DWR 1995a.

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APPENDIX - 2

INFORMATION RELATIVE TO THE PROPOSED LISTING OF SACRAMENTO SPLITTAIL

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February 21, 1995

Executive Summary

This report summarizes data from the 1994 CVP/SWP Biological Assessment and additional recent studies which are relevant to the proposed listing of Sacramento splittail. The major conclusions include the following:

Evidence That the Splittail Population is Not in a State of Decline

- There is some indication that production of young splittail in the estuary may have been reduced in the late 1980s, but recent data from a number of surveys suggest that recruitment improved in recent years. The FWS beach seine survey, which provides the broadest coverage of the splittail range, shows that 1992-1994 abundance was as good or better than "pre-decline" levels.

- Four abundance indices developed for diverse regions of the estuary provide no evidence that there has been a decline in the number of adult splittail.

- In contrast to the other adult indices, the Suisun Marsh and Chipps Island surveys showed a major decline after 1980 followed by little or no resurgence since then. This suggests that the Suisun Marsh/Chipps Island population may be regulated by other factors (or to a greater degree) than those in other regions. However, the fact that recent Chipps Island indices are comparable to abundance levels observed before the "decline" (1976-1977) raises questions about whether splittail are in a consistent state of decline in this region. Moreover, even if a decline has occurred, two independent surveys suggest that splittail presently remain relatively abundant compared to other fish species in the Suisun Marsh/Chipps Island region.

- There is no indication from the period of record that a reduction in the number of spawners influences the ability of the stock to recover. There was no "stock-recruitment" relationship for any survey except Chipps Island, for which the correlation was relatively weak. The species is long-lived and has a high fecundity, allowing the population to respond quickly when environmental conditions improve.

Evidence that the Distribution of Splittail is Wider Than Suggested by FWS

- Data from recent surveys show that the splittail are present at least seasonally in a number of Central Valley tributaries. The species is clearly not "largely confined to the Delta, Suisun Bay, Suisun Marsh and Napa Marsh".

- Suisun Bay does not appear to be the center of the range of splittail, but rather is a component of a broader core of distribution.

Factors Affecting Splittail Abundance

- The 6-year drought appears to be the major cause of recent low abundance levels of young splittail in the estuary based on a strong correlation with delta outflow. However, abundance is also well-correlated with the duration of floodplain inundation, which may provide a large amount of additional spawning, rearing and foraging habitat in wet years. Except for 1993 and the present water year, little flooding has occurred in the range of splittail since 1986, perhaps leading to a series of weaker year-classes in the estuary.

- If incremental levels of outflow are more important to abundance than floodplain inundation, the December 15, 1994 Cal-Fed agreement should enhance splittail population levels. If floodplain inundation is more critical, abundance trends will continue to depend on the frequency of uncontrolled flows in extreme wet years, unless methods are developed to artificially flood riparian and terrestrial habitat in other year types.

- Although hydrology appears to be important to the production of young splittail in the estuary, FWS beach seine data and recent egg and larval analyses show that spawning can be successful in many areas in the Sacramento and San Joaquin rivers and the northern and central Delta in both wet and dry years.

- Despite a correlation between the position of 2 ppt salinity and splittail abundance, splittail do not appear to be "adapted for life in the entrapment zone". Analyses of the distribution and physiology of splittail indicate that they occupy and tolerate a broad range of salinities.

- Salinities during recent years in Suisun Bay, the lower range of splittail distribution, were within levels tolerated by this species.

- There is no evidence that entrainment loss at pumping plants is a primary factor influencing splittail abundance. Analysis of salvage data demonstrates that entrainment increases primarily when large numbers of splittail are present in the system.

Introduction

In January 6, 1994 of the Federal Register, U.S. Fish and Wildlife Service proposed listing the Sacramento splittail (*Pogonichthys macrolepidotus*; Family: Cyprinidae) as "Threatened" under the Endangered Species Act. The rationale for the Proposed Rule is threefold: 1) splittail abundance has declined; 2) splittail distribution has become restricted; and 3) the splittail population faces a number of serious threats. However, on January 10, 1995 FWS extended the deadline for action on this proposal and reopened the comment period based on "substantial disagreement regarding sufficiency or accuracy of the available data".

A recent report prepared by California Department of Water Resources and U.S. Bureau of Reclamation (1994), "Biological Assessment, Effects of the Central Valley Project and State Water Project on Delta Smelt and Sacramento Splittail", contains a substantial amount of new information and analyses related to the proposed listing. Additional analyses on splittail abundance trends have also been performed following the completion of the Biological Assessment. This information was originally summarized in a report to FWS (DWR 1994), however the analyses have since been updated. The key information relative to the rationale for listing is summarized below.

Trends in Splittail Abundance

A number of data sets were analyzed in the Biological Assessment to determine abundance trends of different age classes of splittail. Key databases analyzed include the CVP and SWP salvage operations, FWS beach seine survey, UC Davis Suisun Marsh survey, Delta outflow/San Francisco Bay survey, summer townet survey and fall midwater trawl survey. A complete discussion of sampling and data analysis techniques for these surveys is provided in the Biological Assessment (Attached).

Since the completion of the Biological Assessment, an additional data set, the Chipps Island survey, was analyzed. The methodology for the survey and data analysis was not included in the Biological Assessment, but is briefly described here. The Interagency Ecological Program's annual midwater trawl surveys at Chipps Island, in upper Suisun Bay, are conducted primarily to capture experimentally-released coded-wire-tagged salmon, but they also estimate abundance of outmigrating salmon. The survey was consistently conducted May through June since 1976, although additional months have been sampled in some years. Age classes of splittail captured incidentally in the trawl were separated using the same monthly length-frequency criteria developed from SWP salvage data. Annual abundance indices were calculated as the total catch of each age class captured during May and June divided by the hours sampling effort.

In addition to the development of abundance indices from the Chipps Island trawl, the FWS beach seine database was updated with 1994 data and the number of stations was increased to provide greater coverage of the range of splittail. The additional stations were the American River (AM001S) and Venice Island (SJ026N), bringing the total number of sites used in the index to 21. Despite the availability of splittail data from numerous sampling sites in the system, the value of this database has been questioned because of some sampling gaps (Lesa Meng, FWS, pers. comm). Appendix A summarizes the years in which May and June samples were collected by the beach seine at the core stations. The primary limitation of the database is that 1985-1991 is not covered, so we have no indication of abundance levels for that period. However, the remainder of the database is reasonably complete with respect to the core stations, providing a valuable comparison of "pre-decline" and recent abundance levels. With the exception of the 1985-1991 period, the gaps in the beach seine database are comparable to those in the Suisun Marsh database (see Appendix C of the Biological Assessment), one of the most valuable sources of information about splittail.

The results of the analyses for all data sets are summarized in Figures 1 and 2 for young-of-the-year and adult splittail, respectively. Although these figures represent the best available abundance data for splittail, it should be recognized that each database has limitations. Due to these limitations, abundance trends should be examined concurrently with different estimates rather than focusing on individual indices. More weight should be given to results from the salvage facilities, FWS beach seine, Chipps Island and Suisun Marsh surveys because adequate numbers of splittail were captured, however the other surveys provide valuable data on long-term abundance trends in other parts of their range.

Young-of-the-Year

In their proposed rule, FWS suggests that splittail abundance has declined by 62 percent since 1984. Analyses in the Biological Assessment confirm that young-of-the-year abundance appears to have declined in the estuary during the first part of the recent six-year drought (Figure 1). However, most surveys showed at least a modest improvement in young of the year abundance by the early 1990s. Of particular significance is the FWS Beach Seine survey, which provides the broadest coverage of the range of splittail including stations upstream of the Bay-Delta estuary. The 1993 index was the second highest recorded for all years including the "pre-decline" period (1978-1982). The 1992 and 1994 indices, both critically dry years, are higher than the two comparable dry years (1979 and 1981) in the period before abundance is reported to have decreased . Although not shown in Figure 1, limited beach seine sampling in 1976 and 1977 indicates that abundance levels of splittail were even worse in these two dry years than 1979 or 1981. These results suggest that recent production of YOY splittail in upstream rearing areas is comparable to the "pre-decline" period and is perhaps even stronger.

Adults

FWS had only limited data on adult splittail abundance trends in its preparation of the Proposed Rule. However, FWS reasoned that reduced production of young splittail during recent years may have affected the stock's ability to recover. We developed six different adult abundance indices to examine this issue (Figure 2). Four of the surveys show no evidence that adult abundance has declined. In fact, 1993 levels of adults appear relatively high compared to other years for these surveys.

Although Suisun Marsh and Chipps Island surveys both show a decrease after 1980, it is unclear whether this represents a "decline" or a return to more "normal" levels. The Chipps Island indices in 1976, 1977 and 1979 are comparable to abundance levels following the "decline" of splittail. It is therefore possible that the peak abundance indices in 1978 and 1980 were exceptionally high compared to longer-term population levels. The "decline" of the species in later years may simply be the gradual mortality of these strong year classes. Given the strong similarity between the Suisun Marsh and Chipps Island trends and the proximity between the sampling locations, it is also possible that abundance levels in 1978 and 1980 were also unusually high in Suisun Marsh. As evidence that Suisun Marsh and Chipps Island trends are linked, correlation analyses demonstrate that the indices for 1979-1993 show a highly significant relationship ($r = 0.87$ $p<0.01$).

It is also important to note that even though adult abundance in Suisun Marsh is clearly lower than peak 1980 levels, Department of Fish and Game gillnet surveys in Montezuma Slough suggest that adult splittail remain abundant relative to other fish species. Since 1988, adult splittail have been either the first or second most abundant species captured by gillnets in this region of Suisun Marsh, with no indication of a decline in catch per unit effort (Figure 3). Monthly surveys by PG&E (1992) at sites near Chipps Island confirm that splittail are relatively abundant. Sampling using gillnet, otter trawl, fyke net and beach seine methods during 1991 and 1992 showed that splittail were the second most abundant species based on composite catch.

Based on the above discussion, it is not clear whether splittail are in a consistent state of decline at Suisun Marsh and Chipps Island. However, abundance trends are obviously different than other regions of the estuary. This difference suggests that the Suisun Marsh/Chipps Island population is controlled by other factors, or is affected to a greater degree by a few factors, than splittail in other regions. The major factors affecting splittail abundance in this region remain to be identified.

Although most of the abundance indices indicate that the number of spawners has not declined, there is some evidence that reduced production of young splittail may lead to a small reduction in the number of adults. As shown in Figure 4, there are statistically significant relationships ($p<0.05$) between young-of-the-year indices and the number of adults observed two years later for the SWP, Bay-Delta outflow otter trawl and Suisun Marsh. However, it must be emphasized that these are not 1:1 relationships. For example, a 50 percent reduction in young-of-the-year does not result in a comparable decrease in the adult splittail index two years later; the observed decrease in the adult index is much smaller. This suggests that the adult population is buffered against changes in young splittail. The multi-year age structure of the adult population is likely to be a key mechanism that reduces the effects of poor year classes on the population.

The relationships shown in Figure 4 also suggest that a number of the indices developed for the Biological Assessment are valid indicators of year class strength. The fact that the young-of-the-year indices for the SWP, Bay/Delta outflow study and Suisun Marsh each showed detectable relationships with adult levels two years later suggests that these abundance estimates are not spurious.

Finally, there is evidence that a reduction in the number of spawners does not appear to have influenced the ability of the stock to recover. The "stock-recruitment" relationships shown in Figure 5 demonstrate that there is no correlation between the number of spawners and the production of young-of-the-year in a given year for all surveys except Chipps Island. The Chipps Island relationship is only marginally significant at the $p<0.05$ level and appears to be driven by just one or two data points. If the high young-of-the-year index in 1978 is ignored, the relationship is no longer statistically significant ($r^2=0.17$, $p>0.05$). As a specific example, 1983 had one of the lowest Year 2+ Chipps Island indices on record, yet had the third highest young-of-the-year index. The most likely reason for these observations is that the species is long-lived and has a high fecundity, allowing the population to respond quickly when conditions improve.

Summary

While the number of young splittail in the estuary may have declined over the six-year drought, some recent data suggest that recent levels have improved. In upstream areas, beach seine results indicate that recent young-of-the-year abundance levels are similar to, or perhaps greater than, "pre-decline" levels.

Adult abundance trends also indicate that the number of spawners has not declined except in the region of Suisun Marsh and Chipps Island. Even in the Suisun Marsh/Chipps Island region, splittail remain the second most abundant fish captured by recent DFG and PG&E surveys. Therefore, the ability of the population to recover does not appear have been compromised by the recent drought or by other conditions during the past decade. The previous year (1993) is a case in point. The year 1993 followed six successive years of drought, yet adult abundance indices were fairly strong in most surveys. Production of young-of-the-year also appears to have been substantial in 1993 based on high catches in the FWS beach seine.

Splittail Distribution

In the 1994 Proposed Rule, FWS observes that "..the species is now restricted to a small portion of its former range". The original range was reported to extend "as far north as Redding on the Sacramento River, as far south as the present-day site of Friant Dam on the San Joaquin River, and as far upstream as the current Oroville Dam sites on the Feather River and Folsom Dam site on the American River. The 1994 Proposed Rule states that "it is now restricted to western, northern and southern portions of the Delta" with Suisun Bay as the "center of its distribution" One of the major concerns is that a restricted range may make splittail vulnerable to extinction if stochastic events occur.

Paradoxically, the 1994 Proposed Rule asserts that "splittail are adapted for life in the entrapment zone", the freshwater/saltwater mixing zone historically located in the Suisun Bay of the estuary. The wide historical range of this species appears incompatible with the stated requirement for brackish water habitat.

In the recent 1995 Proposed Rule an additional issue was raised--the possibility that a resident population occurs outside the Delta. If such a population occurs, it could help to stabilize the species against catastrophic events. However, even if resident splittail are discovered upstream of the Delta, it will be difficult to demonstrate that these individuals are distinct from the remainder of the population. A more important question with respect to the proposed listing is whether the overall range of the species has become restricted. The results described below indicate that the range of juvenile splittail remains widespread. The situation with respect to adults is more complicated because they change their distribution seasonally for spawning, however there is no evidence that there has been a recent constriction of range.

Range of Splittail Distribution

The primary reference used by FWS to describe the historical range of splittail is a report by Rutter (1908). His data suggest that splittail were found as far north as Redding on the Sacramento River, as far south as present-day site of Friant Dam on the San Joaquin River, as far upstream as the current Oroville Dam site on the Feather River and the Folsom Dam site on the American River. However, Rutter provides no indication of splittail ages or month of year for each collection site . Without this information, we cannot definitively compare the present to the historical range for the complete life cycle of splittail. In analyzing the distribution data, the range was assumed to include any recent collection of splittail in a given area regardless of age class or month.

Data from recent surveys show that the range of splittail still includes most of the major Central Valley tributaries. Splittail have been collected in the American River (Hanson Environmental 1991), Tuolumne River (Tim Ford, Turlock Irrigation District, Unpublished data; Moyle et al. 1993), the San Joaquin River as far south as Laird Park, and the Mokelumne River (DFG 1991). Additionally, splittail have been caught in the Sutter Bypass off of the Sacramento River (Jones and Stokes 1994), Petaluma Marsh (SWC 1994) and the Napa River (DFG 1989), . We are not aware of any recent surveys of the species composition of the Feather River, so its presence there remains uncertain.

Results of the FWS beach seine survey also provide evidence of the extent of splittail distribution. As shown in Figure 6, substantial numbers of young splittail were caught in upstream areas including the Sacramento River (representing the Sacramento River below Red Bluff Diversion Dam and the lower American River), northern Delta and central Delta through June 1993, a high outflow year. This indicates that significant spawning took place outside of the Delta (Baxter 1994a). The fact that there is no clear decrease in CPUE between April and June suggests that not all young-of-the-year were transported downstream by high spring streamflow in 1993--many young splittail appear to be rearing in upstream areas. In 1994 the survey collected splittail as far north as river mile 184 on the Sacramento River and river mile 74 on the San Joaquin River.

The broad distribution of splittail during 1993 is supported by preliminary egg and larval data, provided as Appendix B (from Wang, In preparation). The 1993 DFG survey results show that young splittail were distributed throughout the region between Suisun Bay, the Delta and the upper Sacramento River (above Verona). Appendix B includes additional results from the 1988-1994 period, although the available stations provide incomplete coverage before 1992. Like the beach seine results, egg and larval sampling shows that splittail spawning occurred upstream of the Delta in 1992 and 1994, both critically dry years. These observations conflict with the FWS conclusion that "the species now largely is confined to the Delta, Suisun Bay, Suisun Marsh and Napa Marsh".

Center of Distribution

The major evidence that Suisun Bay is the center of the distribution splittail is an analysis by Meng (1993), who found that catch of splittail in the fall midwater trawl and Bay/Delta outflow study midwater trawl peaks in this region (Figure 7). However, these two surveys do not sample important upstream areas. As described above, FWS beach seine results demonstrate that large numbers of young splittail are present in areas upstream of Suisun Bay. In 1993 the young-of-the-year catch in upstream areas was one of the highest recorded, yet the fall midwater trawl abundance was modest (Figure 1).

None of the routine Delta sampling programs cover the complete range of adult splittail, so long-term distribution patterns of older splittail are poorly understood. However, in August 1994 an intensive gillnet survey was conducted by DFG, in cooperation with DWR, Metropolitan Water District of Southern California, Kern County Water Agency, and the State Water Contractors, as part of Interagency Ecological Program studies (Baxter 1994b). Nighttime sampling was performed over a two-week period in the upper Sacramento River (below Red Bluff Diversion Dam), north Delta, west Delta, central Delta, south Delta, Suisun Marsh and Suisun Bay. Initial results suggest that the center of distribution during August 1994 extended from Carquinez Strait through the western Delta. Suisun Marsh was not found to have higher abundance than other areas, but rather appears to be part of a broader area of distribution. Additionally, adult splittail were caught over a wide range of salinities, indicating that the species does not require brackish water habitat such as the entrapment zone.

Peak levels of adult splittail between Carquinez Straits and the western Delta does not imply they have become restricted to this region. The survey did not sample all of the potential habitat in upstream areas. Moreover, the survey is representative of the late summer months of a dry year only. Its range is probably widest during winter and spring, when adults migrate upstream to spawn. Figure 8 shows that the Year 2+ catch in the Suisun Marsh declines in spring as spawners leave the area. Coincidentally, the fish salvage facilities located upstream of in the south Delta show a peak in the number of adults during the spring, presumably on their spawning migration. Additional surveys are needed in other months and water year types to better describe the distribution of this species.

Resident Populations Outside of the Delta

Questions about whether resident populations of splittail occur upstream of the Delta are cited as one of the reasons that FWS extended the comment period on their proposed listing. This issue is difficult to address because there is relatively little data on adult splittail, and the distribution of this species shifts seasonally for spawning. Based on the timing of their spawning migration, evidence of adults in upstream areas during August-October would indicate the presence of a resident population.

The August, 1994 IEP gillnet survey is one of the most extensive surveys during this period (Baxter 1994b). As described previously, the survey found no evidence of splittail upstream of the Delta, although not all habitats were sampled.

Potential Threats to the Splittail Population

The Proposed Rule reviews a number a threats to splittail including drought, altered hydrology due to diversions, mortality at Delta diversions, reduction in the availability of brackish water habitat, loss of shallow water habitat to land reclamation actvities, urban and agricultural pollution and introduction of exotic species. The major findings from the Biological Assessment for the first four of these factors are discussed in the following sections.

Drought

The proposed rule observes that "successful reproduction in splittail is highly correlated with wet years". The Biological Assessment confirmed that there is a strong relationship between midwater trawl abundance and mean Delta outflow (Figure 9). The outflow relationship was also recently tested with two YOY additional indices, the SWP salvage (1979-1993) and the Bay-Outflow study otter trawl (1980-1993). Similar significant relationships were found ($p<0.05$), although the r^2 values were lower, perhaps as a result of the shorter period of record than the midwater trawl (SWP: $n=15$, $r^2=0.41$; Bay-Outflow:

n=14, r^2=0.56). There are also comparable relationships between abundance and Delta inflow, which is not surprising given the strong correlation between Delta outflow and Delta inflow.

Based on these results, it is not unexpected that reduced abundance levels of young splittail were observed during the recent drought (Figure 1). However, additional evidence from the Biological Assessment indicates that Delta outflow does not fully explain abundance trends throughout the system. Although high outflow years clearly benefit splittail, it is likely that abundance does not respond as a continuous linear function. The relationship in Figure 9 is fairly "flat" until average February-May outflows surpass about 50,000 cfs, where abundance sharply increases. There appears to be little difference in recruitment in dry to moderate outflow years.

A likely explanation for this trend is that exceptionally strong year classes may only be produced when major storms inundate vegetation in the floodplain, thereby creating a large amount of spawning, rearing, and foraging habitat. This hypothesis was first presented by Caywood (1974) based on observations that flooded vegetation is usually associated with splittail spawning. Caywood also noted that terrestrial foods such as earthworms comprise a significant portion of the diet of splittail and suggested that these food sources may be nutritionally important for spawning success. This hypothesis is supported by informal surveys of anglers in the Miller Park area in the City of Sacramento by DWR staff during winter 1995. Anglers report that the diet of splittail prior to spawning is predominantly earthworms and that there appears to be an habitat preference towards recently-flooded, grassy areas. As further evidence, Caywood observed that splittail are common in Yolo Bypass when it floods and occasionally in Sutter Bypass. These are the two major floodplain areas in the basin. Jones and Stokes (1994) recently confirmed the presence of adult and juvenile splittail in Sutter Bypass during 1993.

The possible importance of floodplain habitat is supported by the statistical analysis shown in Figure 10. The data show a highly significant relationship ($p<0.01$) between the number of days that Yolo Bypass is flooded in winter and spring and the fall midwater trawl index. We have also noted similar statistically significant relationships for the SWP salvage, Chipps Island and Bay-Outflow otter trawl indices. Unfortunately, gage data were not available to perform a similar analysis for Sutter Bypass.

These results do not necessarily indicate that the bypasses are the primary spawning and rearing areas, but they at least provide an index of the inundation of floodplain throughout the basin. However, the bypasses could be valuable habitat if access to terrestrial foods such as earthworms is important for spawning success.

The floodplain inundation hypothesis offers a possible explanation for why splittail year-class strength is not always strong in wet years. The Proposed Rule observes that splittail recruitment within wet years has declined over the past decade. Meng (1993) noted that young-of-the-year abundance was relatively low in 1993 compared to other wet years and suggested that the abundance/outflow relationship may be "decoupling". However, Figure 10 shows that there was little inundation of the floodplain in 1993 despite the year being classified as Above Normal. Outflow was relatively evenly distributed across winter and spring 1993, and reservoirs had a large amount of unused storage capacity following the 6-year drought, so the Yolo and Sutter bypass areas were not needed for long-term flood control. Therefore, inundation of spawning habitat appears to have been relatively low compared to 1982, 1983 and 1986, when the bypasses and other floodplain areas were used extensively for flood control.

An alternative or contributing factor to explain the relatively low index in 1993 is that the spawning stock may have been reduced by six successive years of drought, but analyses described above demonstrate that there is little or no stock-recruitment relationship for this species. Another possibility is that the midwater trawl index is not representative of population trends throughout the system Results from the FWS beach seine, which samples regions upstream of the fall midwater trawl, show that 1993 abundance was exceptionally high. Results from the 1994 seining studies also suggest that abundance can be relatively high in upstream areas in some dry years.

To summarize, the Biological Assessment confirms that drought is correlated with reduced abundance of young splittail in the estuary. However, splittail may remain abundant in upstream areas even in critically dry years (eg 1994). It also appears that floodplain inundation offers a biologically and statistically defensible hypothesis to explain causes for trends in splittail abundance. Studies on the spawning behavior of splittail in floodplain habitat during winter and spring 1995 are an important first step in resolving these issues (Baxter 1995). If outflow levels prove to be the primary factor regulating the production of splittail, the December 15, 1994 Cal-Fed agreement is expected to improve estuarine habitat and abundance. Alternatively, if the frequency with which floodplain is inundated is more important, which we believe is more likely, the new standards will have little or no effect as abundance will continue to depend on the occurence of uncontrolled flows. It is possible that methods could be developed in the future to artificially inundate significant amounts of riparian and floodplain habitat in drier years, however the feasibility of this approach needs to be examined. Reservoir storage and water quality constraints are likely if intentional flooding occurs in drought periods.

Entrapment Zone Position

The Proposed Rule states that "splittail are adapted for life in the entrapment zone". FWS also reports that Suisun Bay, the historical location of the entrapment zone, is the best known nursery habitat for reproduction and larval survival and that the region has been deleteriously affected by increasing salinity from upstream diversions.

In addressing this issue, four biological questions were examined: 1) Is the range of splittail centered in Suisun Bay? 2) Are entrapment zone salinities optimal for splittail? 3) Are recent Suisun Bay salinities within the range tolerated by splittail? 4) Is there a relationship between splittail abundance and entrapment zone position?

The results presented below indicate that the range of the species is not centered in Suisun Bay and its distribution at different salinities is not indicative of an entrapment zone specialist. In addition, measured salinities in Suisun Bay under recent extreme drought conditions appear to be within the range tolerated by splittail. Finally, although there is a statistical relationship between splittail abundance and X2 (2 ppt salinity location, used as an index of entrapment zone position), the distribution and physiology of the species suggests that the entrapment zone is not critical habitat.

It should also be noted that there are major questions about the physics and location of the entrapment zone in the Bay/Delta estuary. Studies by Jon Burau at U.S. Geological Survey during 1994 showed that gravitational circulation, a physical process responsible for the creation of an entrapment zone, occurred near Carquinez Strait, far downstream of its expected position based on specific conductivity profiles in the estuary. These results indicate that the biological significance of the entrapment zone also needs to be reconsidered. This does not, however, mean that the distribution of salinities across the estuary is not important to some fisheries.

Splittail Range: The center of the range of splittail was discussed in the previous section. To review briefly, initial results from IEP gillnet surveys provide evidence that Suisun Bay appears to be part of a broader core of distribution, rather than the center of the range of adult splittail during late summer (Baxter 1994b). The FWS beach seine also indicates that substantial numbers of young splittail use areas well upstream of Suisun Bay.

Analysis of Salinity Requirements: The salinity requirements of splittail were examined using data from three different sources, the Suisun Marsh survey, the Bay-Delta outflow study and the recent IEP gillnet survey. A concern with all the databases is that there was different sampling effort over a range of salinities. This can potentially result in bias when abundance is compared between salinities. Moreover, it is difficult to use distribution data to differentiate between active preferences and tolerance of environmental conditions. For example, splittail may choose to remain in suboptimal salinities if other habitat conditions (eg, food abundance) are positive. Recent studies at UC Davis are helping to resolve this issue (Young and Cech 1995). Initial splittail physiology results show that this species is extremely tolerant of a wide range of salinities. The study found that the critical salinity maximum for YOY and subadults was 22 and 24 ppt, respectively. Preliminary results of salinity endurance tests showed that the 24-hour TLE (time to loss of equilibrium) was 18 ppt for juveniles. The 18 ppt is the same maximum level that Moyle (1976) noted based on field observations. These results are also consistent with distribution data, described below, which show that splittail occur at a broad range of salinity conditions. This suggests that splittail is not an entrapment zone specialist as proposed by FWS.

Of the three databases, the Suisun Marsh survey contained the most splittail observations, providing the greatest opportunity to analyze salinity relationships and to statistically reduce bias. Salinity/abundance was analyzed using an approach similar to Kimmerer (1992) and Obrebski et al. (1992). The data were pooled over all years and stations for which salinity data was available (1979-1992), sorted according to increasing salinity (ppt), then divided into 23 classes of nearly equal sample size. Average salinity values for each class are shown in Table 1. Splittail were separated into different age classes using methods described in DWR/USBR (1994), then abundance data (catch/trawl) were log-transformed before means and 95 percent confidence intervals were calculated for each salinity class.

The results are summarized in Figure 11 for YOY, year 1 and year 2+ splittail. All life stages appear to be less abundant at the lowest (0 - 0.3 ppt) and highest (9.3 - 21.5 ppt) salinities. Abundance of all age classes splittail was variable between this range, with no apparent preference for the 2 - 6 ppt range often used to characterize the entrapment zone. Older splittail show some indication of a peak below 2 ppt, but it is unclear whether this level is significantly different from abundance at higher salinities based on the broad confidence intervals.

Another concern is that the survey includes exceptionally high abundance during the first few years, followed by lower abundance after a dramatic decline. Analysis of the "pre-decline" and "post-decline" periods as a single database may create unexpected biases. This issue was addressed by stratifying the data into "pre-decline" (1979-1982) and "post-decline" (1983-1992) periods, then applying the same methods described for the complete dataset. The salinity classes for the two periods are shown in Table 2. Note that these salinity classes are different from the complete dataset and from each other because of differences in sample size. The results in Figure 12 confirm that fewer year 1 and year 2+ splittail occurred at the highest and lowest salinity classes. However, there is no longer an obvious preference for any single salinity class. It appears that the 1.6 - 1.9 ppt peak on Figure 11 may have been an artifact caused by the combination of data from two very different periods. The highly variable response of all age classes of splittail to salinities between 1 and 8 ppt indicates that distribution patterns are likely to be primarily result of other habitat factors.

Although catch levels of splittail are significantly lower in the Delta Outflow/Bay study, the geographical range of this survey makes it a valuable source of data. The midwater and otter trawl survey catch data were analyzed by grouping average salinity and bottom salinity, respectively, for two periods: January-July and August-December. These data were not adjusted for sampling effort or area.

The results summarized in Figures 13 and 14 show that the highest catches of all age classes were observed in freshwater, not the 2-6 ppt salinity range characterizing the entrapment zone. In general, older age classes of fish are more common at a broader range of salinities but show no detectable change in distribution between the two halves of the year.

In contrast, it appears that young-of-the-year splittail become more abundant at higher salinities in the second half of the year. While midwater and otter trawl catches of young-of-the-year occurred up to 10-13 ppt throughout the year, there were more observations in brackish water during August-December. It is unclear whether this seasonal shift represents an active migration of young-of-the-year to higher salinity water or whether higher salinities intrude into splittail habitat as outflow decreases in later summer and early fall. If intrusion occurs, large numbers of young-of-the-year may be observed at low salinities in winter and spring because they are carried downstream to Suisun Bay and beyond by high flows.

Salinity data from the 1994 IEP gillnet survey were obtained from Baxter (1995). With the exception of a few individuals, all of the splittail caught were adults. Catch-per-hour of splittail for the gillnet survey is summarized by salinity in Table 3. The results are similar to the Suisun Marsh and Bay/Outflow data--splittail occur over a broad range of salinities, with no distinct preference for the 2 to 6 ppt range.

Salinity Trends in Suisun Bay: The assertion that Suisun Bay salinities have become unsuitable for splittail was examined using monitoring data from water years 1991-1993. Measurements of total dissolved solids for two of the stations that bracket Suisun Bay, Martinez and Mallard Slough, are provided in Appendix C.

The salinity tolerances of splittail are not fully known, however initial results from Young and Cech (1995) demonstrated some adverse affects in YOY at levels as low as 18 ppt. This salinity is the same maximum level reported by Moyle (1976) based on field observations. Appendix B shows that the 18,000 ppm (18 ppt) level was exceeded only at Martinez, the downstream limit of Suisun Bay. This suggests that salinity levels remained below harmful levels even during the extreme conditions of the six-year drought and improved substantially in 1993.

Relationship Between Abundance and X2: There is a statistically significant relationship between an indicator of entrapment zone location, X2, and splittail abundance. Fox and Britton (1994) used generalized linear models to develop a relationship between splittail midwater trawl abundance and the location of X2 during February-June ($r^2=0.61$, $p<0.05$). Analyses in the Biological Assessment also show that splittail abundance was negatively correlated with specific conductance in all regions of the estuary in a variety of seasons (Table 4). The highest correlation coefficients were generally found during summer and fall, when specific conductance values tend to be highest. However, the correlations between abundance and X2 or specific conductance do not necessarily indicate a cause and effect relationship. As described above, splittail show no detectable preference towards the salinity range commonly associated with the entrapment zone. A possible explanation for the X2 relationship is that splittail abundance increases in high outflow years when floodplain is inundated. Thus, the relationships between X2 or specific conductance and abundance may be a result of covariance with hydrology, rather than functional.

Altered Hydraulics Due to Diversions

The Proposed Rule lists altered hydraulics as the principal factor leading to the "decline" of splittail. The major concern is net reverse flow, which occurs when Delta inflow from upstream tributaries is insufficient to meet exports and local agricultural diversions. Water is pulled from downstream areas and in some channels upstream tidal flow can be intensified and also cause net upstream flows where they would otherwise not occur. FWS believes that net reverse flows shift the distribution of splittail closer to the State and Federal pumping plants where they are vulnerable to entrainment. Moreover, FWS concludes that when net reverse flows are present, "outmigrating larval and juvenile fish of many species become disoriented".

The reverse flow issue was examined using salvage data from the State Water Project and Central Valley Project. Records of fish salvaged from screening operations at the two pumping facilities provide the best available information on the timing and relative magnitude of splittail entrainment and associated losses. The hypothesis that reverse flow results in increased entrainment was tested statistically through regression analysis of a calculated index of reverse flow, QWEST versus salvage of different age classes of splittail during the 1979-1991 period. The number of days of reverse flow (negative QWEST) was calculated for March-July and February-May, the periods of peak salvage of young-of-the-year and adult (Year 2+) splittail, respectively. No significant association ($p > 0.05$) was found between the number of days of reverse flow in March-July and young-of-the-year salvage at the SWP ($r^2=0.11$; $n=13$) or the CVP ($r^2=0.21$, $n=12$). Similarly, the association was not significant between February-March reverse flow and Year 2+ splittail salvage at the SWP ($r^2=0.22$;$n=12$) or CVP ($r^2=0.022$;$n=12$).

These results are consistent with the results of Department of Water Resources particle tracking studies, which show that reverse flows are a poor indicator of potential entrainment. Simulation modeling using particle tracking is described in further detail in the Biological Assessment.

The Proposed Rule includes concerns about two additional hydraulic effects, reduced Delta outflow and increased salinities in Suisun Bay. FWS states that project-related changes to these two variables adversely affect splittail abundance. As discussed in previous sections of this report, Delta outflow, entrapment zone position and floodplain inundation each offer alternative hypotheses to explain abundance patterns. Although the relative importance of these hypotheses cannot be separated at this time, floodplain inundation is highly consistent with the reproductive biology of splittail and offers a possible explanation for why there is little difference in abundance levels in low to moderate outflow levels (Figure 9). If floodplain inundation is the key factor driving splittail abundance patterns, it is questionable whether diversions have a major effect. Floodplain inundation occurs primarily when uncontrolled flows are in the system--water supply project operations usually have little control over these flows. However, operation of upstream reservoirs play an important role in flood management. For example, in 1993 there was exceptionally large storage capacity in Sacramento Basin reservoirs following the 6-year drought, which reduced the need for operation of the bypass areas for flood control.

Mortality at CVP and SWP Pumping Facilities

Loss at pumping plants and in-Delta diversion sites are listed in the Proposed Rule as a major threat to splittail. FWS reports that "splittail distribution has shifted upstream into the lower Sacramento River and South Delta since 1983", which "increases splittail mortality at the pumps (located in this region)". Mortality rates at the export facilities are reported to be highest in dry years, when total diversion rates are high relative to Delta outflow. Net reverse flow is discussed as a key cause of increased mortality at the pumps. The following evidence from the Biological Assessment indicates that these conclusions are erroneous.

The distribution of splittail was discussed in detail earlier in this report. Of particular note is the wide distribution of splittail in 1993, showing that splittail have a much broader range than that suggested in the Proposed Rule . However, it is possible that salinity intrusion in Suisun Bay during the recent six-year drought resulted in less-suitable conditions at the western part of the range of splittail. Also discussed previously was the observation that there is no association between the frequency of reverse flows (QWEST), and salvage, the best indicator of entrainment at the SWP and CVP.

The effect of operations on splittail entrainment at the SWP and the CVP was examined in further detail using salvage data from the fish screening facilities. Regression analyses were performed on total CVP and SWP salvage during the period of peak young-of-the-year entrainment (May-July) versus total Delta outflow. Figure 15 shows that there is statistically significant ($P<0.01$) relationship between CVP salvage and Delta outflow. The relationship for the SWP (Figure 16) was not statistically significant at the $p<0.05$ level, but salvage levels show a similar increasing trend with outflow.

Possible differences in salvage between wet and dry years were also tested using an alternative approach, the Mann-Whitney U-test. Total SWP salvage of young-of-the-year for 1979-1991 was grouped into "dry" (critical-below normal) or "wet" (above normal-wet) years. Differences between the two groups were significant at the $p<0.01$, with salvage greater in wet years.

Results using these statistical tests are not consistent with the statement in the Proposed Rule that mortality at the export facilities is highest in dry years. Moreover, additional analyses from the Biological Assessment demonstrate that entrainment rates are not linked with diversion levels. Figures 17 and 18 show that young-of-the-year salvage is not significantly ($p>0.05$) related to exports at the CVP and SWP, respectively.

The best explanation for the observed results is that salvage levels at the export facilities reflect the abundance of splittail in the system. Splittail are most abundant in wet years, when Delta outflow (and inflow) is high (Figure 9). It is likely that higher salvage levels in wetter years are a result of an increase in the number of splittail throughout the estuary. As evidence, Figure 19 shows that there is a significant relationship between the midwater trawl index and salvage of young-of-the-year splittail at the CVP and SWP ($p<0.05$). Thus, it appears that splittail recruitment has a greater effect on the magnitude of loss at the export facilities than operations.

The question still remains whether the relative magnitude of impacts from diversions to the population increases in dry years. If the abundance of young splittail is reduced, such as during part of the 6-year drought, even relatively modest entrainment loss could be important at the population level. One approach to examine this issue is to develop an index that incorporates year-class strength. To achieve this end, monthly salvage data for young-of-the-year splittail were divided by the annual midwater trawl indices.

In this discussion, the index is referred to as "entrainment index" rather than "salvage index" to avoid confusion with actual salvage numbers. The concept is similar to the loss rate index California Department of Fish and Game developed for striped bass (Kolhorst et al 1993). However, the loss rate index is based on calculated losses of striped bass, and the entrainment index for splittail uses salvage as an index of losses. By incorporating year class strength, both indices provide a measure of when impacts are likely to be greatest at the population level. A possible bias with the entrainment index is that the fall midwater trawl index may not completely represent year-class strength because it may partly reflect some entrainment losses in the previous spring. The entrainment index also does not take into account seasonal changes in predation and screening efficiency, which could result in variation in salvage levels. Despite these limitations, the entrainment index is one of the best available tools to examine relative impacts at the population level.

Calculated monthly entrainment indices for the CVP and SWP are shown in Figures 20 and 21, respectively. These indices do not support the FWS conclusion that the projects have the greatest effect on young-of-the-year abundance in dry years. Indeed, the entrainment indices suggest that the relative impact of entrainment at the CVP (Figure 20) and SWP (Figure 21) on young-of-the-year was generally lower during the recent drought than in previous years. Therefore, there is no evidence that entrainment losses are responsible for the recent lower levels of splittail young in the estuary.

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SALINITY CLASS	SALINITY RANGE PPT		
1	0	-	0
2	0.01	-	0.3
3	0.31	-	0.6
4	0.61	-	1
5	1.01	-	1.3
6	1.31	-	1.6
7	1.61	-	1.9
8	1.91	-	2.1
9	2.11	-	2.4
10	2.41	-	2.8
11	2.81	-	3.2
12	3.21	-	3.7
13	3.71	-	4
14	4.01	-	4.4
15	4.41	-	4.8
16	4.81	-	5.2
17	5.21	-	5.9
18	5.91	-	6.5
19	6.51	-	7.4
20	7.41	-	8.2
21	8.21	-	9.3
22	9.31	-	10.8
23	10.81	-	21.5

TABLE 1: SALINITY CLASSES FOR ANALYSIS OF SUISUN MARSH DATA, 1979 - 1992

The range covering 2 -6 ppt is highlighted.

1979-1982

SALINITY CLASS	SALINITY RANGE PPT		
1	0	-	0.2
2	0.21	-	0.6
3	0.61	-	0.9
4	0.91	-	1.1
5	1.11	-	1.3
6	1.31	-	1.5
7	1.51	-	1.9
8	1.91	-	2
9	2.01	-	2.3
10	2.31	-	2.9
11	2.91	-	3.5
12	3.51	-	4.2
13	4.21	-	4.8
14	4.81	-	5.5
15	5.51	-	6.9
16	6.91	-	8.5
17	8.51	-	14

1983-1992

SALINITY CLASS	SALINITY RANGE PPT		
1	0	-	0
2	0.01	-	0.4
3	0.41	-	0.9
4	0.91	-	1.6
5	1.61	-	2.1
6	2.11	-	2.6
7	2.61	-	3.2
8	3.21	-	3.8
9	3.81	-	4.2
10	4.21	-	4.8
11	4.81	-	5.2
12	5.21	-	5.9
13	5.91	-	6.5
14	6.51	-	7.5
15	7.51	-	8.5
16	8.51	-	9.8
17	9.81	-	11
18	11.01	-	22

TABLE 2: SALINITY CLASSES FOR ANALYSIS OF SUISUN MARSH DATA FOR PRE-DECLINE AND POST-DECLINE PERIODS

The range covering 2 -6 ppt is highlighted.

Table 3. Hours fished, total catch and catch-per-hour of splittail by one ppt salinity interval. Salinity data are approximate due to measurement being attributed to catch over a relatively long period of time (0.5 to 5.0 hours). Data are from locations 41-63 only, therefore they over estimate catch-per-hour in the zero to one ppt interval. Minimum and maximum salinities measured for these locations were 0.2 and 10.9, respectively.

Salinity	Catch-per-Hour	Catch	Hours Fished
0.0 - <1.0	0.27	44	165
1.0 - <2.0	1.00	23	23
2.0 - <3.0	1.02	42	41
3.0 - <4.0	0.14	1	7
4.0 - <5.0		0	0
5.0 - <6.0	0.32	9	28
6.0 - <7.0	0.55	11	20
7.0 - <8.0	0.77	33	43
8.0 - <9.0	0.67	74	111
9.0 - <10.0	0.30	23	76
10.0 - <11.0	0.19	12	63

Table 4

Results of Correlation Analyses Between Splittail Midwater Trawl Abundance and Mean Seasonal Estimates Specific Conductance for Five Regions in the Upper Estuary

Values are mean seasonal specific conductance for 1971 through 1991.

Correlation Coefficients

Region	Winter	Spring	Summer	Fall
Southern Delta	-0.50*	-0.64*	-0.74***	-0.62***
Central Delta	-0.32	-0.30	-0.44*	-0.36
Northern Delta	-0.31	-0.29	-0.26	-0.29
Western Delta	-0.32	-0.35	-0.42*	-0.39*
Suisun Bay	-0.49*	-0.58**	-0.60***	-0.53**

* $P<0.05$
** $P<0.01$
*** $P<0.005$

YOY

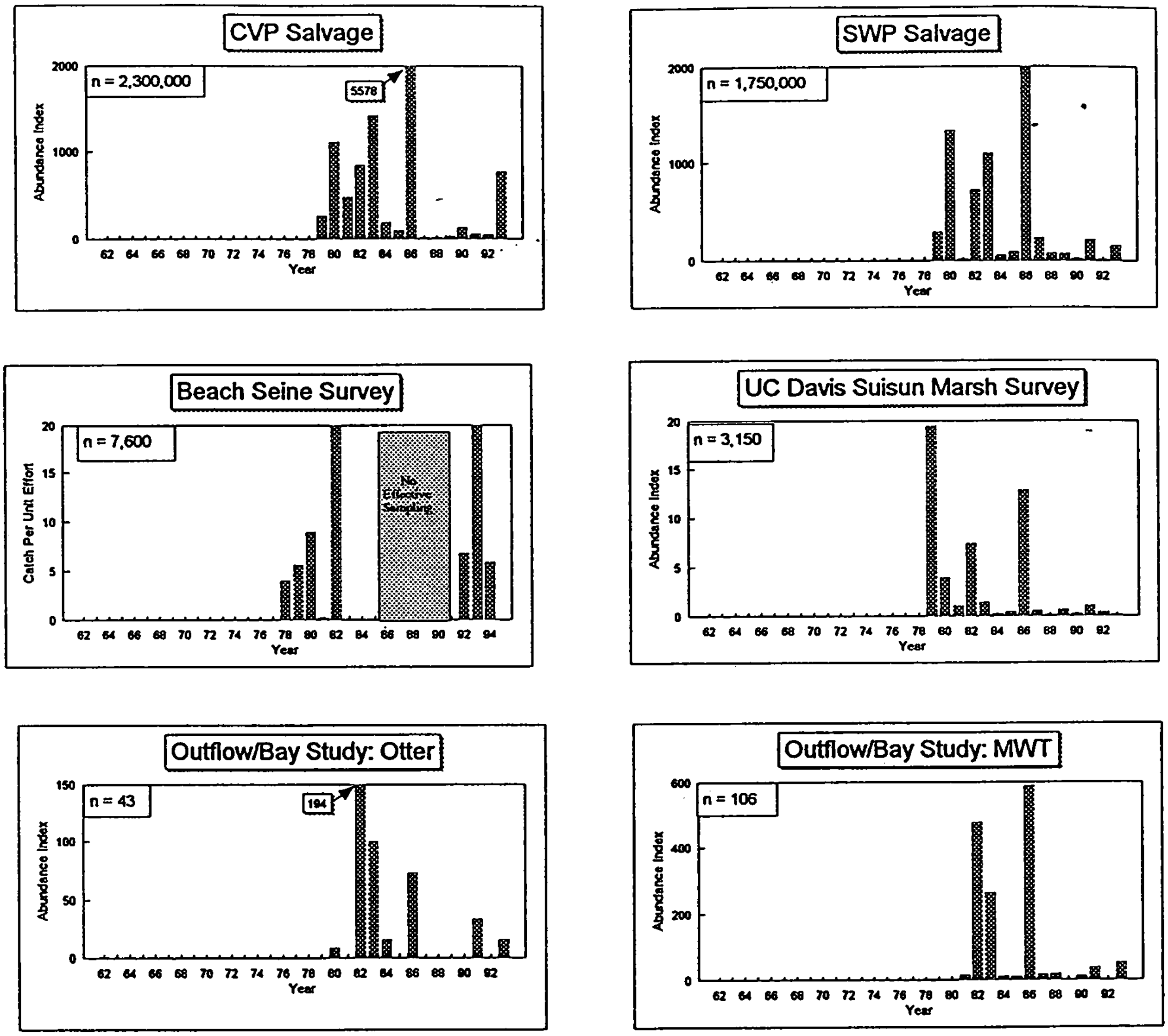


Figure 1 (Part 1). TRENDS IN SPLITTAIL YOUNG OF THE YEAR, AS INDEXED BY NINE INDEPENDENT ESTIMATES. THE APPROXIMATE NUMBER OF FISH FOR WHICH THE ABUNDANCE ESTIMATES ARE BASED ARE SHOWN FOR EACH SURVEY THROUGH 1993. NOTE THAT THE ABUNDANCE INDEX UNITS ARE NOT COMPARABLE BETWEEN SURVEYS

YOY

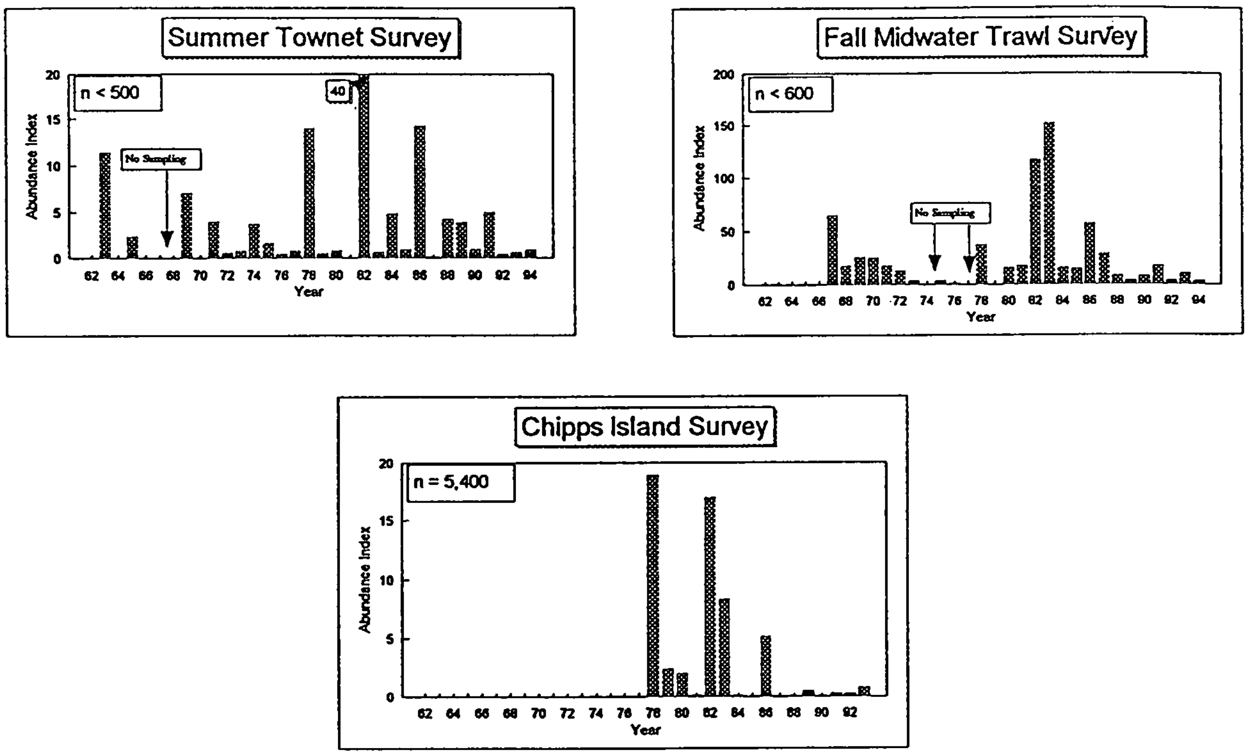


Figure 1 (Part 2). TRENDS IN SPLITTAIL YOUNG OF THE YEAR, AS INDEXED BY NINE INDEPENDENT ESTIMATES. THE APPROXIMATE NUMBER OF FISH FOR WHICH THE ABUNDANCE ESTIMATES ARE BASED ARE SHOWN FOR EACH SURVEY THROUGH 1993.

YEAR 2+

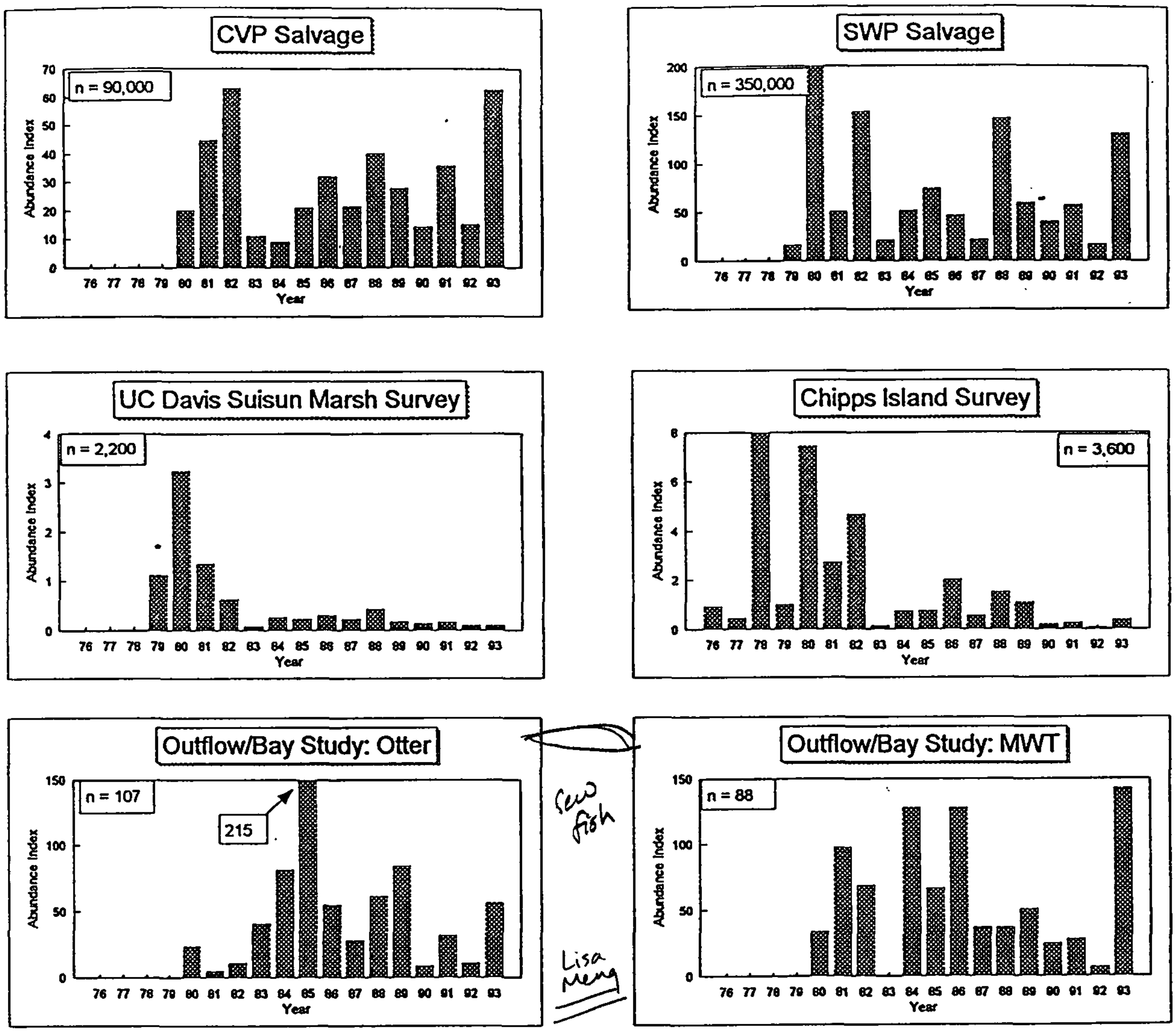


Figure 2. TRENDS IN YEAR 2+ SPLITTAIL, AS INDEXED BY FIVE INDEPENDENT ESTIMATES. THE APPROXIMATE NUMBER OF FISH USED TO DEVELOP ABUNDANCE ESTIMATES ARE SHOWN FOR EACH SURVEY. NOTE THAT ABUNDANCE INDEX UNITS ARE NOT COMPARABLE BETWEEN SURVEYS.

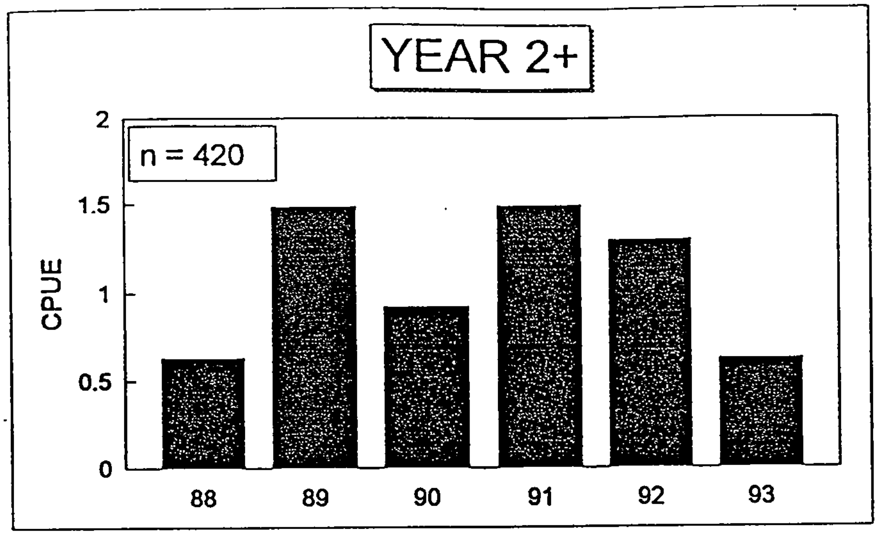


FIGURE 3 .Catch Per Unit Effort for DFG Suisun Marsh Salinity Control Structure gill net studies (1988-1993).

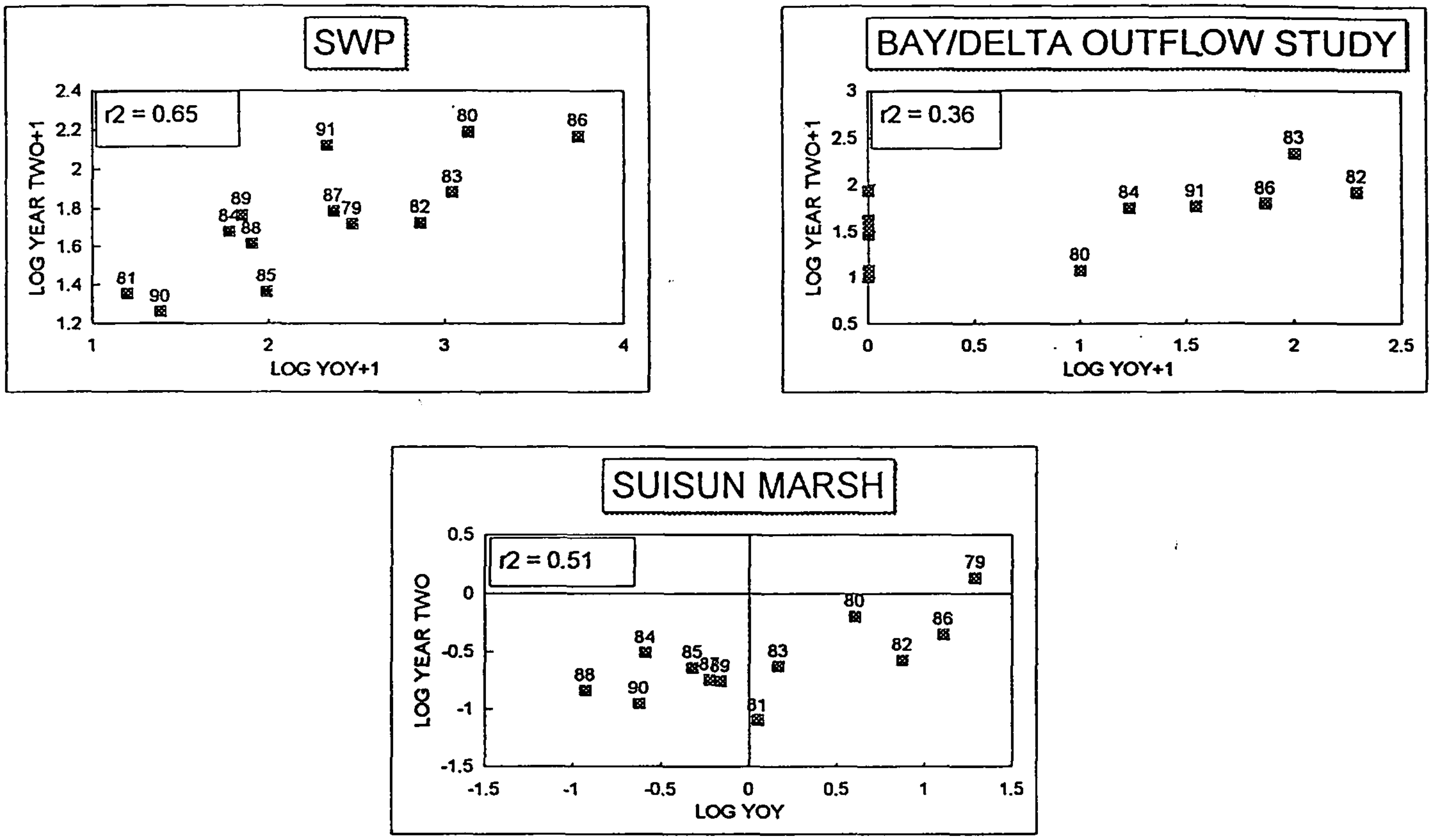


FIGURE 4. RELATIONSHIPS BETWEEN YOUNG-OF-THE-YEAR ABUNDANCE AND YEAR 2+ ABUNDANCE TWO YEARS LATER FOR SWP, BAY/DELTA OUTFLOW STUDY AND SUISUN MARSH INDICES.

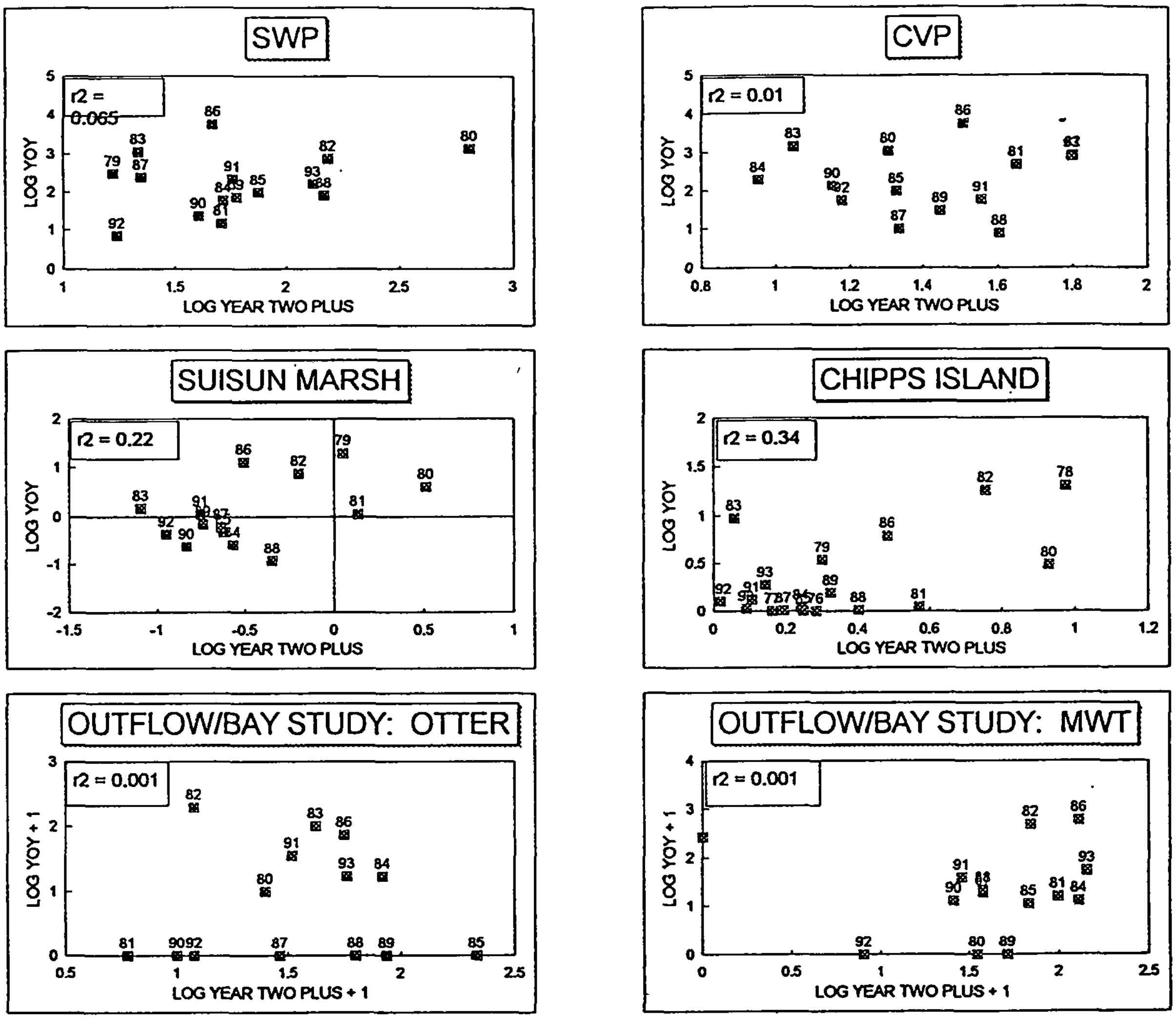


FIGURE 5: STOCK-RECRUITMENT RELATIONSHIP FOR SIX SPLITTAIL ABUNDANCE INDICES. ONLY THE CHIPPS ISLAND RELATIONSHIP IS SIGNIFICANT AT THE p<0.05 LEVEL.

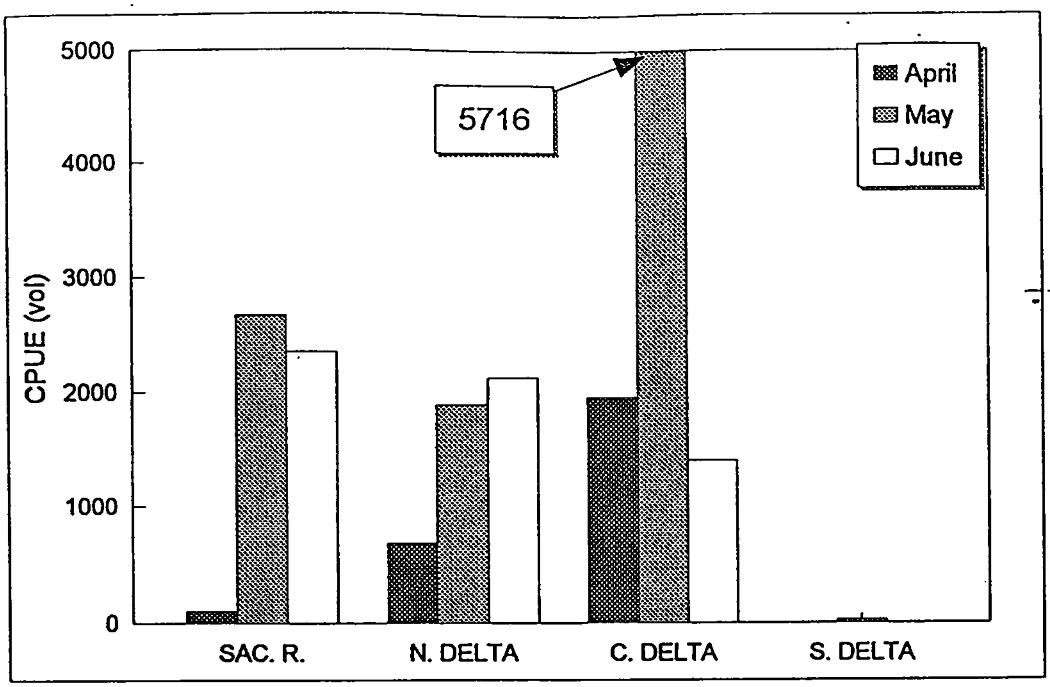


Figure 6
CATCH-PER-UNIT-EFFORT (VOL) OF YOUNG-OF-THE-YEAR SPLITTAIL BY THE FWS BEACH SEINE SURVEY FOR FOUR REGIONS, 1993.

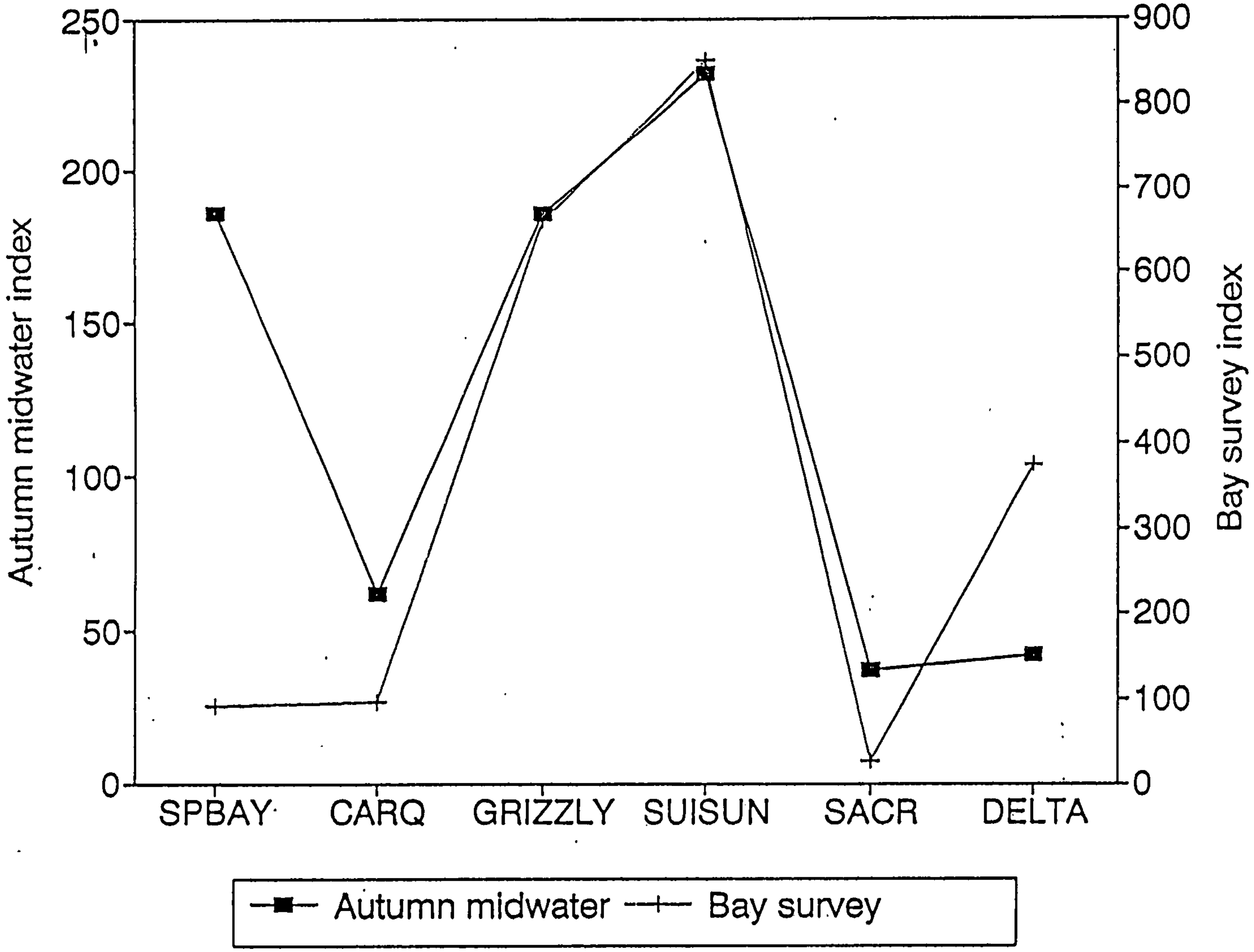
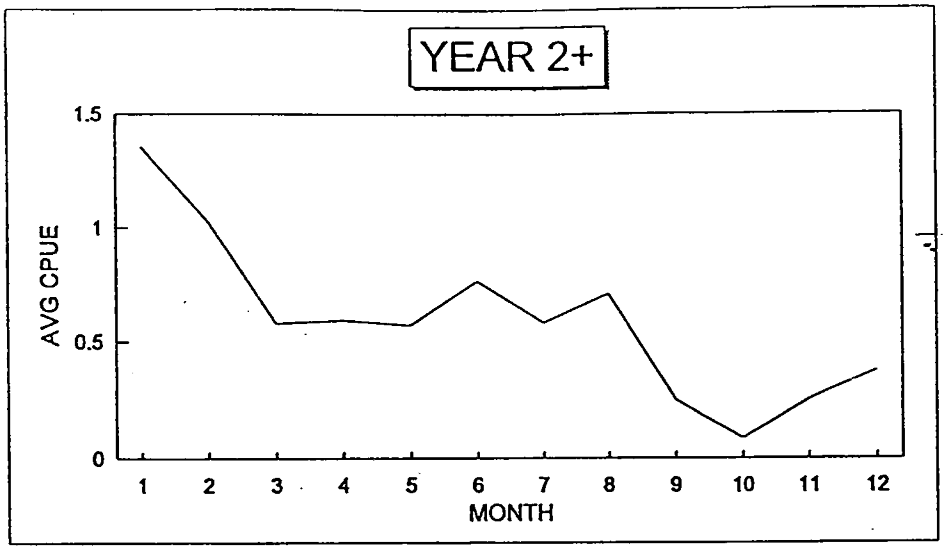


FIGURE 7: Splittail Distribution and Numbers of Splittail Caught by the Fall Midwater Trawl and Bay/Outflow Study. Source: Meng, unpublished data.



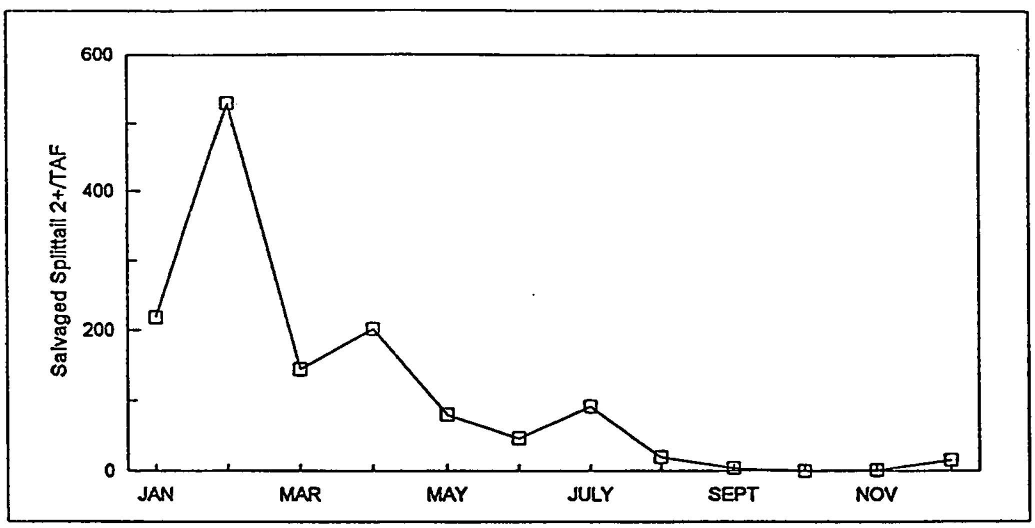


FIGURE 8: Seasonal trends in adult (year 2+) splittail.
The top figure represents average catch/trawl in the Suisun Marsh survey (1979-1991) and the bottom figure is average estimated salvage/AF exported at Skinner Fish Facility (1980-1991).

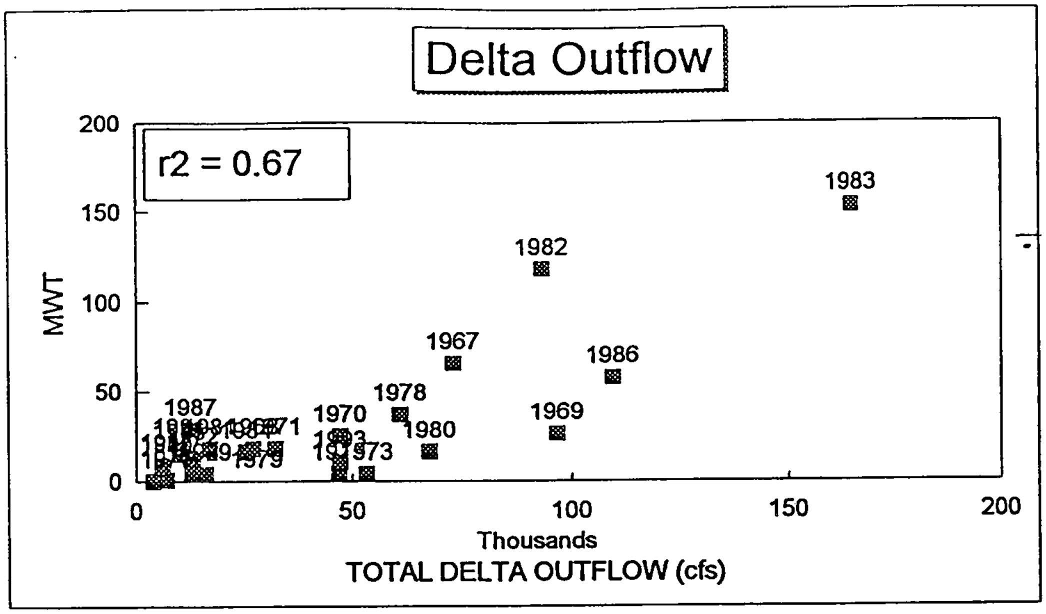


Figure 9 . The relationship between the fall midwater trawl index for splittail and mean Delta outflow (February - May, 1967-1993).

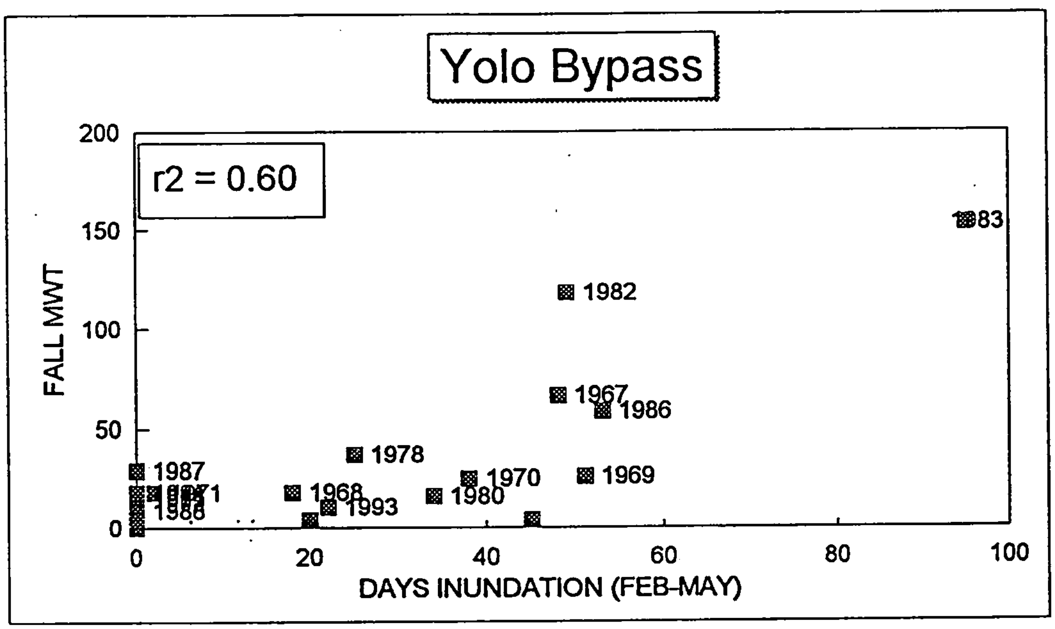


Figure 10. Estimated number of days in February-May that Yolo Bypass was inundated versus the splittail fall midwater trawl (1967-1993).

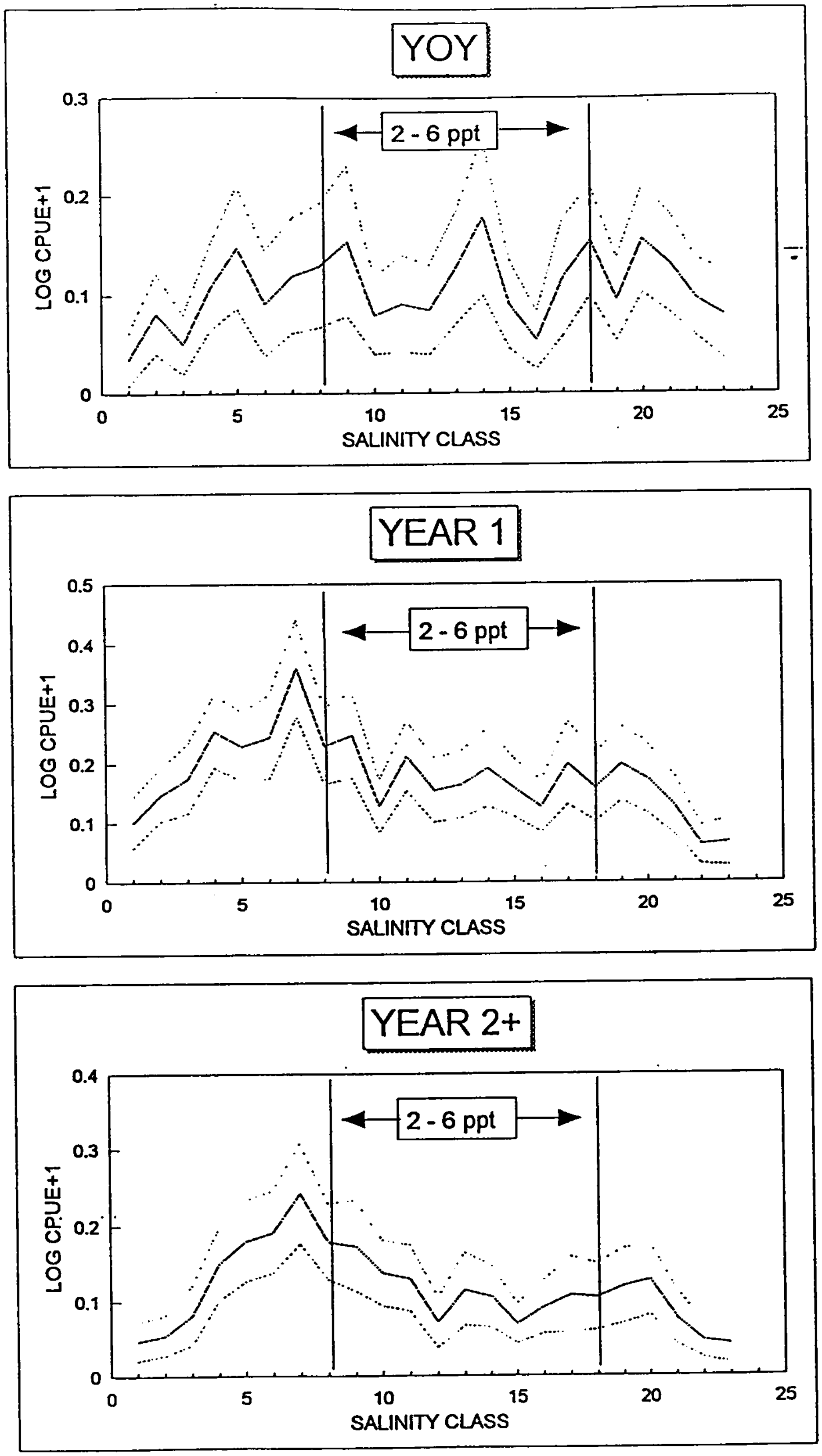


FIGURE 11: LOG + 1 SPLITTAIL ABUNDANCE VERSUS SALINITY CLASS FOR SUISUN MARSH SURVEY (1979-1992).

The mean and 95% confidence levels are shown.

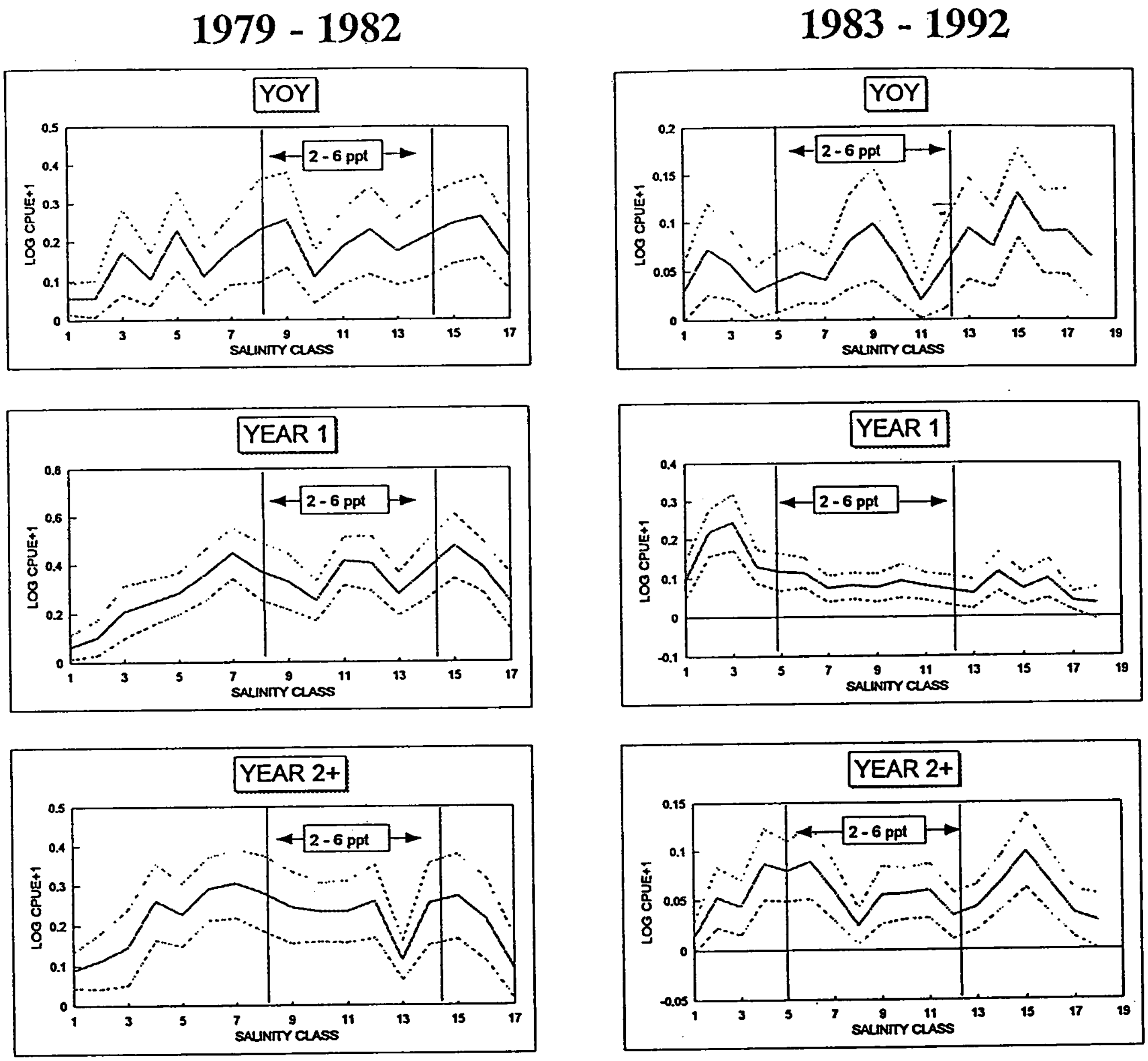


FIGURE 12: LOG + 1 SPLITTAIL ABUNDANCE VERSUS SALINITY CLASS IN SUISUN MARSH FOR PRE-DECLINE (1979-1982) AND POST-DECLINE (1983 - 1992).

The mean and 95% confidence levels are shown.

OTTER TRAWL

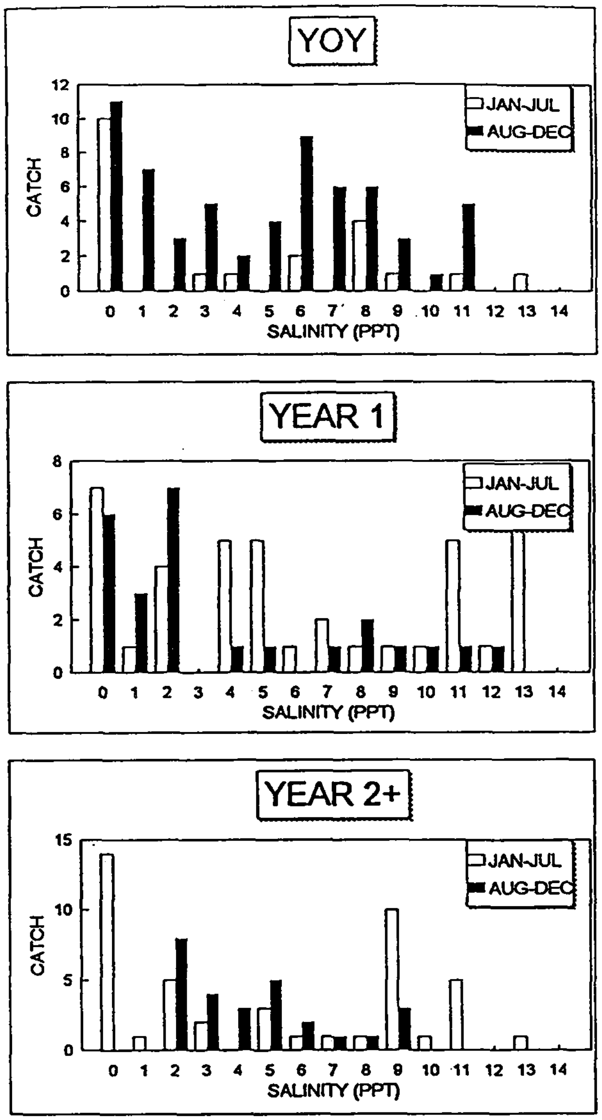


FIGURE 13: Splittail catch versus average salinity from the Bay-Delta Outflow Study midwater trawl (1980-1992). The three age classes of splittail were separated using length-frequency data.

MIDWATER TRAWL

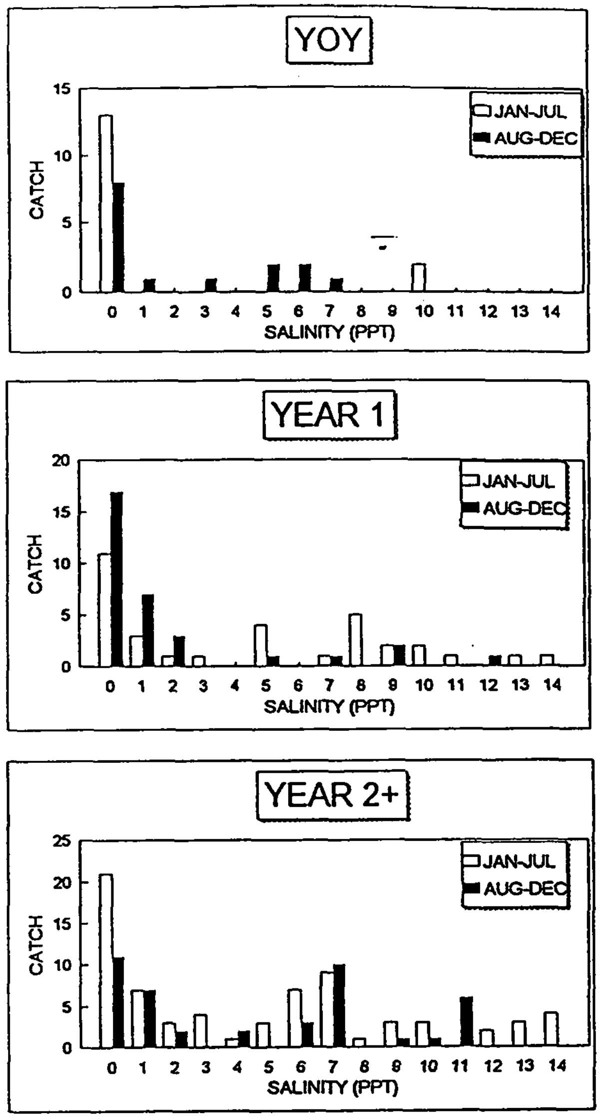


FIGURE 14: Splittail catch versus bottom salinity from the Bay-Delta Outflow Study otter trawl (1980-1992). The three age classes of splittail were separated using length-frequency data.

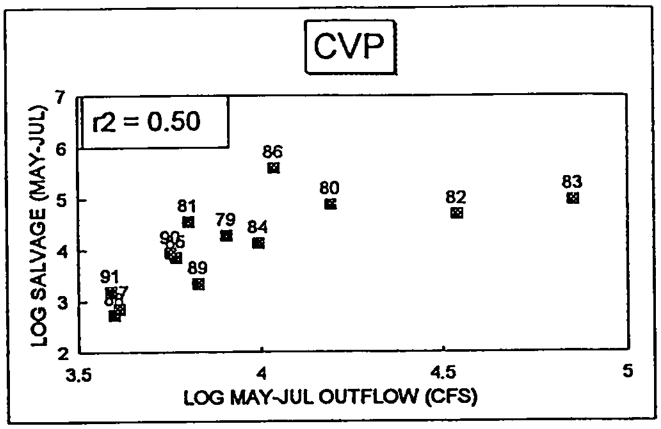


Figure 15. Relationship between average CVP salvage (May-July) and average total Delta outflow (May-July), for 1979-1991.

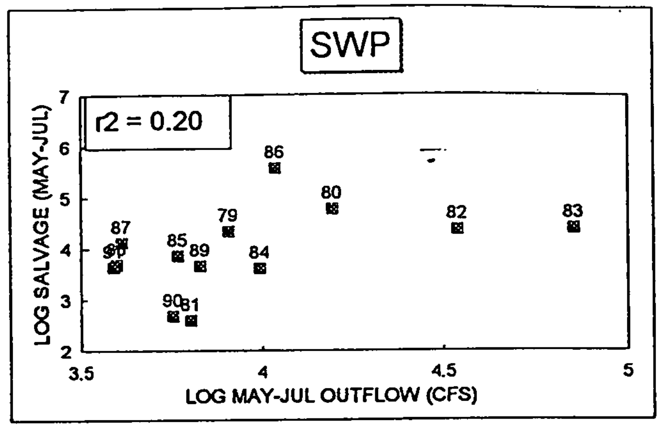


Figure 16. Relationship between average SWP salvage (May-July) and average total Delta outflow (May-July), for 1979-1991.

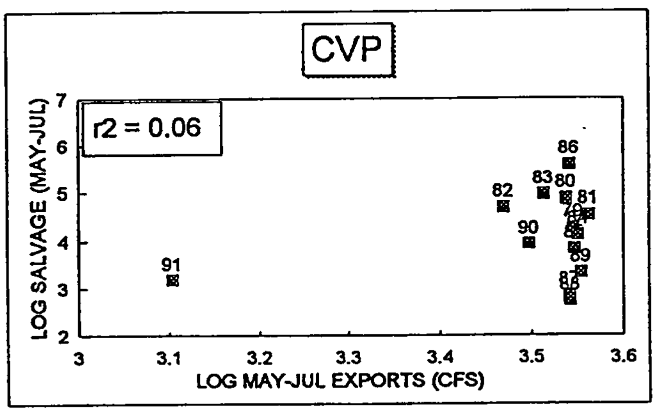


Figure 17. Relationship between average CVP salvage (May-July) and average CVP exports (May-July), for 1979-1991.

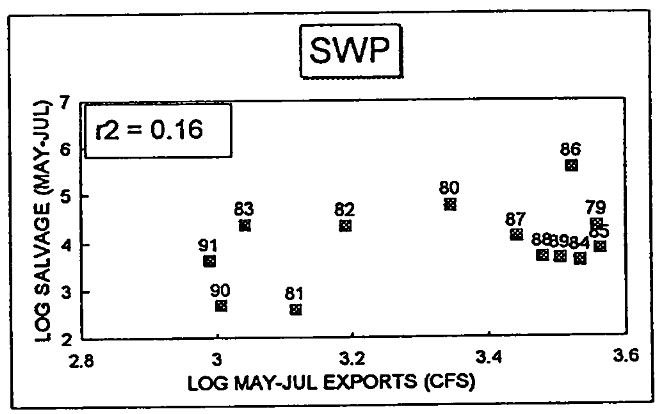


Figure 18. Relationship between average SWP salvage (May-July) and average SWP exports (May-July), for 1979-1991.

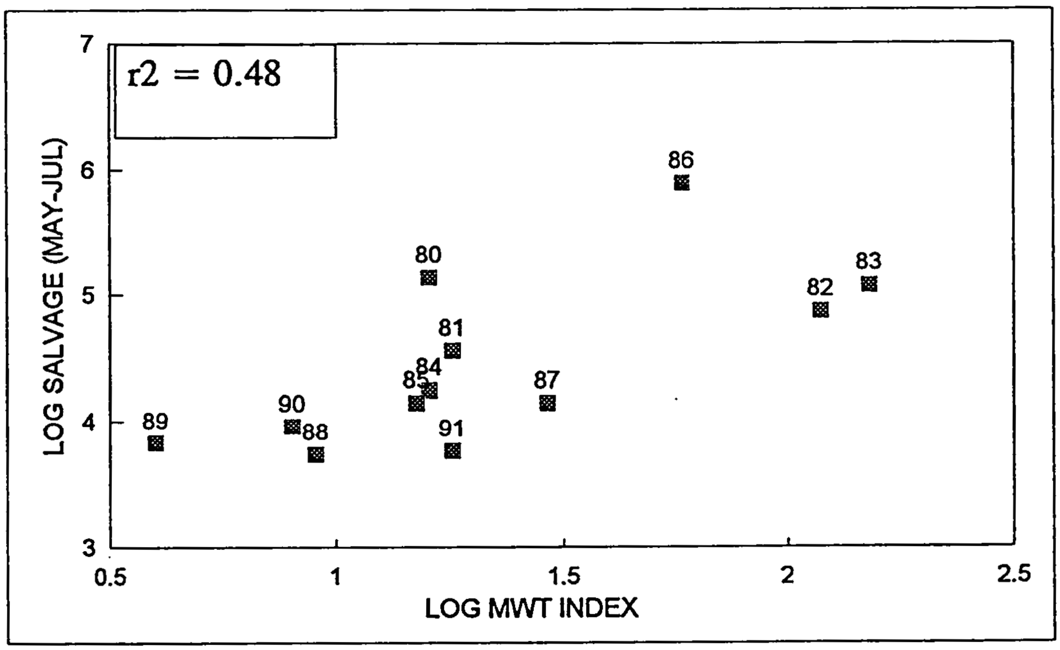


FIGURE 19. Salvage of YOY splittail at the CVP and SWP versus the fall midwater trawl index for 1980-1991. The relationship is significant at the $p<0.05$ level.

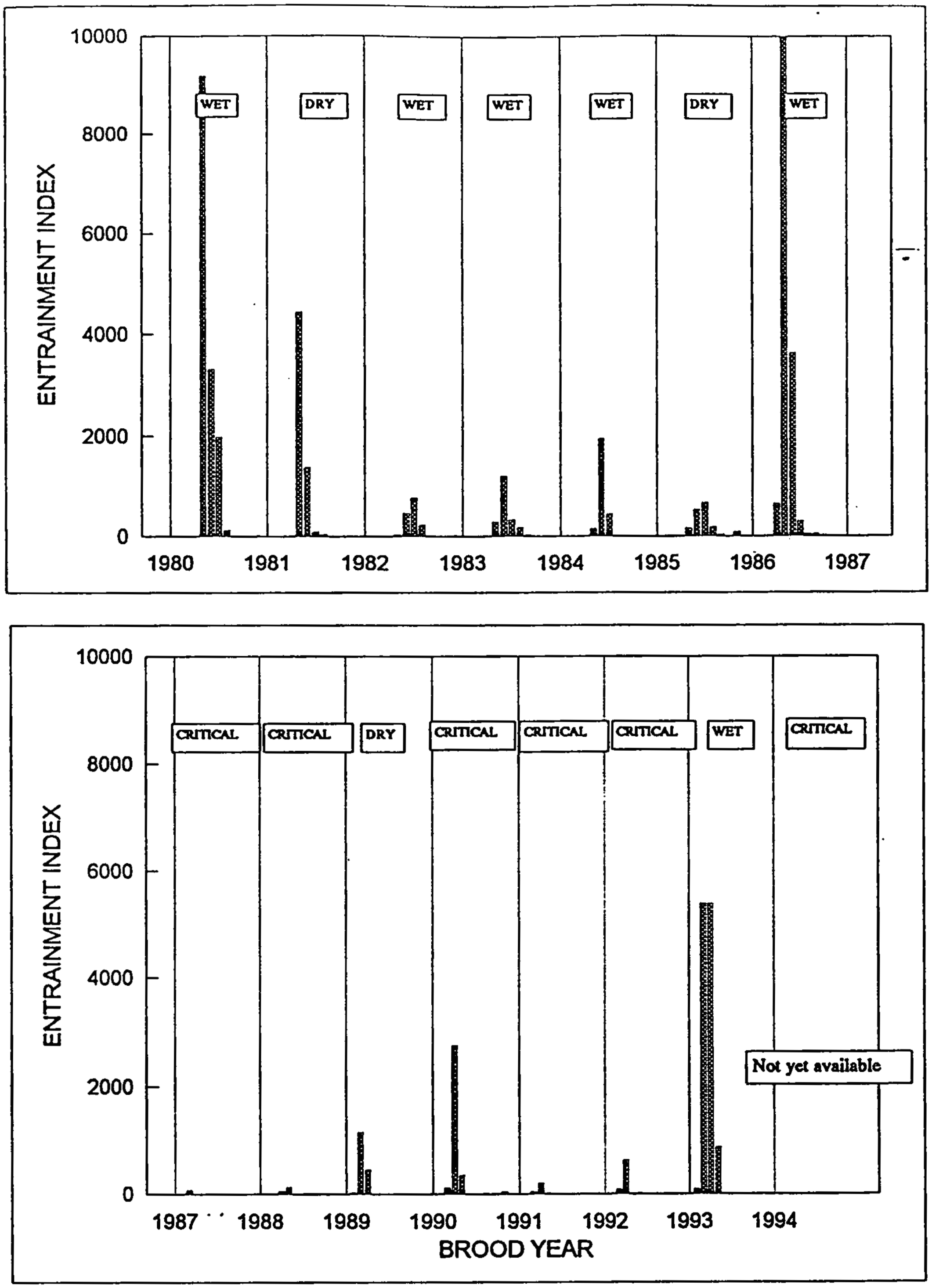


Figure 20. Monthly splittail entrainment indices (January-December) at Tracy Fish Fish Facility for 1980-1993 brood years, separated using salvage and size-frequency data. The entrainment index equals the monthly young-of-the-year salvage divided by annual midwater trawl index.

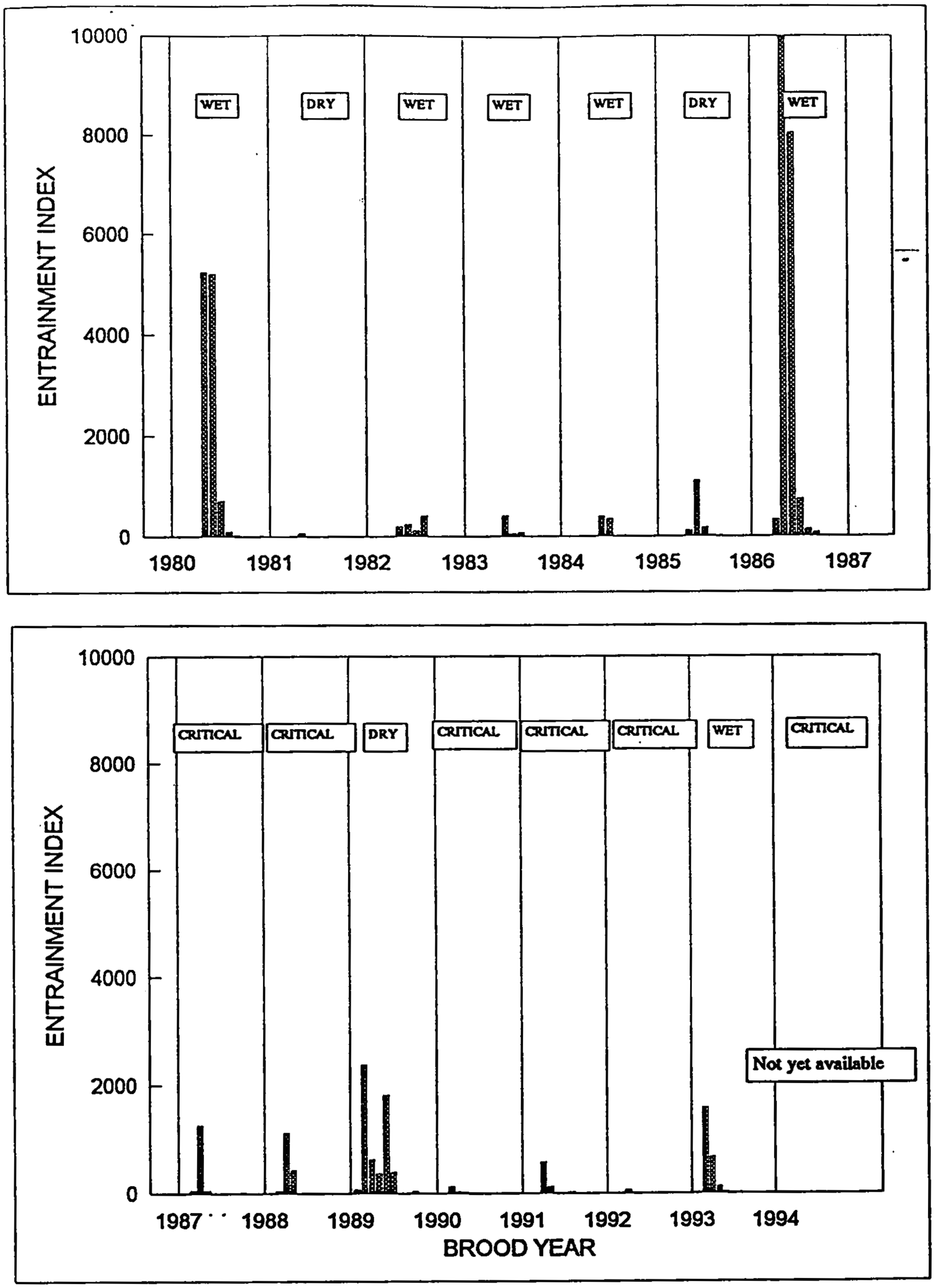


Figure 21. Monthly splittail entrainment indices (January-December) at Skinner Fish Fish Facility for 1980-1993 brood years, separated using salvage and size-frequency data. The entrainment index equals the monthly young-of-the-year salvage divided by annual midwater trawl index.

APPENDIX A: SUMMARY OF DATA GAPS (IN BLACK) FOR FWS BEACH SEINE CORE STATIONS

STATION

YEAR	MONTH	AM001S	DS002S	GS010E	LP003E	MK004W	MR010W	MS001N	SF014E	SJ001S	SJ005N	SJ026N	SJ041N	SR012E	SR014W	SR017E	SR024E	SR043W	SR049E	SR060E	TM001N	XC001N
78	5																					
	6																					
79	5																					
	6																					
80	5																					
	6																					
81	5																					
	6																					
82	5																					
	6																					
83	5																					
	6																					
84	5																					
	6																					
85	5																					
	6																					
86	5																					
	6																					
87	5																					
	6																					
88	5																					
	6																					
89	5																					
	6																					
90	5																					
	6																					
91	5																					
	6																					
92	5																					
	6																					
93	5																					
	6																					
94	5																					
	6																					

Appendix B

Splittail Early Life Stages Collected in the Sacramento-San Joaquin Estuary, 1988-1994

Note that catch data have not been corrected for effort.

Source: Dr. Johnson Wang (Unpublished Data).

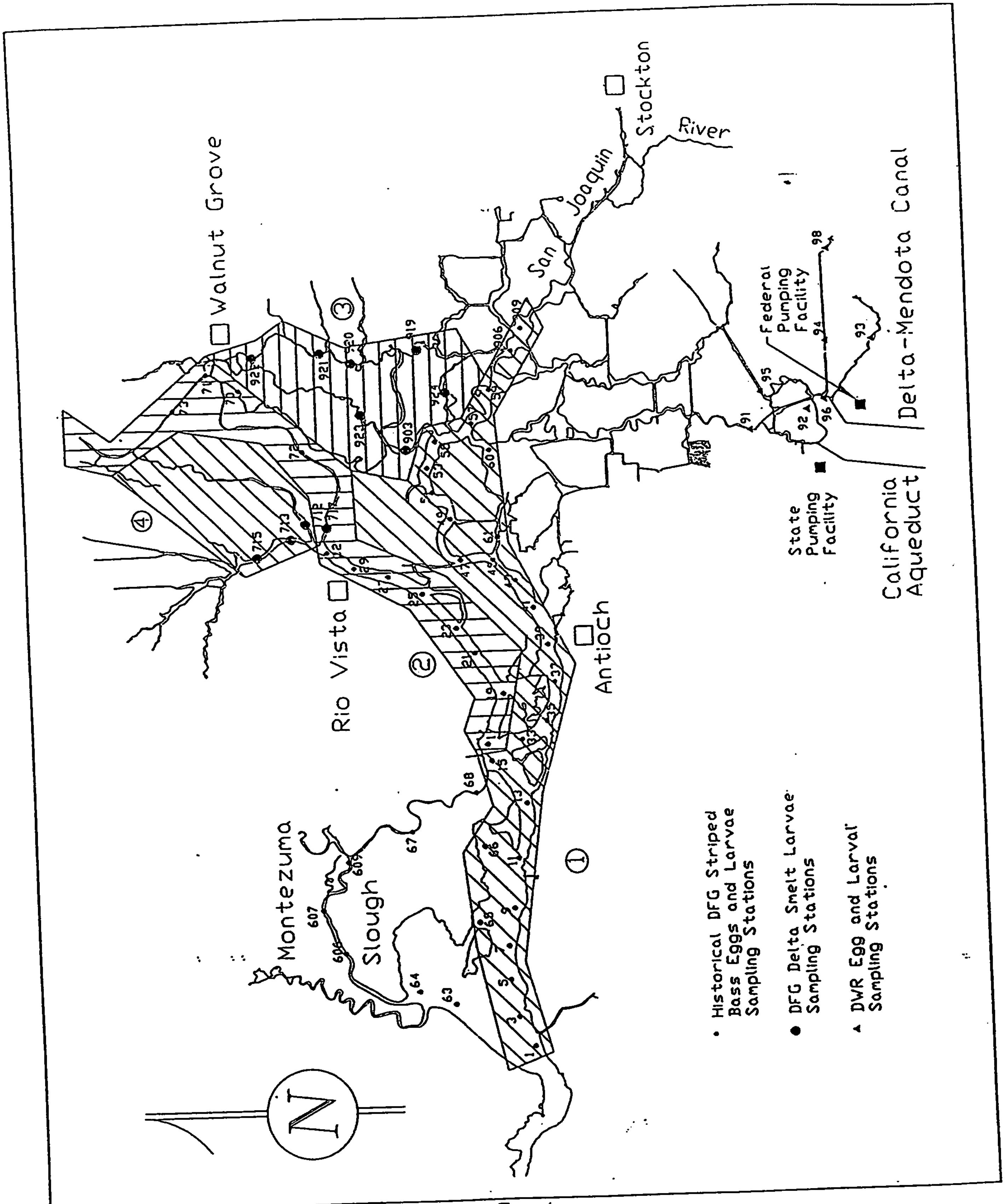


Figure 1
DEPARTMENT OF FISH AND GAME ICHTHYOPLANKTON SAMPLING STATIONS AND SAMPLING AREAS, 1991

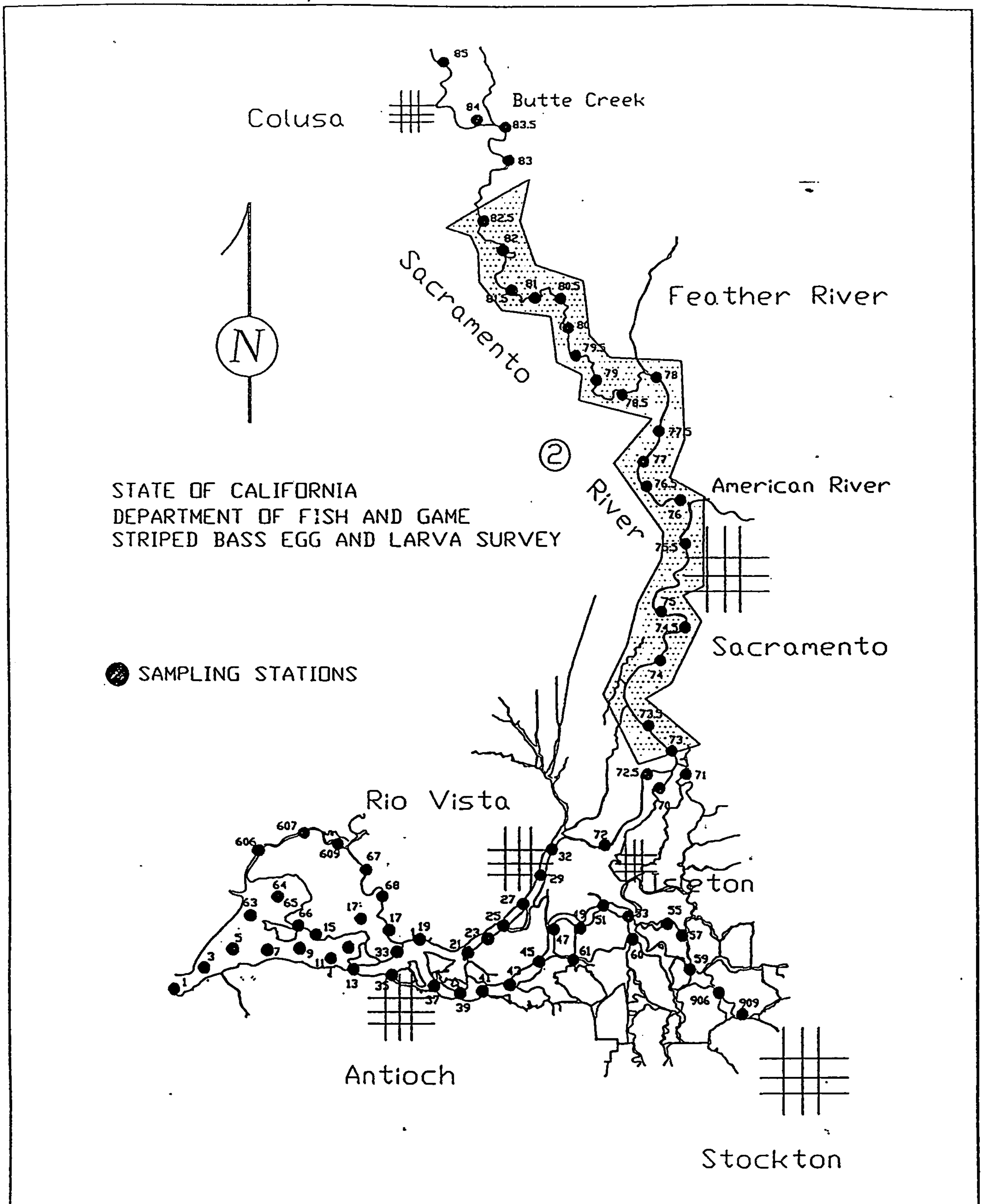


Figure 1 (continued)
DEPARTMENT OF FISH AND GAME ICHTHYOPLANKTON SAMPLING STATIONS AND SAMPLING AREAS, 1991

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1988		
04/16/88		
32	1	7.0
57	1	7.5
909	1	7.3
05/02/88		
47	1	8.2
49	1	8.0
51	1	8.8
53	1	7.4
05/06/88		
27	1	8.0
05/14/88		
57	1	7.8
59	1	7.5
05/26/88		
37	1	7.5
05/30/88		
15	1	7.0
33	1	7.0
39	1	7.7
43	1	6.8
906	1	6.9
909	1	7.2
06/03/88		
47	1	4.7
57	1	7.3
61	1	7.1
06/11/88		
53	1	6.5
06/23/88		
41	1	7.5

Station No.	Number Caught	Sizes (mm Total Length)
1989		
04/12/89		
17	1	9.6
27	2	9.5 10.0
29	8	10.0 10.2 10.4 10.4 10.4 11.0 11.7 11.8
32	3	9.2 9.2 17.5
33	2	7.8 9.5
45	1	5.5
04/16/89		
19	1	11.2
32	5	5.5 5.8 6.5 11.8 12.0
04/20/89		
72	1	12.5
73	1	17.7
745	1	13.1
04/24/89		
21	1	7.7
23	1	14.5
906	1	7.0
73	1	12.0
74	1	12.5
04/28/89		
70	2	7.6 7.9
71	1	7.1
73	3	7.3 7.5 7.7
74	4	7.0 7.2 7.6 7.7
745	6	7.0 7.2 7.3 7.3 7.7 7.7
75	3	7.3 7.5 7.5

Station No.	Number Caught	Sizes (mm Total Length)
1989 (continued)		
05/02/89		
29	1	8.0
32	1	7.4
51	1	7.7
59	1	7.0
71	1	7.3
73	1	8.0
735	2	13.4 14.0
75	1	7.0
05/06/89		
745	1	14.5
05/10/89		
41	1	6.7
05/14/89		
73	1	14.6
05/18/89		
29	1	7.5
71	1	7.5
725	1	7.0
75	1	14.8
05/26/89		
43	1	7.1
49	1	6.5
06/03/89		
51	1	6.7
06/19/89		
21	1	6.9
06/23/89		
21	1	6.9

Station No.	Number Caught	Sizes (mm Total Length)
1990		
04/14/90		
61	1	7.5
04/16/90		
29	1	7.7
55	1	7.2
04/20/90		
39	1	6.5
775	1	7.0
785	2	7.0 7.5
80	1	7.0
81	2	7.5 7.8
82	2	7.3 8.2
04/22/90		
41	2	5.9 9.0
53	1	6.6
55	1	7.0
906	1	6.7
815	1	7.2
04/24/90		
41	1	7.0
57	2	6.2 6.5
61	1	6.4
78	1	7.0
785	2	7.5 7.7
79	4	6.7 7.0 7.3 8.0
795	1	7.6
805	1	7.5
04/26/90		
37	1	6.7
57	1	6.0
59	1	6.5
78	1	7.8
82	1	9.0

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1990 (continued)		
04/28/90		
45	1	7.2
05/02/90		
21	1	6.7
41	1	6.8
60	1	7.2
785	1	6.5
79	1	7.0
795	1	9.2
05/04/90		
775	1	8.0
79	1	7.2
80	1	7.8
05/06/90		
82	1	7.0
05/08/90		
39	1	7.2
906	1	7.3
775	1	7.2
805	1	7.4
81	1	8.7
05/10/90		
57	1	7.1
775	3	7.2 7.8 8.0
785	2	7.7 8.0
79	5	7.0 7.2 7.8 8.0 8.0
815	2	6.8 6.9
825	2	7.0 7.3
05/12/90		
906	1	6.5
775	2	6.8 7.2
785	1	7.7
1990 (continued)		
05/14/90		
60	1	6.8
61	1	6.8
775	3	6.6 7.3 8.0
78	1	7.0
785	1	7.7
79	1	7.3
05/16/90		
47	1	6.5
61	1	7.0
79	1	7.1
05/20/90		
78	2	7.2 7.5
05/24/90		
37	1	6.8
05/30/90		
23	1	40.0
785	1	10.5
79	1	10.0
06/15/90		
795	1	8.3
06/19/90		
775	4	5.0 6.5 9.4 10.4
825	1	10.0
1991		
04/04/91		
32	3	7.5 7.6 8.0
55	1	7.6
04/06/91		
57	3	7.3 7.7 8.1
906	1	7.6
04/10/91		
23	1	9.0
29	2	7.9 8.6
04/12/91		
29	2	8.6 8.6
59	1	7.4
04/16/91		
51	1	7.4
04/24/91		
78	1	7.0
825	1	7.8
04/26/91		
74	1	7.4
76	1	8.4
82	1	7.8
04/28/91		
735	1	7.5
75	1	8.0
765	2	7.2 8.4
77	1	7.2
785	1	7.2
825	1	7.5
1991 (continued)		
04/30/91		
77	4	4.5 4.5 7.5 8.8
775	1	7.6
785	3	7.5 7.6 7.7
79	1	7.5
795	1	8.1
80	1	7.4
815	3	6.3 7.3 7.6
82	8	6.5 7.2 7.4 7.5 7.7 7.7 7.7 7.8
825	2	6.4 7.4
05/02/91		
745	1	7.2
78	1	7.7
785	3	7.2 7.3 7.3
79	4	7.0 7.2 7.2 7.3
795	5	7.0 7.2 7.7 7.8 8.3
80	3	7.5 8.1 8.3
805	1	7.5
81	2	6.8 7.2
815	2	7.2 7.5
82	6	7.1 7.3 7.3 7.7 7.8 7.8
825	4	7.1 7.2 7.4 7.5
05/04/91		
745	1	7.0
77	1	7.2
775	3	7.1 7.5 8.2
78	2	6.8 7.8
785	3	7.5 7.5 7.7
79	5	7.0 7.1 7.2 7.3 8.0
795	1	7.7
80	6	7.4 7.5 7.5 7.7 7.8 8.0
805	3	7.0 7.4 7.7

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1991 (continued)		
05/04/91 (continued)		
81	5	6.9 7.3 7.5 7.7 7.8
82	5	7.1 7.2 7.4 7.7 7.8
825	3	7.2 7.5 7.7
05/06/91		
75	1	7.3
76	1	7.7
775	1	7.8
78	6	6.9 7.0 7.2 7.5 7.9 8.1
80	1	7.9
81	1	7.7
815	1	7.7
82	1	7.8
825	2	7.2 8.2
05/08/91		
735	1	8.8
745	1	7.2
75	4	7.7 7.7 8.0 8.0
77	1	7.7
775	1	7.8
79	2	7.2 7.8
80	7	7.2 7.3 7.5 7.5 7.7 8.0 8.0
825	1	6.9
05/10/91		
725	1	8.5
70	2	7.5 7.8
738	2	7.3 8.0
745	2	8.3 8.6
76	3	8.0 8.4 23.5
765	2	7.3 8.2
77	1	7.5
79	2	7.9 8.0
1991 (continued)		
05/12/91		
57	1	7.1
72	2	8.0 8.1
74	1	9.0
745	7	7.3 7.5 7.5 8.3 8.6 8.8 9.0
75	6	7.0 7.2 7.2 7.7 7.8 8.4
7.6	2	7.3 7.6
765	1	7.8
775	1	7.8
78	1	7.6
795	1	7.7
82	1	7.8
05/14/91		
73	1	7.2
74	1	7.1
755	1	7.3
765	1	7.5
77	2	7.0 7.5
775	5	7.3 7.6 7.8 7.9 8.0
05/16/91		
72	1	7.5
725	1	8.2
70	1	7.0
805	1	8.0
05/18/91		
725	1	9.0
74	1	8.5
775	1	7.2
79	1	7.6
815	1	7.9
05/20/91		
755	1	7.2
77	2	29.0 32.5
1991 (continued)		
05/22/91		
775	1	28.5
05/23/91		
923	1	6.5
05/24/91		
805	1	9.8
05/26/91		
80	1	7.8
05/28/91		
76	1	8.7
06/03/91		
5	1	38.0
21	1	38.0
43	1	7.0
71	1	7.1
74	1	8.8
77	1	8.0
06/05/91		
735	1	7.0
75	2	8.0 8.2
06/06/91		
785	1	8.1
80	1	10.2
805	2	8.0 8.4
06/07/91		
78	1	8.4
785	2	7.8 7.8
79	1	7.9
815	1	7.0
1991 (continued)		
06/09/91		
76	2	8.0 9.4
77	1	6.7
06/11/91		
72	1	9.3
06/15/91		
57	1	7.3
06/19/91		
9	1	44.5

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1992		
03/03/92		
76	2	6.7 7.6
765	1	7.5
77	1	6.5
775	7	6.7 6.9 7.0 7.3 7.5 7.5 7.8
03/07/92		
712	2	7.2 7.5
715	2	7.2 7.2
725	1	7.1
73	1	8.0
735	4	7.3 7.7 7.7 7.9
74	2	7.2 7.8
755	6	7.1 7.2 7.2 7.3 7.5 7.7
76	3	7.4 7.5 7.5
765	4	7.4 7.4 7.5 7.5
77	3	7.4 8.0 8.0
775	2	7.7 8.0
03/11/92		
47	1	7.3
53	1	8.5
60	1	8.0
906	1	7.9
755	1	7.7
765	3	7.7 8.2 8.5
77	10	7.6 7.8 7.9 7.9 8.0 8.1 8.6 8.7 8.8 9.2
775	7	7.8 8.0 8.0 8.5 8.7 8.8 9.0
03/12/92		
70	2	7.4 9.1
03/13/92		
73	2	7.0 7.1
735	5	7.2 7.5 8.2 9.0 9.2
74	13	7.2 7.7 7.7 8.3 8.3 8.5 8.7 8.7 8.7 8.8 9.1 9.2 9.3
1992 (continued)		
03/15/92		
27	2	7.8 8.5
32	3	6.8 6.8 9.7
72	1	8.3
03/17/92		
70	1	7.7
713	1	14.2
715	1	8.7
716	2	8.2 8.5
72	1	8.3
725	1	9.3
735	2	7.0 9.0
745	1	8.6
75	1	9.2
755	4	7.6 7.7 7.7 9.4
76	1	10.0
785	1	9.5
79	1	9.9
03/19/92		
41	1	8.0
43	1	8.7
59	1	8.0
03/20/92		
26	3	7.8 8.5 8.7
919	1	7.6
921	3	8.2 8.2 8.6
923	1	8.0
03/23/92		
712	1	10.1
77	1	8.6
1992 (continued)		
03/27/92		
77	1	10.3
775	1	9.8
785	1	8.1
79	1	7.5
03/31/92		
29	1	11.9
70	1	13.7
712	1	11.0
713	1	12.8
716	1	10.3
775	1	7.5
78	1	7.7
04/04/92		
72	1	14.3
73	1	7.7
74	1	8.2
745	2	7.2 8.1
75	1	7.8
755	1	16.0
76	1	7.3
765	1	18.6
775	2	7.1 7.2
04/06/92		
70	1	7.6
712	1	7.0
713	1	6.6
717	1	7.7
725	1	7.9
73	1	7.8
735	1	7.4
74	1	7.8
1992 (continued)		
04/08/92		
32	2	7.4 7.4
37	2	7.0 7.3
72	1	7.5
735	4	7.2 7.6 7.7 7.8
75	1	8.0
755	2	7.0 7.1
765	1	7.5
77	1	7.6
04/10/92		
712	1	6.7
725	1	7.7
735	1	7.7
04/14/92		
37	1	7.2
725	1	7.5
74	1	7.8
04/16/92		
32	2	7.5 7.5
715	1	6.3
04/17/92		
745	4	7.1 7.5 7.7 7.7
75	10	7.0 7.0 7.0 7.2 7.3 7.3 7.4 7.5 7.5 7.6
755	5	7.5 7.7 7.8 8.0 8.0
76	2	7.0 7.0
765	1	7.4
77	1	29.5
775	4	7.4 7.5 7.5 8.0
78	1	7.7
785	1	7.1
79	6	6.7 6.7 6.8 6.8 6.9 7.5
795	1	6.9

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1992 (continued)		
04/18/92		
70	2	7.7 8.1
713	2	6.9 7.1
716	1	7.3
735	2	7.5 7.6
04/20/92		
32	2	8.2 8.2
59	1	7.1
715	1	7.3
716	1	7.3
75	1	8.3
755	2	6.8 7.4
765	1	7.8
77	1	7.8
78	2	7.1 7.9
785	1	7.6
795	1	7.0
04/21/92		
903	1	24.5
04/22/92		
70	3	7.7 7.7 7.7
713	1	29.3
717	1	7.6
75	4	6.6 7.0 7.5 8.3
755	7	7.2 7.2 7.3 7.4 7.7 7.7 7.8
76	1	7.0
77	1	8.3
775	1	29.5
785	1	7.6
04/24/92		
33	1	7.0
70	1	7.8
716	1	6.2
04/26/92		
74	1	7.2
77	2	7.8 35.0
04/28/92		
27	3	5.7 7.1 7.5
716	1	7.5
04/30/92		
713	1	7.8
735	1	8.0
05/02/92		
15	4	6.1 6.8 7.1 7.3
32	1	6.8
77	1	7.2
05/06/92		
716	1	7.0
05/08/92		
33	1	7.5
713	1	6.5
716	1	7.2
75	1	8.1
77	1	8.3
775	1	6.9
05/10/92		
79	1	8.2
05/12/92		
33	1	7.1
716	1	7.4
05/13/92		
76	1	8.9
05/14/92		
716	1	7.1
765	1	8.3
05/16/92		
745	1	6.7
775	1	6.8
05/18/92		
715	1	7.1
716	1	7.3
725	1	9.1
05/20/92		
716	1	6.8
05/21/92		
925	1	6.7
05/22/92		
43	1	6.8
05/24/92		
923	1	27.7
06/23/92		
716	1	7.4
1993		
03/11/93		
735	5	7.3 7.4 7.4 7.4 7.7
755	1	7.3
76	2	7.0 8.0
03/15/93		
32	1	7.6
70	1	8.0
71	1	6.0
716	1	7.8
78	1	7.5
785	1	7.3
03/16/93		
920	3	7.5 7.7 7.9
921	11	6.8 7.0 7.2 7.4 7.4 7.5 7.6 7.9 8.3 8.3 8.3
925	3	7.3 8.0 8.0
926	4	7.5 7.6 7.7 8.3
03/17/93		
718	2	7.3 7.7
03/19/93		
716	1	9.1
718	2	7.6 8.0
735	1	7.9
03/23/93		
05	1	7.5
21	1	10.5
27	1	7.6
49	1	9.0
51	1	7.8
713	1	7.2
716	2	8.0 9.3
718	2	7.8 9.0
720	1	9.0
78	1	11.0

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
03/24/93		
919	1	7.7
920	3	6.8 7.5 7.7
921	5	7.4 7.4 7.6 7.9 7.9
923	2	7.0 7.7
924	1	8.0
03/25/93		
718	1	8.9
719	1	8.5
03/27/93		
9	1	9.9
13	1	9.5
17	2	8.7 9.5
21	1	8.6
47	1	8.0
49	1	8.0
51	1	7.8
55	2	7.3 8.0
59	1	7.5
716	2	7.4 8.9
72	1	11.3
78	1	12.7
03/29/93		
719	1	8.5
03/31/93		
1	1	10.5
13	2	6.7 7.7
76	1	6.6
04/01/93		
515	1	7.8
67	1	4.7
716	1	6.7

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
04/04/93		
1	1	7.0
23	2	8.1 8.3
27	1	7.7
29	2	7.2 7.7
43	1	7.9
55	2	6.2 6.7
71	1	7.4
713	1	7.7
717	2	6.3 6.8
73	2	7.7 7.8
735	2	7.7 7.7
74	2	6.7 7.7
75	3	7.5 7.6 7.7
755	5	7.2 7.3 7.3 7.8 7.9
76	4	6.5 6.6 7.1 7.7
765	2	7.7 8.1
77	4	7.3 7.5 7.5 7.7
775	4	6.7 7.2 7.4 7.5
04/07/93		
37	1	7.5
04/08/93		
9	1	7.4
11	3	7.5 7.8 7.8
15	6	7.2 7.4 7.5 7.5 7.7 7.7
17	9	6.6 6.7 7.1 7.3 7.5 7.5 7.6 7.7 7.7
25	4	6.8 7.7 7.9 8.1
27	16	6.6 6.6 6.9 7.2 7.3 7.5 7.5 7.6 7.6 7.6 7.6 7.7 7.7 7.7 7.8 7.8
29	4	7.3 7.5 7.7 8.1
32	2	6.2 6.4
45	1	7.0
71	2	7.1 7.1
712	2	7.2 7.3

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
04/03/93 (continued)		
713	1	7.4
72	3	7.2 7.3 7.7
725	1	6.9
73	4	7.4 7.4 7.5 7.6
74	2	7.6 7.8
745	1	6.7
75	13	6.9 7.0 7.0 7.3 7.3 7.4 7.5 7.5 7.6 7.7 7.7 7.8 7.9
755	10	7.0 7.1 7.1 7.2 7.3 7.3 7.4 7.6 7.8 8.3
76	4	6.6 7.5 7.6 7.7
765	3	7.2 7.8 10.3
77	1	6.7
04/09/93		
26	2	7.7 7.8
46	2	7.2 7.8
903	3	7.7 7.7 8.1
923	3	7.3 7.5 7.7
940	2	7.3 7.3
04/12/93		
5	1	7.8
9	1	7.2
13	2	7.4 7.7
15	1	8.3
21	1	7.3
23	1	7.4
29	3	7.6 7.8 7.9
32	2	7.8 7.8
35	1	7.3
37	1	8.5
41	2	7.8 7.9
47	1	7.0
51	1	6.7
53	2	7.3 8.0
59	1	7.4

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
04/12/93 (continued)		
61	1	8.0
70	2	7.7 9.2
712	1	7.9
713	1	7.0
725	1	8.6
735	1	8.0
74	1	8.1
745	3	7.7 7.7 8.4
75	10	6.2 7.6 7.7 7.8 8.0 8.1 8.3 8.3 8.5 8.6
755	5	7.3 7.7 7.7 7.8 8.2
775	2	7.8 8.5
76	7	6.7 6.8 7.4 7.5 7.5 7.7 7.7
765	4	7.6 7.7 7.8 9.1
04/14/93		
716	3	7.3 7.6 8.0
04/16/93		
7	2	6.8 7.0
17	1	8.5
19	2	8.1 9.7
25	2	7.5 8.9
27	3	7.4 8.0 8.5
29	3	8.3 8.4 8.7
41	1	6.8
61	1	8.0
70	4	8.3 8.5 9.3 9.4
712	1	9.2
713	3	8.1 9.3 27.3
715	2	8.1 8.8
716	3	7.8 7.9 8.3
72	1	8.0
725	1	8.7
73	4	8.7 8.8 9.0 9.4
735	1	8.8
74	1	8.7

TABLE B-1

SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
04/16/93 (continued)		
745	8	7.2 7.6 8.2 8.2 8.4 8.4 8.4 8.5
75	2	8.3 8.7
755	3	8.1 8.3 9.5
76	7	8.3 8.3 8.6 9.1 9.3 9.5 9.8
765	1	8.6
77	9	7.8 8.0 8.4 8.5 8.8 8.8 9.6 10.0 10.5
775	1	7.3
04/17/93		
46	1	7.7
68	2	7.4 7.7
903	4	8.7 9.0 9.2 9.5
920	3	7.7 7.8 8.1
921	2	7.7 8.0
940	14	7.7 7.7 7.8 8.2 8.2 8.2 8.4 8.5 8.5 8.6 9.0 9.4 9.6 9.7
04/20/93		
11	1	7.7
17	1	8.5
19	3	9.7 9.7 10.5
21	1	10.3
23	5	7.6 9.1 9.8 10.7 11.0
25	3	9.3 10.6 27.7
29	12	8.7 8.7 9.0 9.1 9.5 9.5 9.5 9.7 9.7 10.2 10.2 10.5
32	1	10.3
37	2	6.0 6.7
51	1	8.6
59	1	7.2
61	1	8.0

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
04/20/93 (continued)		
70	1	10.0
71	5	9.7 10.1 10.1 10.6 10.8
713	6	8.2 8.7 9.0 10.2 10.8 11.3
716	1	10.1
717	3	8.8 9.3 10.6
725	2	9.5 9.6
73	2	8.0 9.3
74	1	10.4
745	1	7.0
76	3	6.8 8.5 9.0
77	3	9.0 10.0 10.2
785	1	9.7
04/24/93		
32	2	9.7 11.4
47	1	8.8
53	1	10.0
713	1	9.3
76	2	11.2 11.7
765	1	10.7
77	2	10.3 12.4
04/25/93		
903	1	7.0
04/28/93		
35	1	6.5
05/02/93		
32	1	13.7
43	1	7.2
713	1	20.3

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
05/06/93		
60	1	7.9
725	1	32.0
05/07/93		
29	1	8.5
32	1	6.6
05/10/93		
74	1	7.5
765	1	25.8
05/14/93		
73	1	26.7
77	1	7.0
05/26/93		
717	1	8.0
775	1	7.3
05/27/93		
920	1	7.2
06/03/93		
725	1	7.1
755	1	9.5
06/07/93		
15	2	7.2 8.0
33	1	7.0
720	1	6.8

Station No.	Number Caught	Sizes (mm Total Length)
1993 (continued)		
06/08/93		
55	1	7.6
06/11/93		
761	1	8.0
06/12/93		
940	1	7.6
735	1	7.4
75	1	7.7
735	1	7.9
07/01/93		
13	1	8.2
72	1	8.1
725	2	7.7 7.9
07/09/93		
67	1	50.0

TABLE B-1

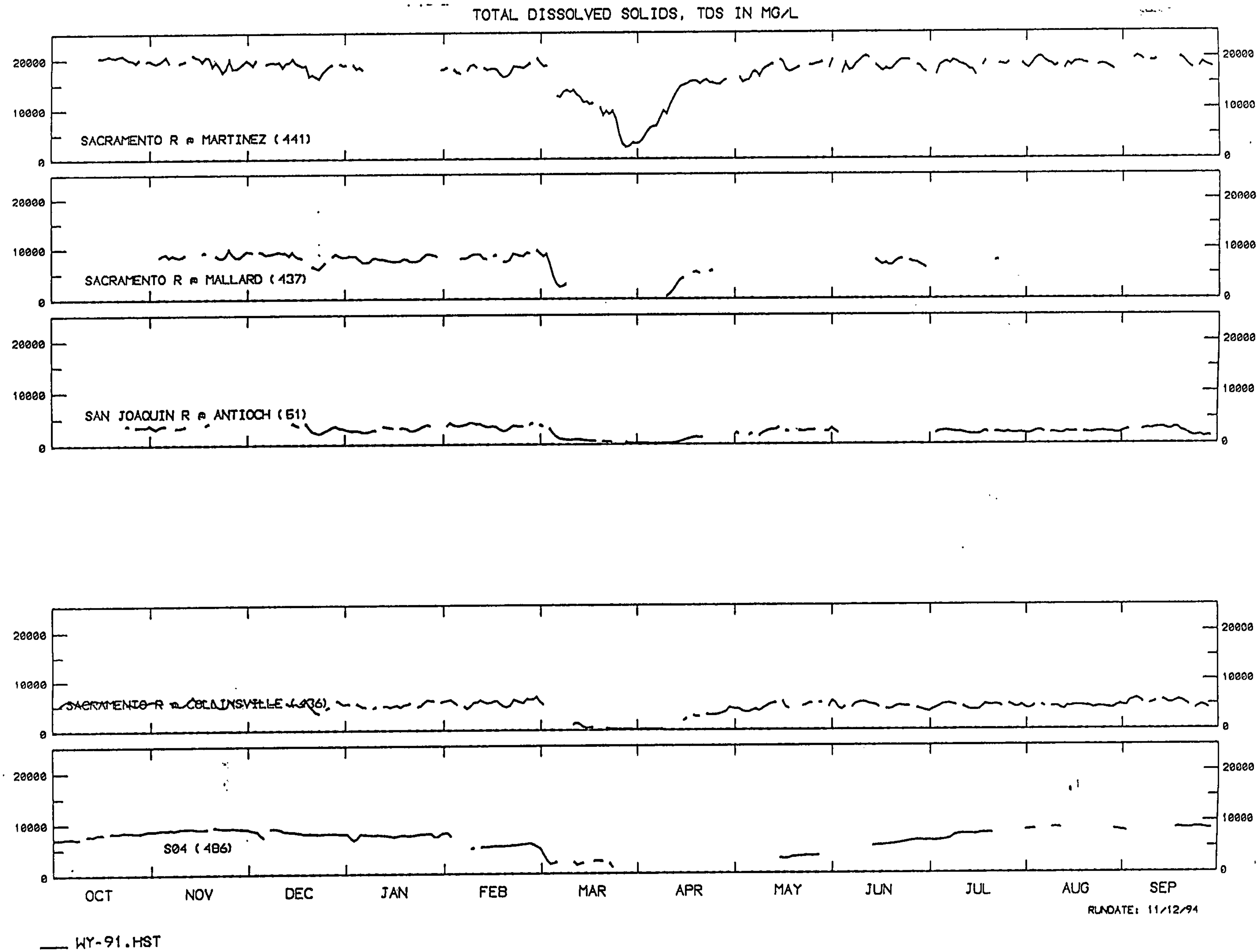
SPLITTAIL EARLY LIFE STAGES COLLECTED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY, 1988-1994

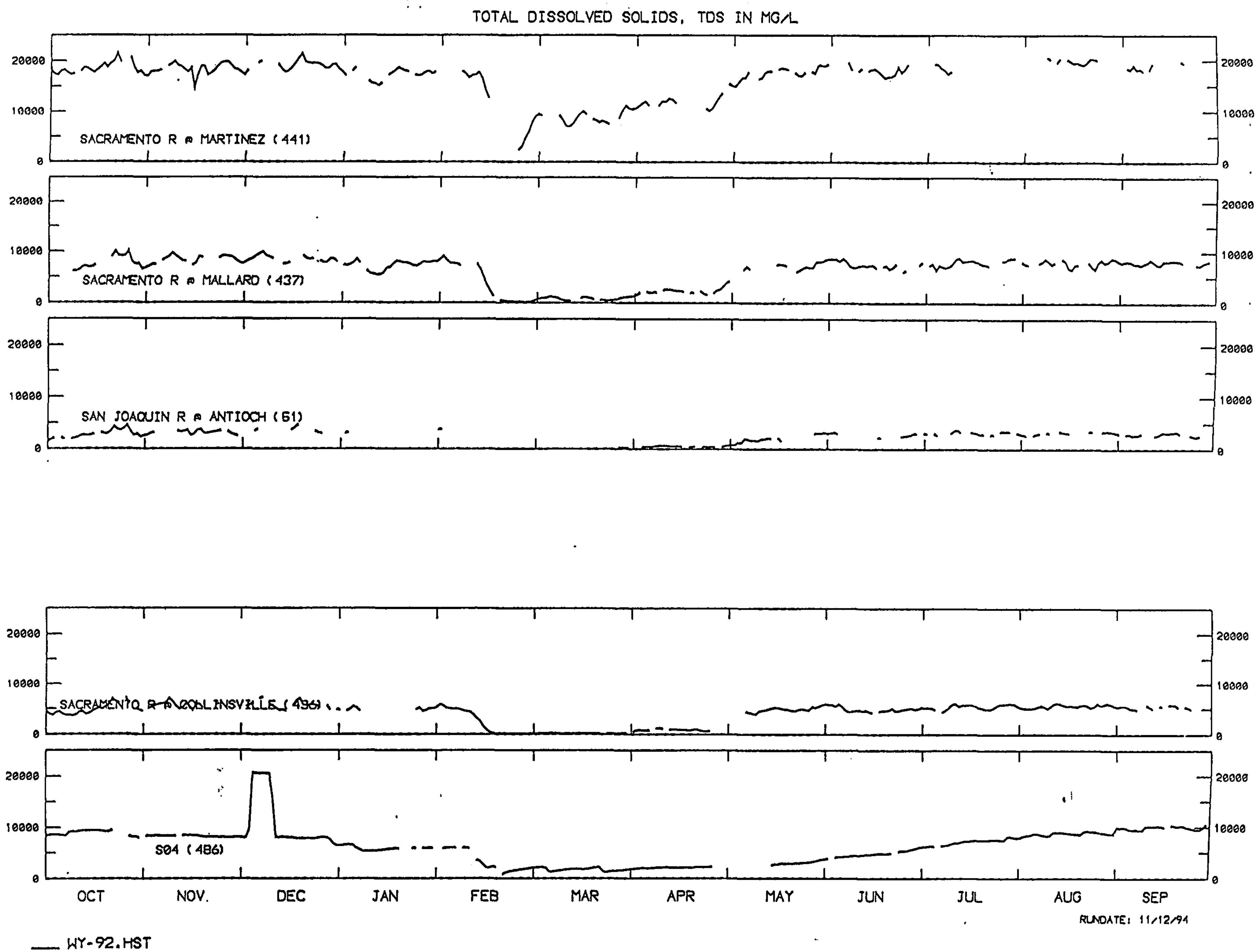
Station No.	Number Caught	Sizes (mm Total Length)
1994		
03/23/94		
76	1	6.6
03/27/94		
745	1	6.6
03/31/94		
32	1	7.1
712	1	6.4
04/04/94		
713	1	7.0
71	1	7.4
715	1	7.8
725	1	6.8
74	2	7.1 7.2
76	1	7.8
04/08/94		
71	1	7.7
72	2	6.6 7.3
735	3	6.3 6.4 7.3
745	2	5.9 7.2
04/12/94		
712	1	7.5
735	1	6.3
75	1	6.8
755	1	7.5
76	3	6.5 7.0 7.3
1994 (continued)		
04/16/94		
53	1	7.0
61	1	7.0
71	1	7.9
712	1	7.4
725	2	7.2 7.5
76	3	7.3 7.5 8.0
04/20/93		
70	1	7.0
71	1	8.2
735	1	7.3
74	1	6.7
745	2	7.7 8.0
04/24/94		
35	1	7.0
71	2	7.2 7.3
717	1	7.2
725	1	7.5
74	5	7.0 7.1 7.2 7.2 7.5
745	2	6.2 7.0
75	3	6.8 7.2 7.9
76	1	6.5
906	1	6.7
04/25/94		
903	2	7.0 7.2
1994 (continued)		
04/28/94		
72	1	7.4
725	1	7.6
735	1	6.8
74	1	7.8
76	1	7.3
05/02/94		
29	1	6.5
51	1	6.9
55	1	7.7
755	1	6.8
761	1	7.5
05/06/94		
716	1	8.2
73	1	7.9
74	2	7.6 8.0
745	2	7.5 7.6
75	1	7.9
755	3	7.1 7.4 7.7
05/14/94		
29	1	6.5
715	1	8.0
05/18/94		
27	1	7.2
1994 (continued)		
05/22/94		
76	1	6.4
05/26/94		
75	1	8.0
05/31/94		
716	2	6.5 7.2
06/03/94		
33	1	7.6
06/05/94		
720	1	7.0
06/12/94		
919	1	6.8

Appendix C

Salinity Monitoring Data from Suisun Bay, Water Years 1991-1993

Mean Tidal Day (25-hour) values are shown as parts per million Total Dissolved Solids


TOTAL DISSOLVED SOLIDS, TDS IN MG/L
SACRAMENTO R @ MARTINEZ (441)
SACRAMENTO R @ MALLARD (437)
SAN JOAQUIN R @ ANTIOCH (51)
SACRAMENTO R @ COLLINSVILLE (436)
S04 (486)
20000
10000
0
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
RUNDATE: 11/12/94
WY-91.HST



TOTAL DISSOLVED SOLIDS, TDS IN MG/L
SACRAMENTO R @ MARTINEZ (441)
SACRAMENTO R @ MALLARD (437)
SAN JOAQUIN R @ ANTIOCH (51)
SACRAMENTO R @ COLLINSVILLE (436)
S04 (486)
20000
10000
0
OCT
NOV.
DEC
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
RUNDATE: 11/12/94
WY-92.HST

TOTAL DISSOLVED SOLIDS, TDS IN MG/L