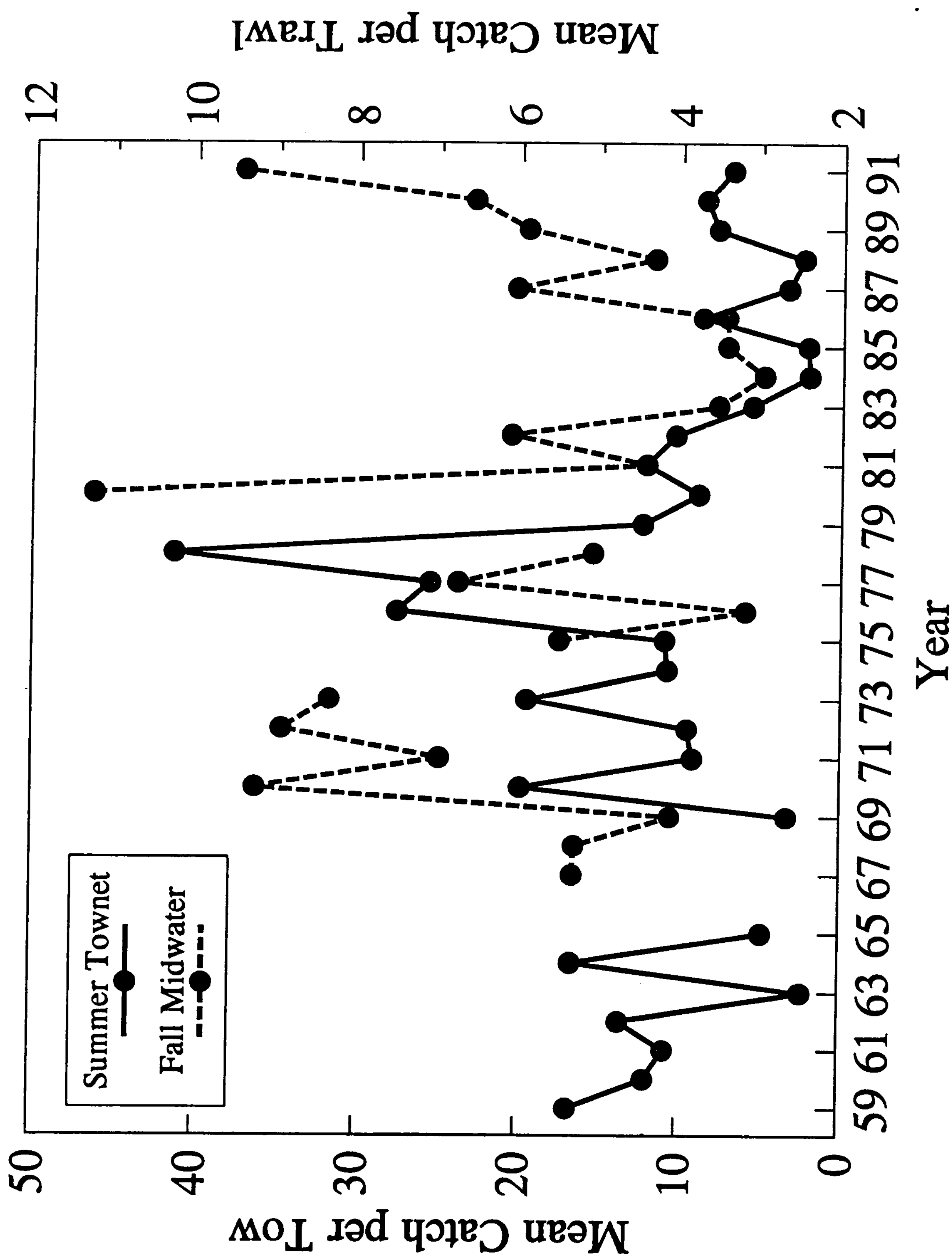

Figure 10. Mean-catch-per-tow/trawl for stations with delta smelt present. Townet data represents mean catch per tow with delta smelt present for surveys 1 and 2 (left axis). Midwater trawl data represents mean catch per trawl for stations with delta smelt present (right axis).

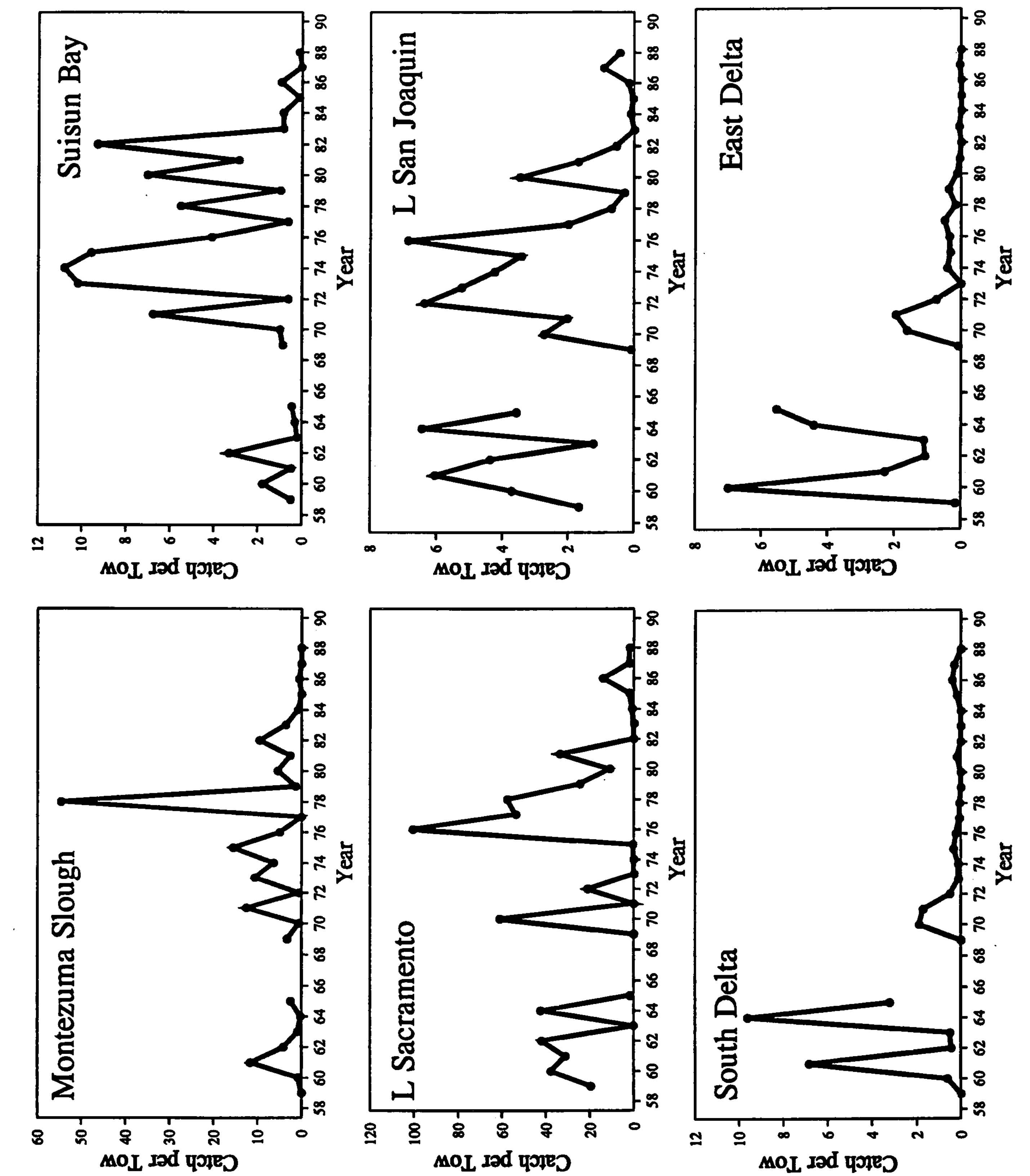

Figure 11. Abundance of delta smelt by area based on the summer townet survey. L. Sacramento is the Sacramento River between Collinsville and Rio Vista. L. San Joaquin is the San Joaquin River between Antioch and San Andreas shoal west of the Mokelumne River.

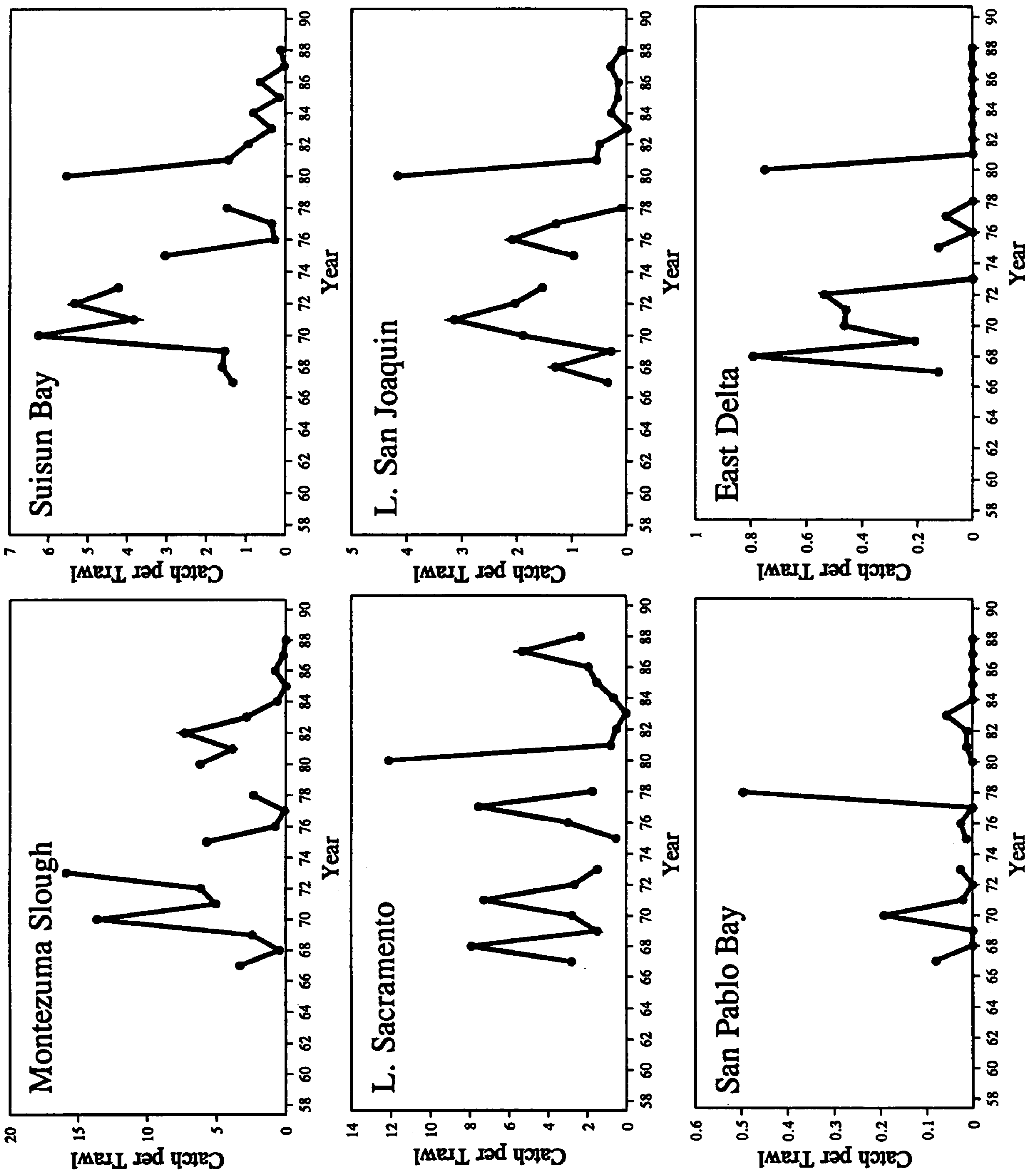

Figure 12. The catch-per-trawl of delta smelt in the midwater trawl survey by areas comparable to those used by the summer townet survey (Figure 11) except for the addition of San Pablo Bay and the South Delta which was not sampled after 1975.

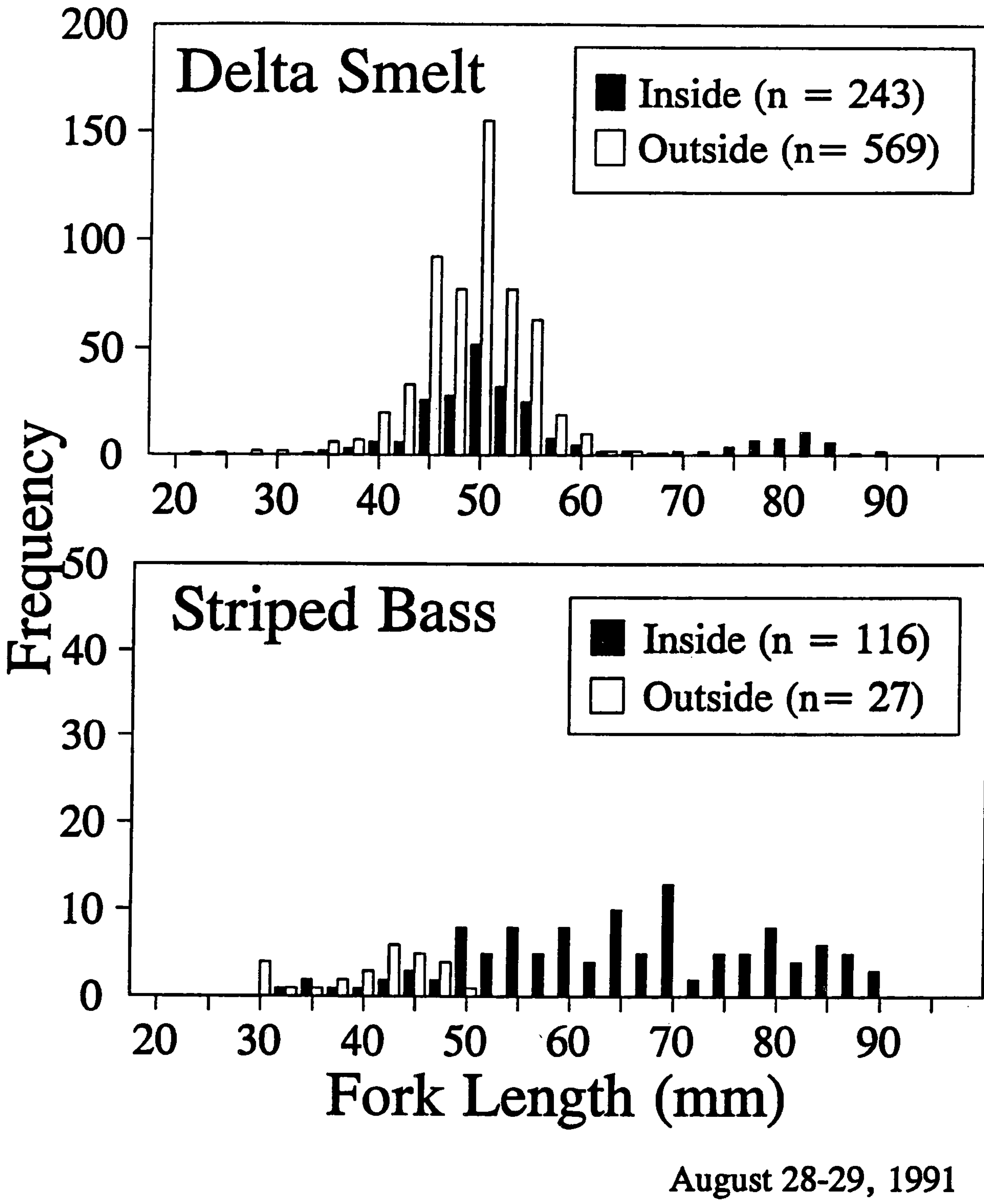

Figure 13. Length-frequency distributions for a.) delta smelt and b.) striped bass in a midwater trawl net evaluation study, August 28-29, 1991. Solid "inside" bars represent fish captured in the standard 1/2 inch midwater trawl codend, open "outside" bars represent fish captured in the 1/8th inch bobbinnet cover. A total of eleven tows were used. Only young-of-the-year striped bass < 100mm FL were used.

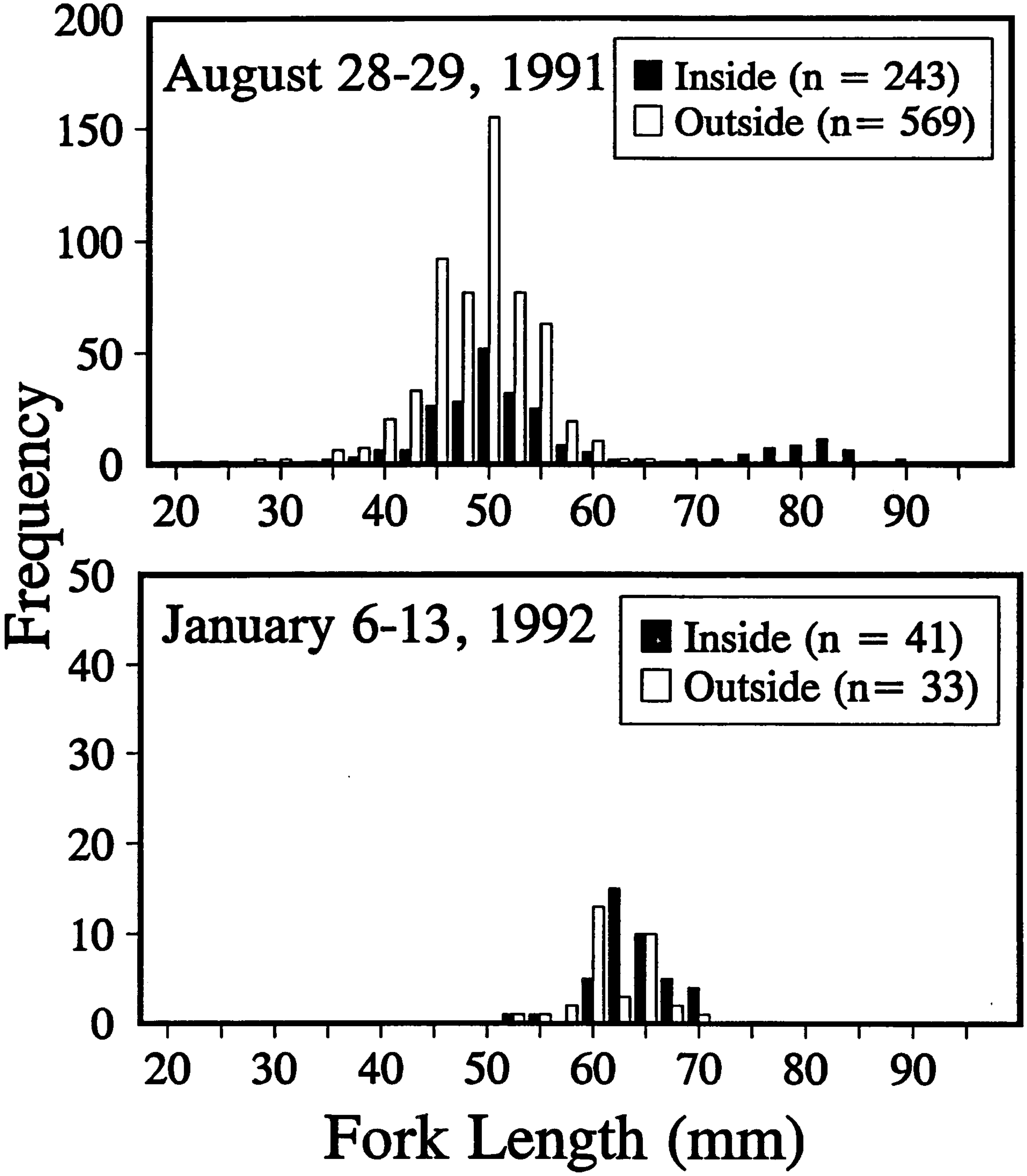

Figure 14. Comparison of length-frequency distributions of delta smelt captured a.) August 28-29, 1991 and b.) January 6-13, 1991. Solid "inside" bars represent smelt captured in the standard 1/2 inch stretch-mesh midwater trawl codend, open "outside" bars represent smelt captured in the 1/8th inch bobbinnet cover. Mean fork lengths (mm): a.) August 28-29, 1991 "inside" = 56.2 $\pm$ 12.9 sd, "outside" = 50.1 $\pm$ 5.2 sd; b.) January 6-13, 1992 "inside" = 64.9 $\pm$ 3.7 sd, "outside" 62.9 $\pm$ 3.6 sd.

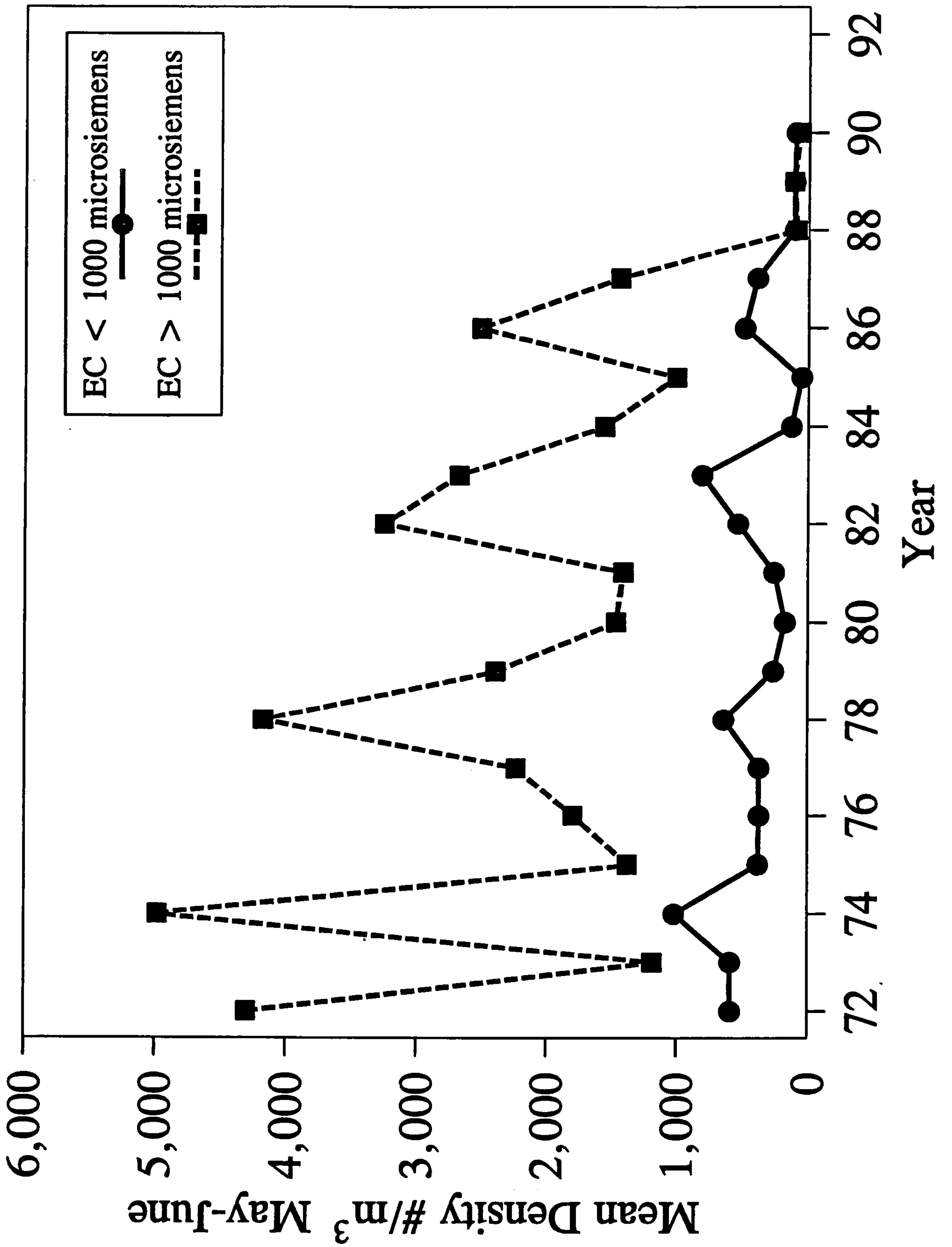

Figure 15. Mean density of Eurytemora affinis per m^3 in the Estuary during May and June. Data is from the zooplankton study.

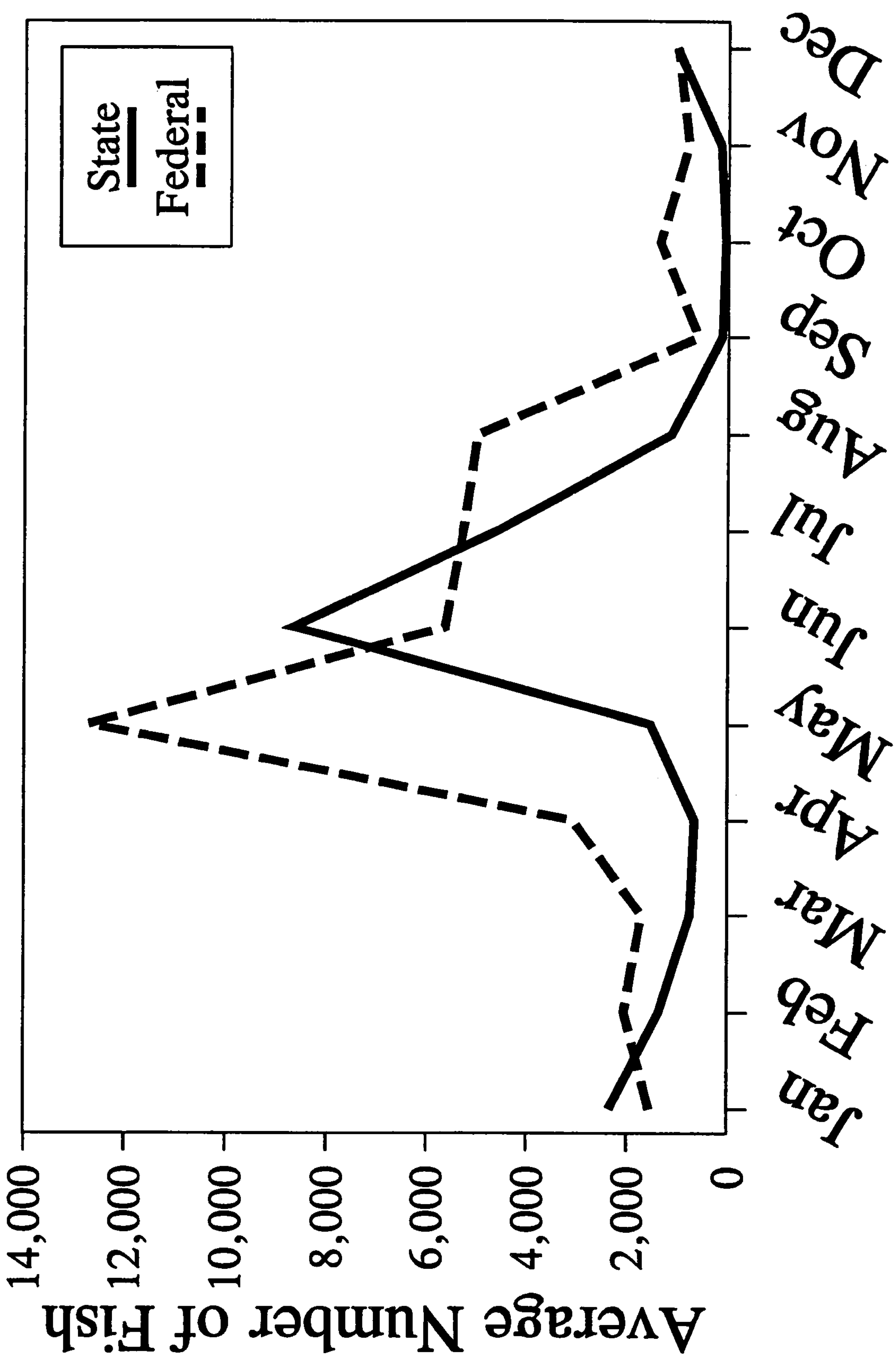

Figure 16. Monthly averages of the estimated adult delta smelt salvage at the State and Federal Water Project diversions from 1980-1990.

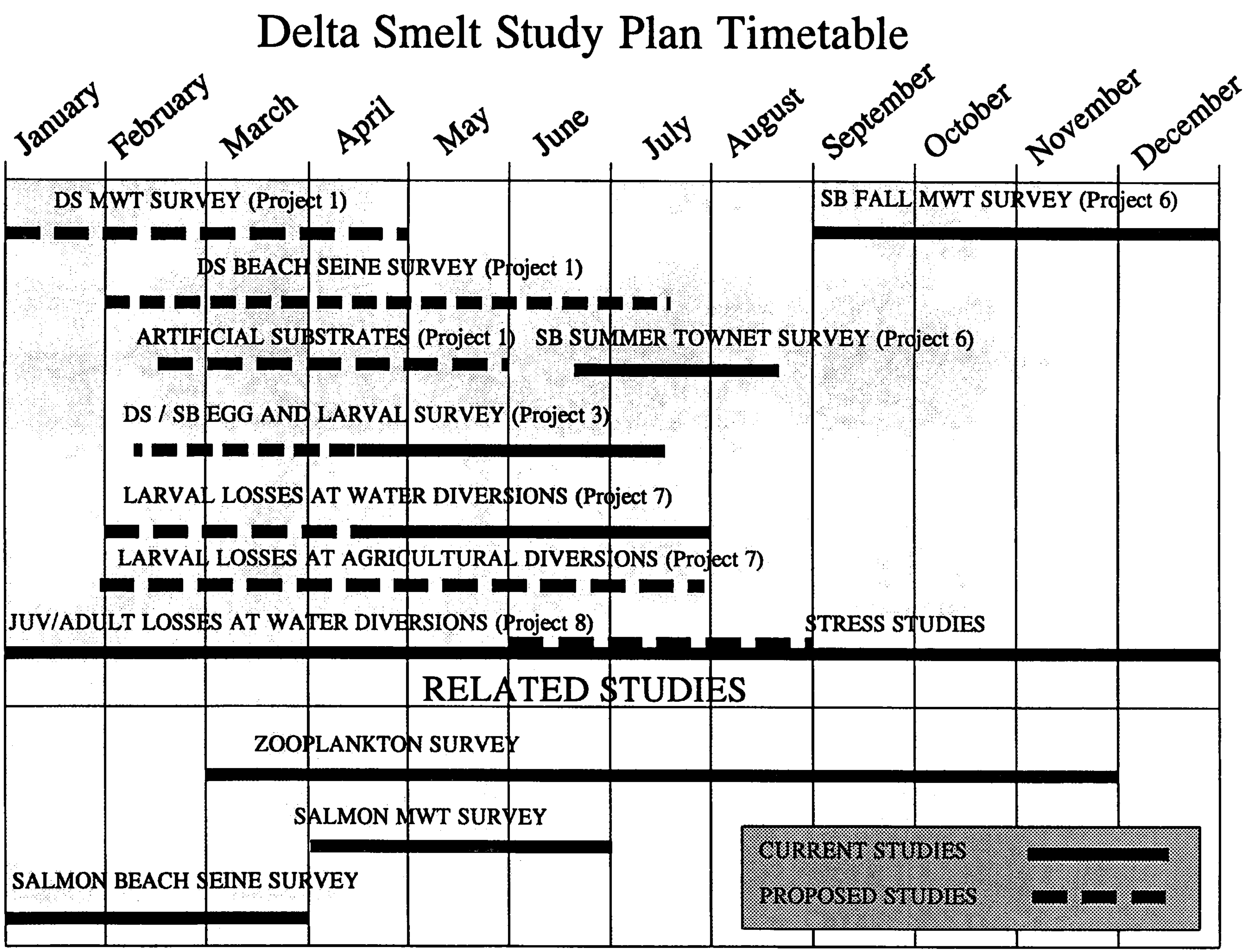

Figure 17. Timetable of field sampling for delta smelt study. *Current studies are presented in solid lines, proposed studies in dashed lines.*

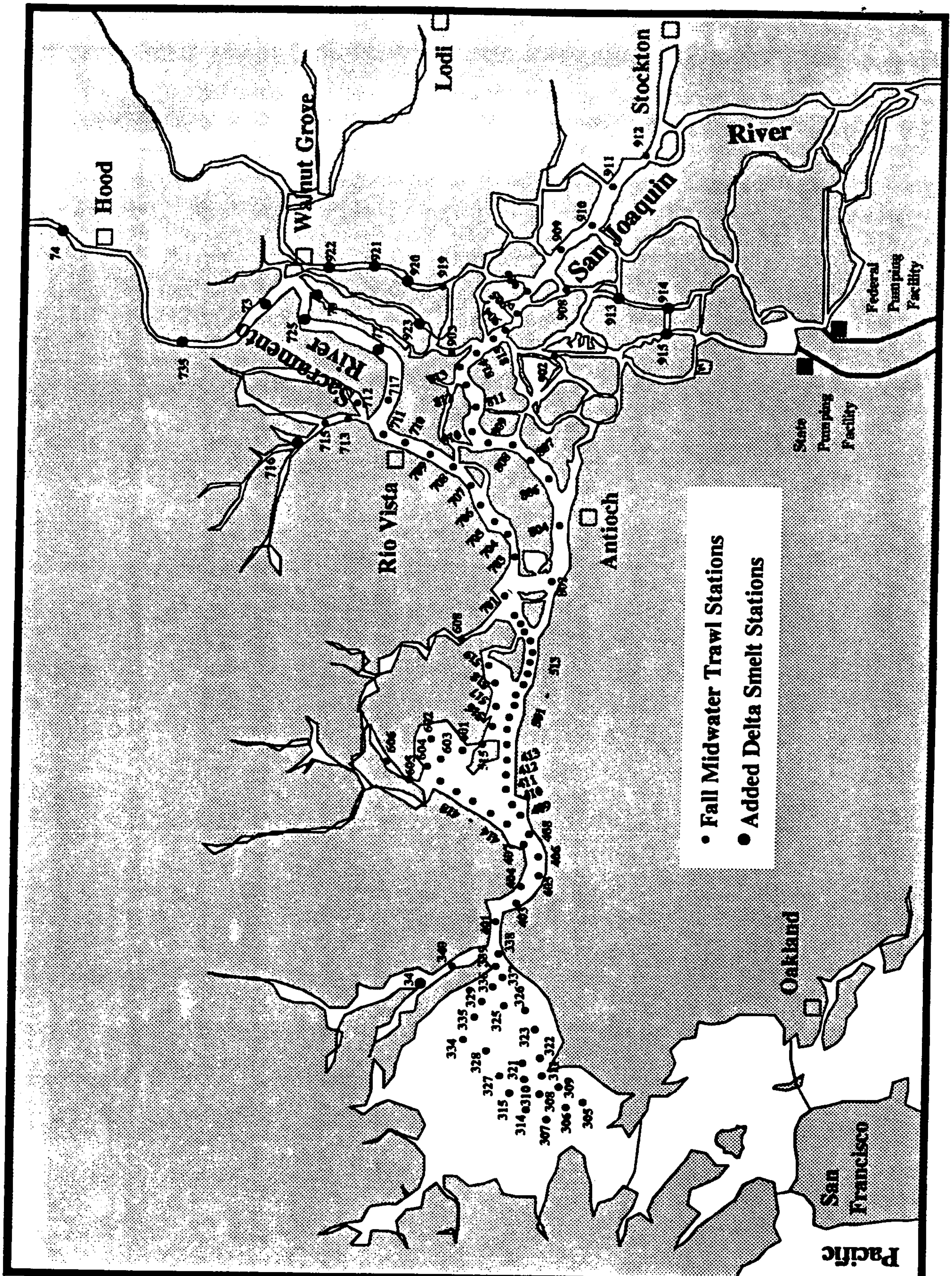

Figure 18. CDFG delta smelt midwater trawl stations for 1992. Current fall midwater trawl stations •, added delta smelt stations o .

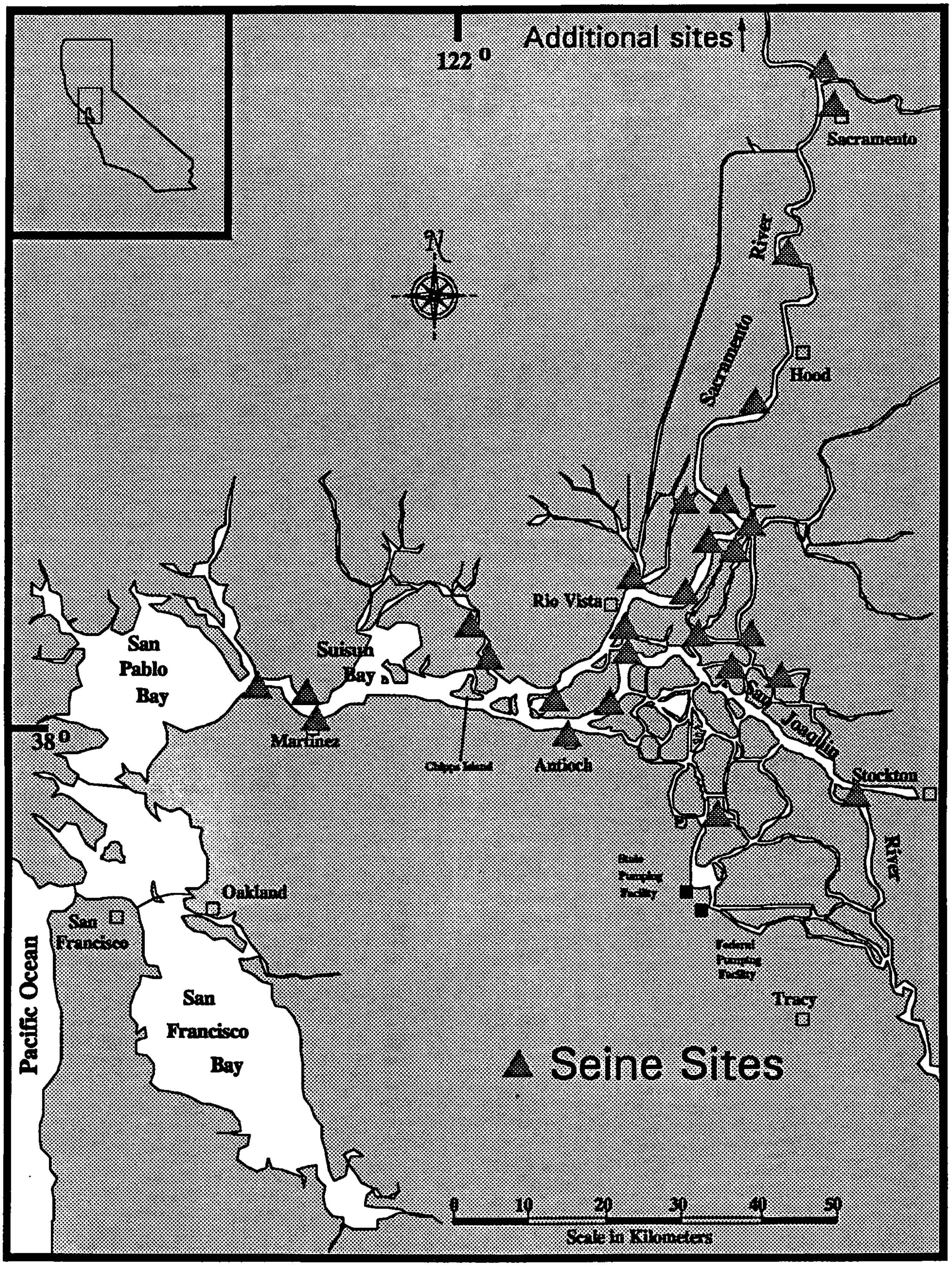

Figure 19. Beach seine recovery sites for delta smelt seine survey run in conjunction with the Interagency salmon fry studies. There are additional sites on the upper Sacramento River which do not appear on this map.

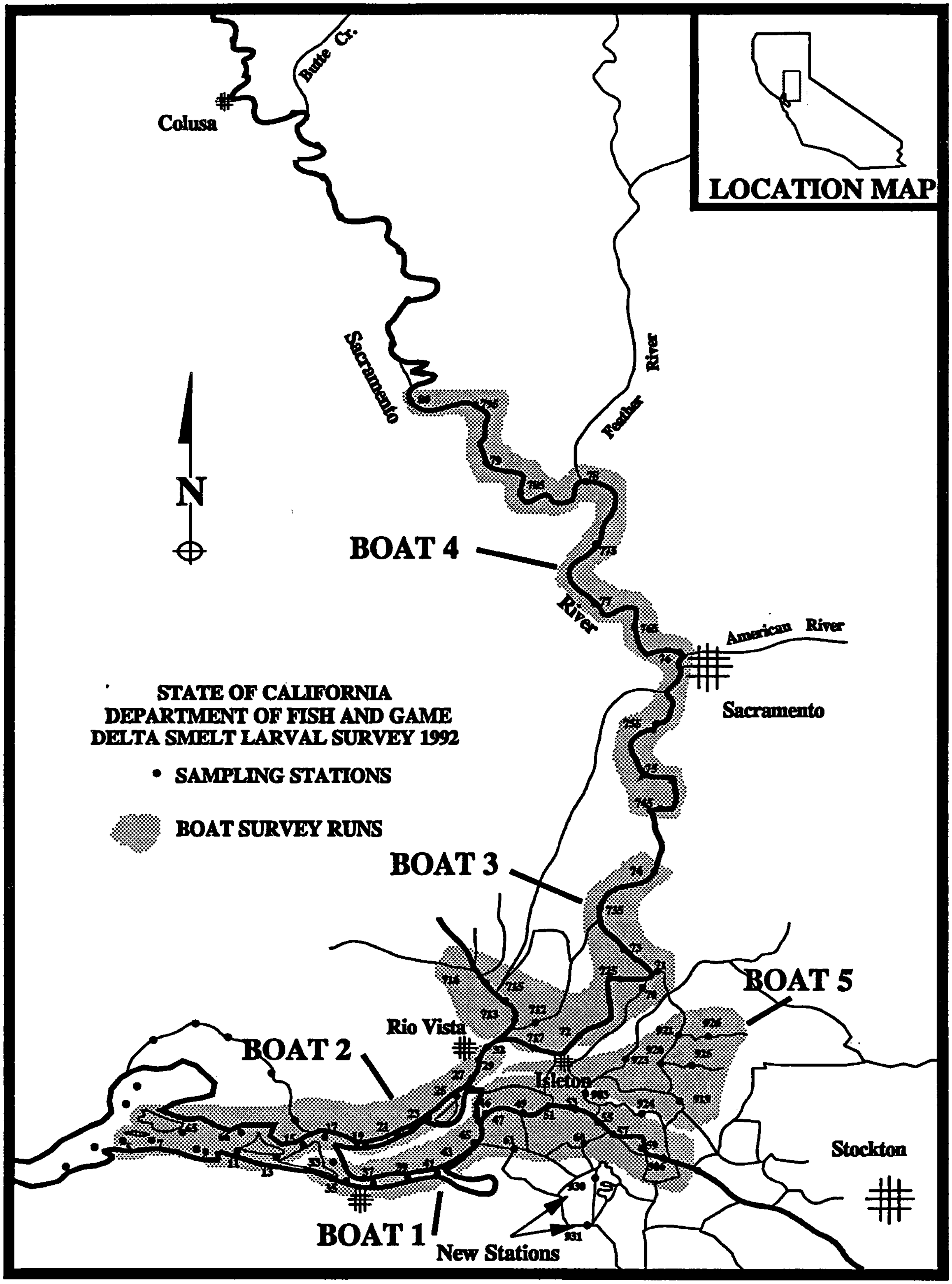

Figure 20. Delta smelt larval survey stations for 1992. Sampling is done every fourth day until late March when every other day sampling will commence for certain runs.