ON THE REFINEMENT OF THE USE OF SALINITY AS THE BASIS FOR A STANDARD TO USE IN CONJUNCTION WITH FLOW TO PROTECT IMPORTANT LIVING RESOURCES OF THE SAN FRANCISCO ESTUARY

Report of a Workshop
held at the
Bay Conference Center
Tiburon, California
17 December 1991

MARINE SCIENCES RESEARCH CENTER
STATE UNIVERSITY OF NEW YORK

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Marine Sciences Research Center

J.R. Schubel
Project Director

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ON REFINEMENT OF THE USE OF SALINITY AS THE BASIS FOR A STANDARD TO USE IN CONJUNCTION WITH FLOW TO PROTECT IMPORTANT LIVING RESOURCES OF THE SAN FRANCISCO ESTUARY

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INTRODUCTION

This report summarizes the principal conclusions and recommendations of a workshop held at the Bay Conference Center in Tiburon, California on 17 December 1991.

This was the second in a series of workshops sponsored by the San Francisco Estuary Project to develop the scientific rationale for setting an appropriate estuarine standard to manage freshwater inflow to the estuary to conserve and, if appropriate, to restore key living resources and important estuarine values and functions.

The first workshop was held on 27-29 August 1991. The report of that workshop is presented in MSRC Special Report 94. The goals of that workshop are briefly summarized in Exhibit 1 and its principal conclusions in Exhibit 2.

EXHIBIT 1

BRIEF RECAP OF GOALS OF THE FIRST WORKSHOP

27-29 AUGUST 1991

- To assess the usefulness of the position of the entrapment zone (EZ) as a tool for managing freshwater inflow to the estuary.

- If the EZ is found to be a useful surrogate for managing freshwater inflow, recommend appropriate positions of the EZ for different seasons of the year to protect important ecosystem values and functions.

- If the EZ is found not to be a useful management tool, a search should be made to find an appropriate estuarine phenomenon that is a surrogate for freshwater inflow and to explore how it could be used.

- To identify important and specific areas of research to reduce the uncertainty associated with the surrogate selected for managing freshwater inflow.

EXHIBIT 2

SOME CONCLUSIONS OF THE FIRST WORKSHOP

•The best "measures" for freshwater inflow standards are some combination of freshwater inflow and a diagnostic response of the estuary to freshwater inflow. The best measure of inflow is Delta outflow, but because this is not yet monitored routinely, dayflow is the next best measure.

•The position of the entrapment zone was rejected as the basis for a standard. It was rejected because of

* Uncertainty in its significance
* Difficulty in fixing its position
* Existence of multiple EZs at times

•Since the EZ is not an acceptable surrogate for managing inflow, what response of the estuary could be the basis for a standard for managing inflow to protect important ecosystem values and functions?

•Near-bottom salinity was selected from a variety of candidates. It was selected because

* Salinity is of fundamental ecological importance
* Salinity integrates processes of interest and importance
* Salinity measurements are easy, inexpensive and robust

EXHIBIT 2
CONTINUED

•What measure of salinity is most appropriate for development of a standard?

* The 2 ‰ isohaline at 1m above the bottom. While this value is somewhat arbitrary, the 2 ‰ near-bottom isohaline is a diagnostic index to the leading (landward) edge of the entrapment zone and the seaward limit of very low salinity habitat.

•What is the appropriate standard?

* The position of the 2 ‰ near-bottom isohaline for each season to provide an appropriate level of protection of important living resources and ecosystem values and functions.

•Recommended approach for setting a standard based on salinity.

* Develop and refine seasonal matrices of the responses of the estuary and biota to different positions of the 2 ‰ near-bottom isohaline and associated inflow.

EXHIBIT 2

CONTINUED

* Develop and refine the graphic tool that portrays the relationship of the success of key species to the location of the 2 ‰ near-bottom isohaline

It is important to point out that the entrapment zone was not rejected as a surrogate for freshwater inflow because the location of the entrapment zone and the strength of its characteristic processes are not coupled to freshwater inflow. They are. Nor was the entrapment zone rejected because it is unimportant to important ecosystem values and functions. It is. The entrapment zone was rejected as a tool for managing freshwater inflow to the estuary because the relationships of EZ position and EZ processes to freshwater inflow are complex and are not sufficiently well understood to use the position of the EZ as a routine management tool. Much more research will be needed before the EZ can be used as a surrogate for managing inflow.

In the process of evaluating and rejecting the EZ as a management tool, the first workshop affirmed that while it rejected the EZ, it did not reject the value of having a diagnostic measure of the response of the estuary to changes in freshwater inflow to use in conjunction with inflow. Participants were nearly unanimous in their agreement that an estuarine response was desirable, that the measures should be simple and inexpensive to determine accurately, that it should be understandable to the public and that it should, of course, be coupled closely and unambiguously to freshwater inflow.

After evaluating a number of alternatives, the first workshop settled on salinity measured at 1m above the bottom as the best estuarine surrogate for managing freshwater inflow.

Salinity is an appropriate measure of the response of the estuary to changes in freshwater inflow upon which to develop a standard for managing inflow. A salinity standard should be used in conjunction with flow. The standard proposed by the first workshop is an appropriate one -- the position of the 2 ‰ near-bottom isohaline as a function of season. The reasons for selecting salinity as the basis for a standard were discussed in detail in the report of the first workshop. They were reaffirmed by the majority of the participants in the second workshop.

Participants, particularly the academic scientists, did not feel that they should recommend specific salinity standards, i.e. they did not think it was appropriate for them to recommend specific positions of the 2 ‰ near-bottom isohaline. They emphasized that they thought they could contribute more to the process of developing the information needed to set standards by returning to the matrix strategy identified in the first workshop. This strategy called for the development of a matrix for each season which arrays a variety of responses of the Bay to different freshwater inflow and associated locations of the 2 ‰ near-bottom isohaline scenarios. The argument is that armed with this information, decision makers could identify a zone within which to keep the 2 ‰ isohaline to increase the probability of producing a set of desired responses. Or put another way, decision makers would know how the estuary and its living resources would respond to a range of combinations of flows and associated positions of the near-bottom 2 ‰ isohaline and would, therefore, be in a position to select the combination that would promote the desired results.

Near-bottom salinity would become the basis for an estuarine standard to be used in managing freshwater inflow to the estuary. The standard would be expressed as a geographic position within the estuary for each season of the 2 ‰ isohaline at 1m above the bottom. The seasonal positions of the 2 ‰ would be selected to protect important living resources, the estuarine ecosystem and important societal values and uses. In the first workshop participants developed a matrix for zeroing in on a zone within which to locate the 2 ‰ near-bottom isohaline to achieve desired environmental results. These four (one for each season) locations would become the seasonal salinity standards. The matrix is an array of important environmental and biological properties as a function of riverflow and associated position of the 2 ‰ isohaline, Exhibit 3.

While a matrix is useful and indeed a powerful way of summarizing important information for management decisions, it is not a very elegant way of presenting the integrated relationship of position of the 2 % isohaline with environmental benefit. The first workshop developed a graphical tool for this purpose, Exhibit 4. This conceptual curve indicates that there is a zone within which progressive seward displacement of the 2 ‰ isohaline -- a phenomenon which is achieved by increasing freshwater inflow -- produces a fairly rapid increase in biological benefits. Upstream of this zone there is little biological benefit and downstream there may even be a loss of biological benefits. The curve developed by the first workshop is conceptual. Testing the concept with real data became the basis for the second workshop.

EXHIBIT 3

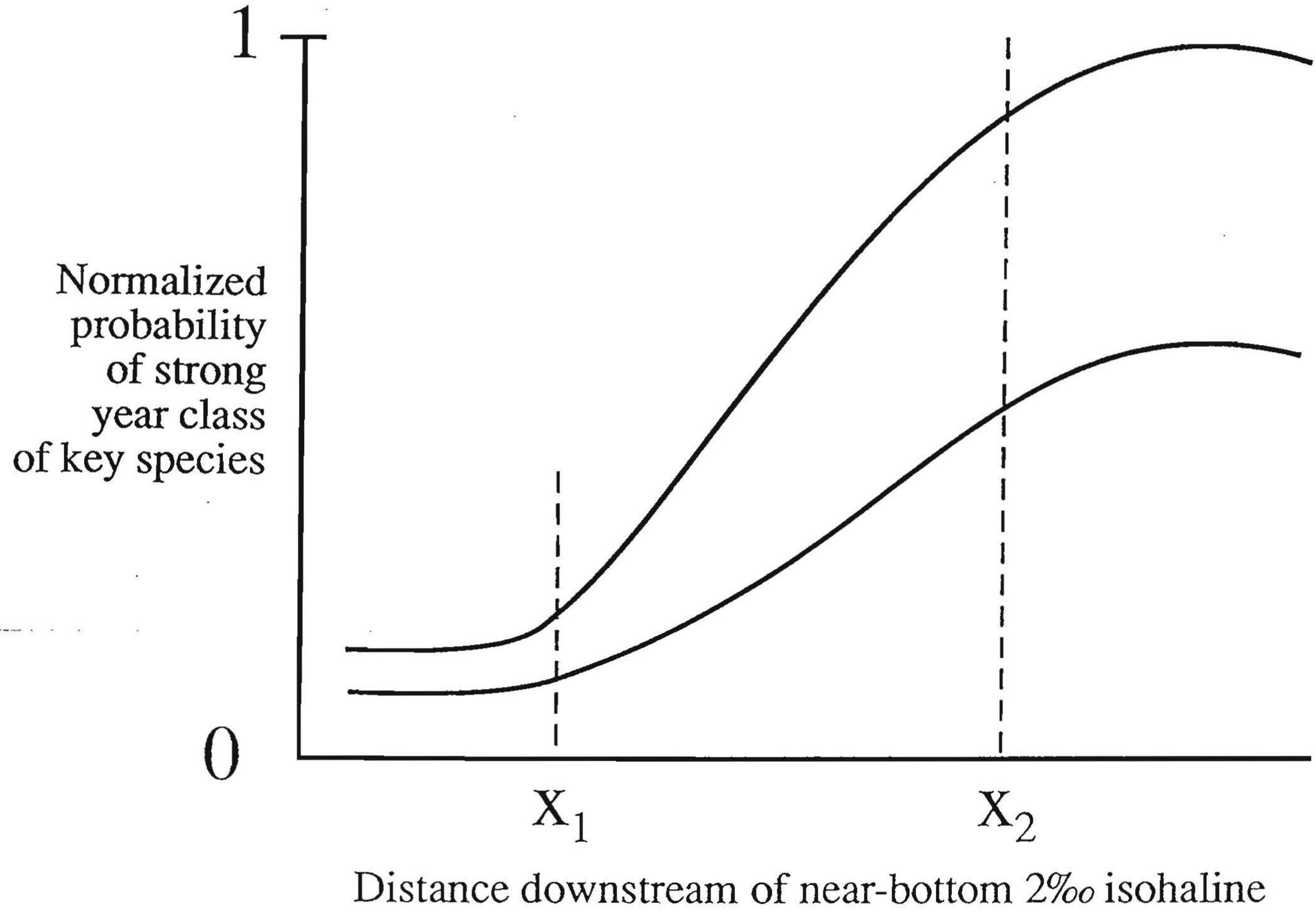
THE MATRIX

AN EXAMPLE OF A MATRIX TO USE IN IDENTIFYING THE APPROPRIATE POSITION FOR LOCATING THE 2 ‰ NEAR-BOTTOM EFFECTS ON VARIOUS PROCESSES AND PROPERTIES BY PLACING ISOHALINE AT DIFFERENT LOCATIONS WITHIN THE ESTUARY (SEASON ___)

PROCESSES AND PROPERTIES	SALINITY MEASURED 2PPT + 1 M FROM BOTTOM		
	LOCATION 1 (Farthest Upstream)	LOCATION 2	LOCATION 3 (Farthest Downstream)
FW FLOW			
FW & EZ HABITAT			
TURBIDITY MAXIMUM			
SUSPENDED SEDIMENTS Mass Lost to System Budget			
INPUTS AND FATES OF PARTICLE-BOUND TOXICS			
VOL. AGR. RETURN WATER			
PHYTOPLANKTON Prim. Productivity Biomass Distribution Abundance			
NEOMYSIS			
MARINE & EST. FISHES			
UPSTREAM LIMITS Vol. of habitat Abundance Suscept. to Delta Div. To entrainment Survival of yr. class Food supply Migration			
TIDAL MARSH			
MANAGED MARSH			
INVASION BY MARINE SPP.			
ENDANGERED SPP.			

EXHIBIT 4

A Graphical Tool for Selecting a Salinity Standard for San Francisco Bay and Delta



Wim Kimmerer was engaged by the San Francisco Estuary Project office to develop, for a variety of important species, relationship of some measure of the biological success of those species as a function of position of the near-bottom 2 ‰ isohaline. His results are discussed in the following section.

The seasonal positions of the 2 ‰ isohaline -- the seasonal salinity standard -- was intended to be an upstream limit only. If the 2 ‰ isohaline were "parked" at a prescribed location throughout a season, the benefits of having a standard would be compromised. The downstream limit should be unconstrained and efforts should be made to ensure variability.

ANALYSES PERFORMED FOR THE SECOND SFEP WORKSHOP

Wim Kimmerer

17 December 1991

The outcome of the August workshop was a general agreement on the following:

1. The utility of the position of the 2 ‰ isohaline as an index of habitat location in the estuary.
2. The idea that habitat location could be as good a predictor of various measures of system response as flow, and that it would be much easier to measure than flow.
3. A matrix of qualitative or quantitative system responses to various categories of 2 ‰ position, different for each season.
4. The form of the expected response of various species to position of the 2 ‰ isohaline.

The actual responses in item 3, and the numerical values of the responses in item 4, could not be determined without a reanalysis of the data. I was tasked at the conclusion of the first workshop with developing the numerical responses in item 4. The objective of this work was to convert existing relationships between year class strength of various species and flow into relationships with position of a salinity value of 2 ‰ at the bottom.

The analysis had two components: an analysis of the historical pattern of position of 2 ‰, and an analysis of the responses of various species to this position.

SALINITY POSITION

In general, the approach was to use surface specific conductance from the continuous monitoring program to establish a long-term record of salinity at a particular site (Mallard Slough near Chipps Island, river km 75). This was then related through regression with the position of the 2 ‰ isohaline from grab samples. Under high flow conditions when the Chipps Island salinity was near 0, a regression with log flow was used instead.

Sources of data

1. Continuous monitoring sites for conductivity, particularly that at Mallard Slough across from Chipps Island. Data are for 1984-1991, but contain many gaps. For the most part I used daily means of the hourly data. Although tidally filtered data would have been better, the departures from monthly means would not be great.

2. Grab samples from the Department of Water Resources (DWR) and the Department of Fish and Game (DFG), mainly at the surface but also at the bottom from DFG since 1981. Note: these samples were taken near high slack water and this may have introduced bias.

3. U.S. Bureau of Reclamation (USBR) samples from surface and bottom taken between 1969-1981.

4. U.S. Geological Survey (USGS) and U.S. Bureau of Reclamation (USBR) Seabird profiles in 1985-6.

5. Bottom salinities from current meters in Suisun Bay in 1978-80.

6. A few additional data from James Cloern (pers. comm.)

7. Daily DAYFLOW estimates of Delta outflow.

8. Tidal range for Suisun Bay (mean high - mean low) predicted from the first 6 harmonic constants; the latter were obtained from the Cheng/Burau tidal model.

Analysis and results

1. First I determined the relationship between outflow and tidal range and salinity at the Mallard Slough continuous monitoring (CM) station. This eventually resulted in a single regression equation including flows lagged 3, 6, and 9 days, daily tidal range, and various second- through fourth-order terms (r^2 = 0.73).

2. Next I used this regression to fill in gaps in the continuous monitoring (CM) data set. Figure 1 shows the data for calendar year 1986 including observed data, model predictions, and filled-in values. Note that there are time periods over which the model over-predicts or under-predicts the salinity. Over-prediction is greater in summer months and under-prediction greater in winter. I suspect that this may be due at least in part to errors in estimation of flows at low

values. In addition, differences in sea level due to seasonal patterns of atmospheric pressure and wind speed and direction could also account for some of these differences (note that I used predicted tides in the regression).

3. All of the data on salinity at (within 1 km of) Chipps Island were combined to permit a check of the regression model and to get estimates of means for each month from 1968 to 1991. Monthly means were obtained from (1) the grab sample data taken at the bottom, (2) the surface sample data corrected to bottom salinity based on the location and the surface salinity, and (3) the filled-in CM data. The best estimate for each month was a mean of the grab samples if available, or if not the CM data. Before 1984, this was replaced with the CM data predicted by the regression.

4. Position of the 2 ‰ isohaline at the bottom was estimated in a similar way. Grab samples with values between 1.5 and 2.5 were used along with a regression between salinity at Chipps Island and position of the 2 ‰ isohaline. For high flows, when salinity at Chipps was essentially zero, we developed a regression between flow (lagged 6 days) and position of the 2 ‰ isohaline. The point at which these two estimates crossed each other (and the data) was used to demark where the two regressions were used to fill in the 2 ‰ data.

The results of this analysis are summarized in Figures 2-5. Salinity at Chipps Island was useful for predicting position of 2 ‰ as long as that was landward of 70 km; seaward of that position flow had to be used. The relationships we obtained were within the scatter of the data from those determined by Williams and Arthur (Figure 2).

Two problems with these analyses were that I did not use the USBR long-term continuously monitored salinity data, and that the grab samples are much more frequent in the latter part of the data set. (There are some samples missing from this though, and I have to determine why).

SYSTEM RESPONSES

Sources of data

1. DFG Bay study: abundance indices of longfin smelt, Bay shrimp, starry flounder using a variety of kinds of sampling gear and by various estimates.

2. DFG striped bass study: various measures including Peterson egg abundance indices, young-of-the-year (YOY) indices, midwater trawl juvenile indices, and ratios among these.

3. Delta smelt abundance indices from the DFG fall midwater trawl samples.

4. Neomysis mercedis abundance from DFG zooplankton study.

5. Chinook salmon smolt survival through the Delta from USFWS.

Data used

1. Bay shrimp annual abundances weighed by area.

2. Starry flounder annual abundances weighted by area and log-transformed.

3. Lonfin smelt annual abundances weighted by area and log-transformed.

4. Striped bass log juvenile abundance index.

5. Striped bass log ratio of YOY to Peterson egg abundance index.

6. Chinook salmon survival through the Delta.

7. Neomysis mercedis log abundance.

Analysis

Volume of habitat, determined as the distance between surface salinities of 1 and 6 ‰, were determined from the DFG zooplankton data set (Figure 6). These values do not show as strong a relationship with position of 2 ‰ as orginally expected; however, a better relationship could be obtained with the CM station data.

I used linear regressions in most cases to get the linear model with the highest r^2 value, subject to using the data most relevant to the species and life stage being examined (Figures 7-16). The chinook salmon and Neomysis data were analyzed using position from the same month. Otherwise, I sought the highest r^2 not to get a more significant fit (since any selection of relevant months would have been significant), but to get the most precise rendition of the relationship. This approach provoked some argument at the workshop, as did the use of only linear relationships.

Two of the graphs (Figures 7 and 9) include broken-line relationships that could serve as alternatives to the regression. This in turn will be superseded by the analysis Alan Jassby has suggested, in which the form of the curve is dictated more by the data. These are presented here as an illustration of how alternative analysis may lead to different conclusions.

In the case of Neomysis it was clear that the response was complex, so I used three line segments, chosen by eye and fitted by calculating means of two segments of data containing no apparent variation with salinity field (Figure 17).

Combination of target species

The use of linear (or log-linear) models was criticized by workshop participants on several grounds, so I did not present the following analysis, which is based on these models. Briefly, I was looking for a method for combining the analytical results from the previous section.

First I scaled each of the individual responses to a maximum of 100% (Figure 18). Then I concocted a weighting factor with two parts: a userchosen weighting factor and a seasonal weighting factor. These are contained in a spreadsheet containing a table (Table 1) of user-defined values for the weighting factors and the months during which those species/stages are affected by flow. The spreadsheet weights each species by the proportion of the chosen season during which it is affected. For example, Crangon franciscorum is affected from February through May (an arbitrary choice on my part), so its seasonal weighting factor is 0.67 for winter and spring and 0 for the remainder of the year; if all months are chosen, the seasonal factors are all 1.

TABLE 1. SPREADSHEET FOR COMBINING RESPONSES OF TARGET SPECIES

	SPECIES/STAGES INCLUDED	WEIGHTING FACTOR	MONTHS START	MONTHS END	OVERALL WEIGHTING
CF	CRANGON FRANCISCORUM ABUNDANCE	0.5	2	5	0.0%
SF	STARRY FLOUNDER ABUNDANCE INDEX	1	1	5	0.0%
LS	LONGFIN SMELT ABUNDANCE INDEX	1	1	5	0.0%
BJ	STRIPED BASS JUVENILE INDEX	1	1	12	89.7%
BY	STRIPED BASS SURVIVAL TO YOY	1	1	4	0.0%
SS	SALMON SMOLT SURVIVAL THRU DELTA	2	4	6	0.0%
NE	NEOMYSIS ABUNDANCE	0.2	4	10	10.3%
	SEASON (ENTER 1, 2, 3, 4, OR 0):	4			

WINTER = 1 (JAN-MAR)
SPRING = 2 (APR-JUN)
SUMMER = 3 (JUL-SEP)
FALL = = 4 (OCT-DEC)
ALL = = 0

The response of this model to changes in factors are illustrated in Figures 19-27. The figures show the current model output along with that of the previous figure.

Conclusions

Although there are problems with this analysis I think it will prove robust with a bit of improvement. First, the position-flow relationship, although incorporating a good deal of scatter, is not notably different from those determined by others. Second, the fishery relationships all show the same response, in a qualitative sense, to changes in position of the 2 ‰ near-bottom isohaline. Third, these responses are similar to those found for flow, and have similar predictability in most cases.

It is important to point out two aspects of this work not generally understood at the workshop. First, salinity position is used as an index of habitat location, not as an index of stress or other physiological condition. Thus, it is appropriate to consider the location of the 2 ‰ salinity isohaline as indicative of conditions not only in that vicinity, but elsewhere in the estuary. Second, the choice of species to analyze was based mainly on known relationships with flow, but this encompasses most of the estuarine species for which good abundance data exist. The notable exception is Delta smelt, for which some additional analysis is warranted.

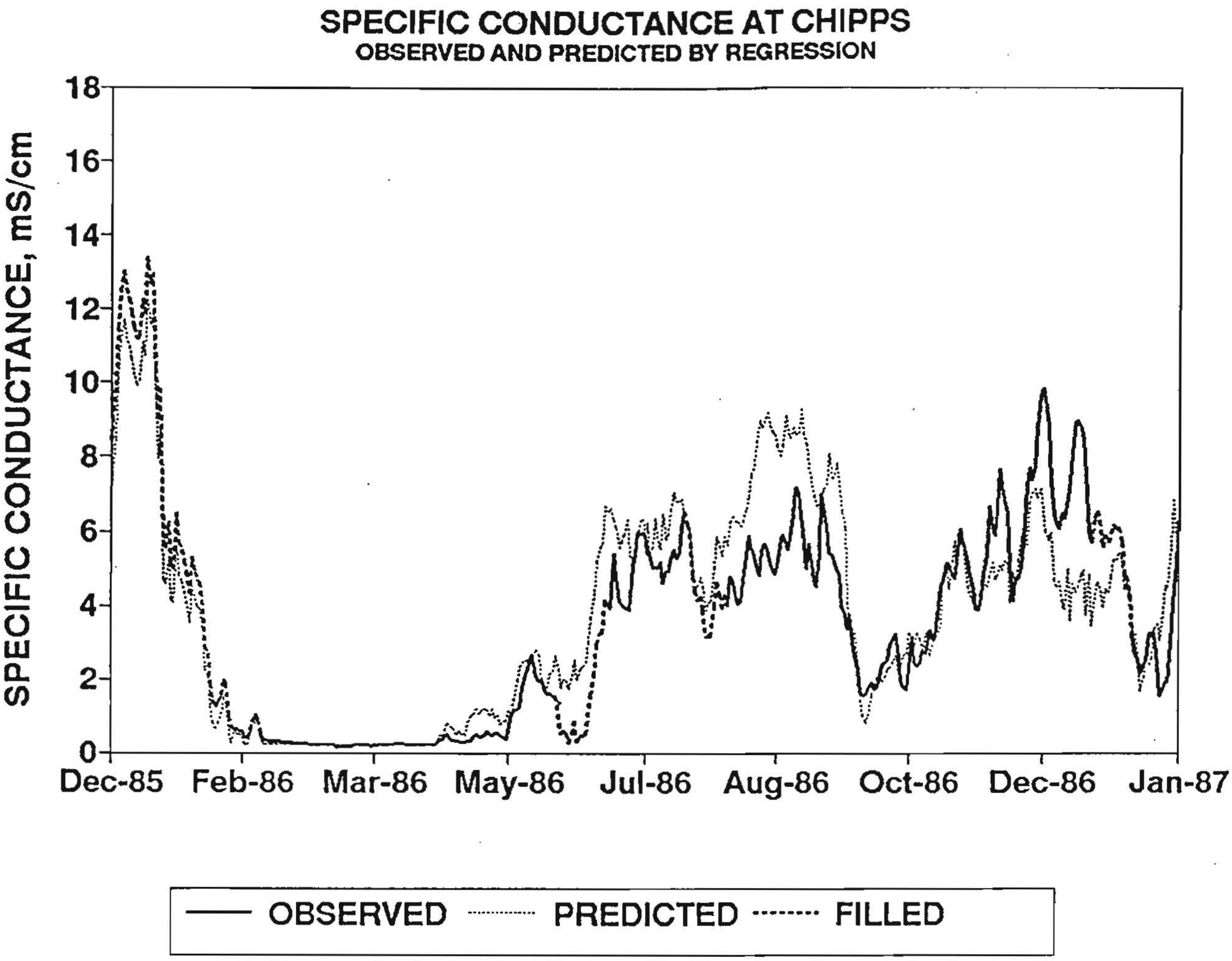


Figure 1. Continuous surface specific conductance at Mallard Slough: observed data, prediction of regression on flows and tidal range, and observations filled-in using the predictions.

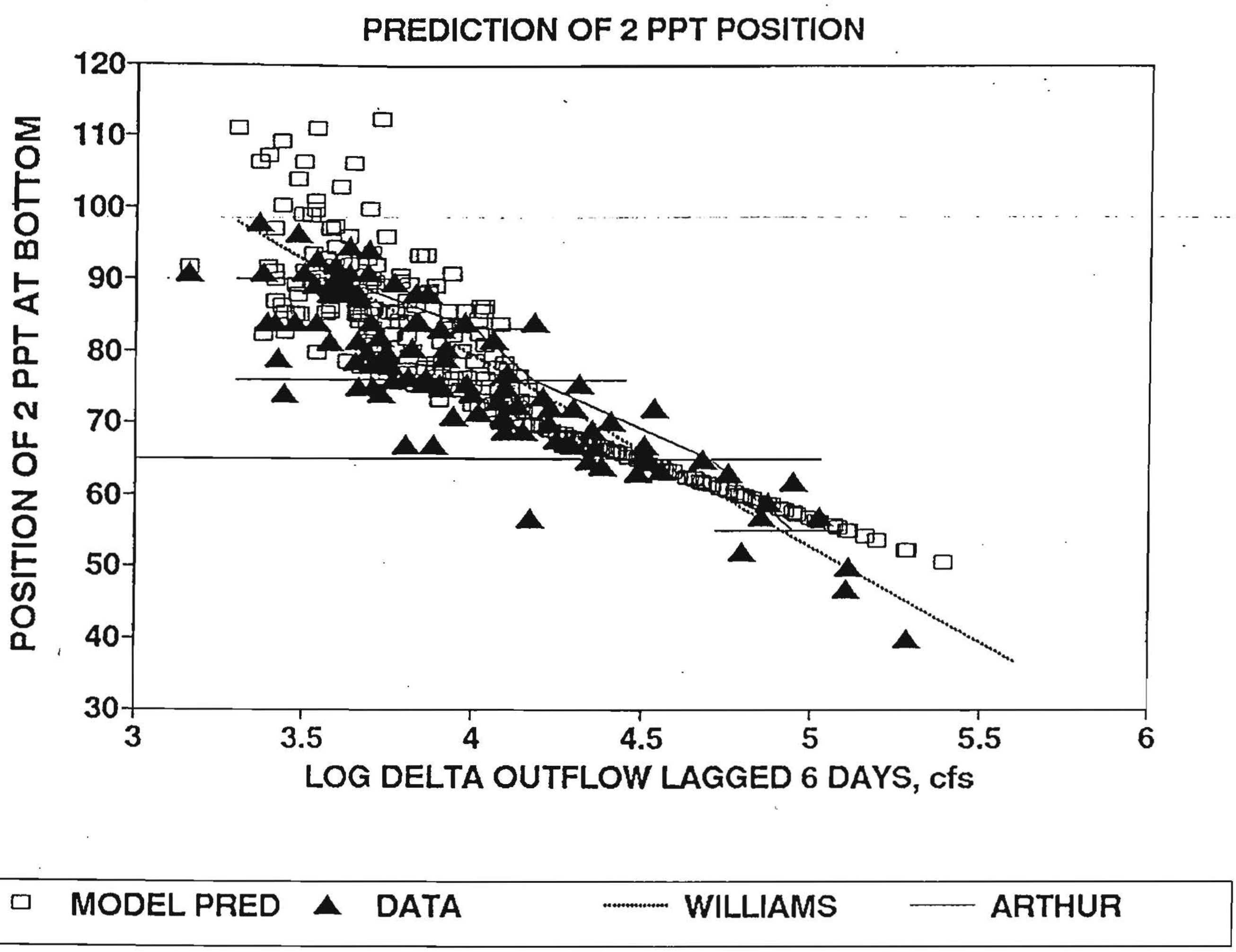


Figure 2. Various predictions of the position of the 2 ‰ near-bottom isohaline. Triangles are bottom grab samples used in this analysis. Open squares are predictions of monthly means from the model. The regression model of Williams and Hollibaugh (1989) is shown for comparison, as is the range of flows over which each position was observed by Arthur (1987).

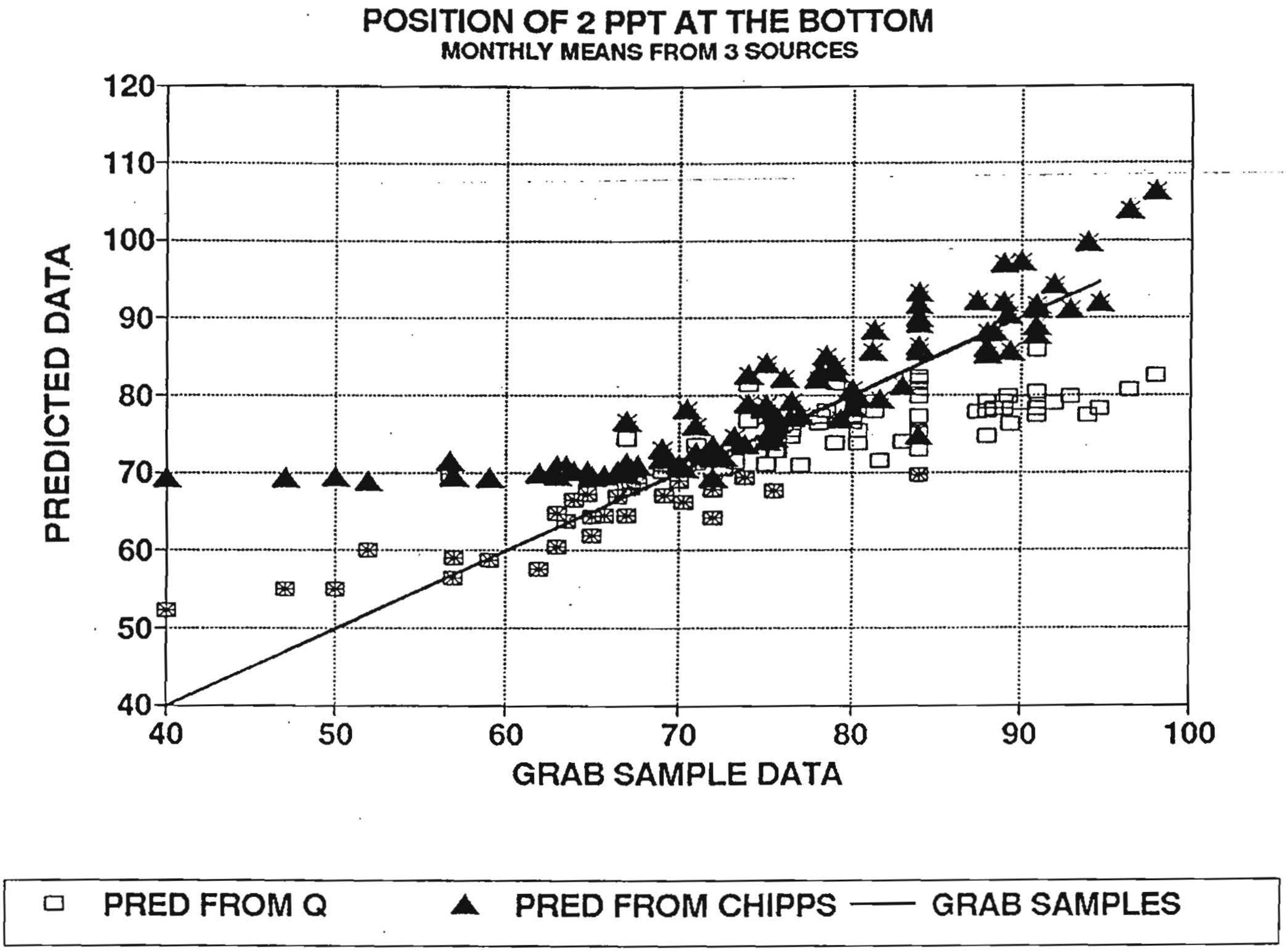


Figure 3. Position of the 2 ‰ isohaline near the bottom from grab samples vs. predictions using the Chipps Island salinity data and flow.

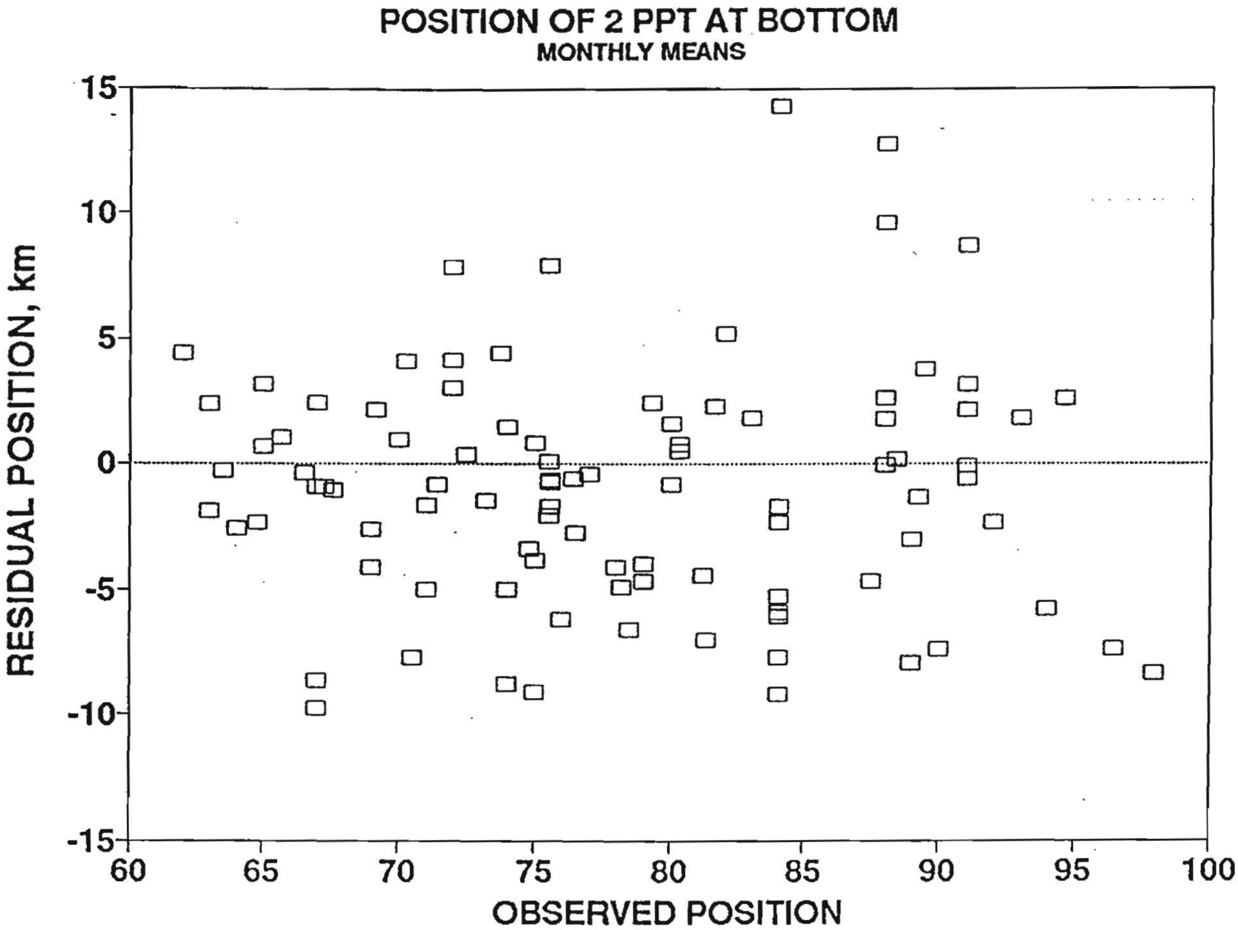


Figure 4. Residuals of the predicted 2 ‰ position near the bottom for months when grab sample data were available.

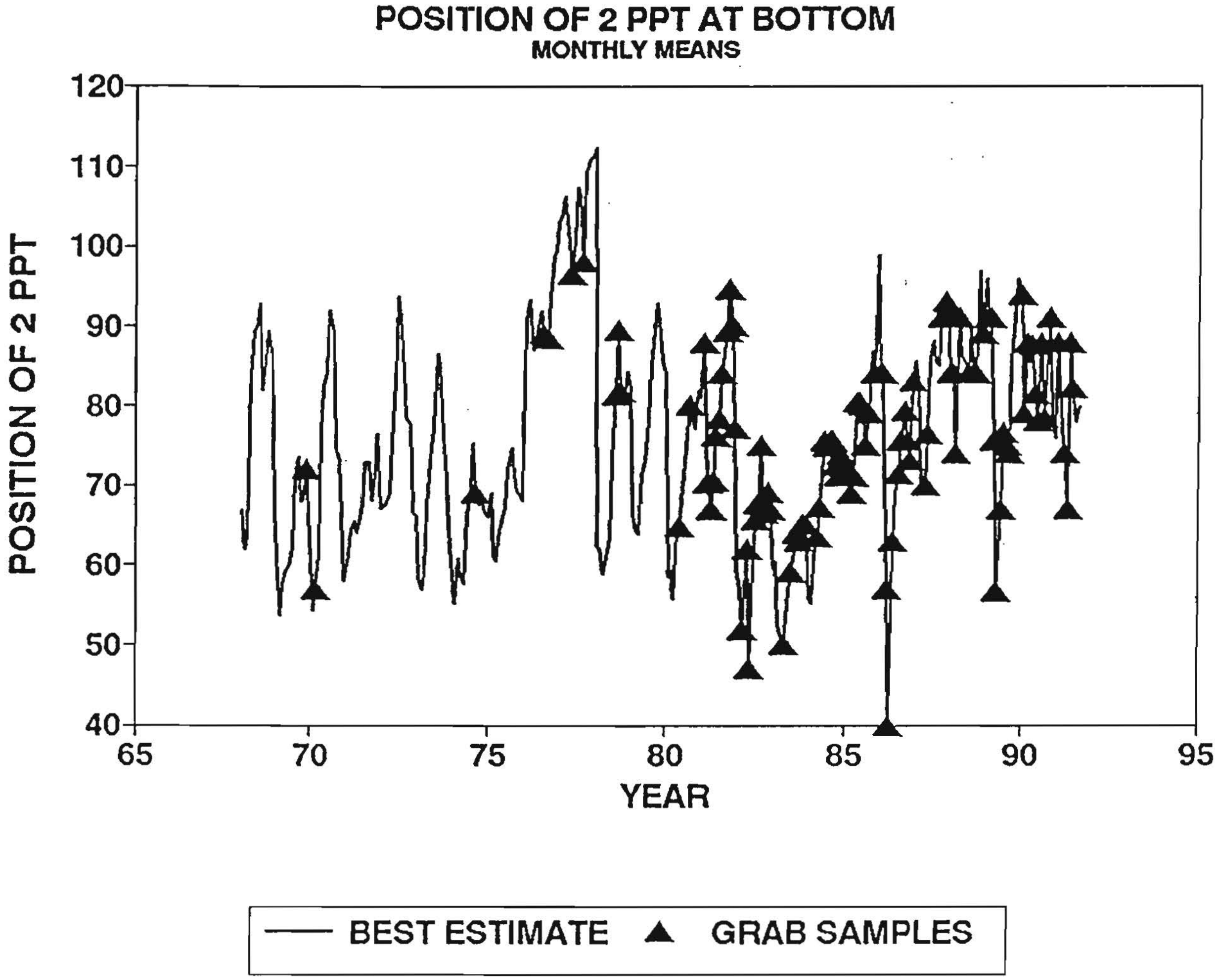


Figure 5. Time course of the best estimate of position of the 2 ‰ near-bottom isohaline.

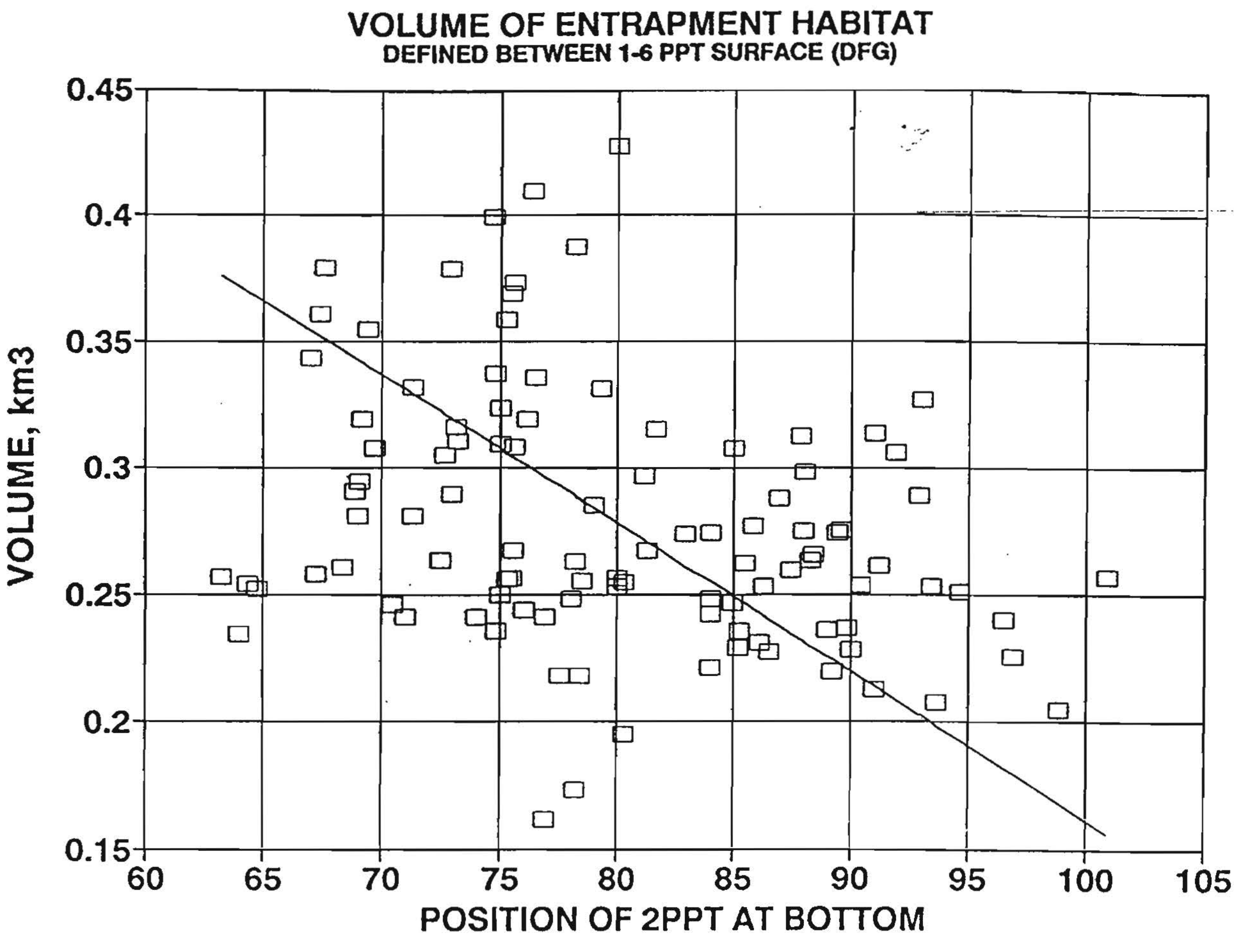


Figure 6. Volume of habitat between surface salinities of 1 and 6 ‰ plotted against position of 2 ‰ near the bottom. The straight line is a geometric mean regression (r^2=0.093).

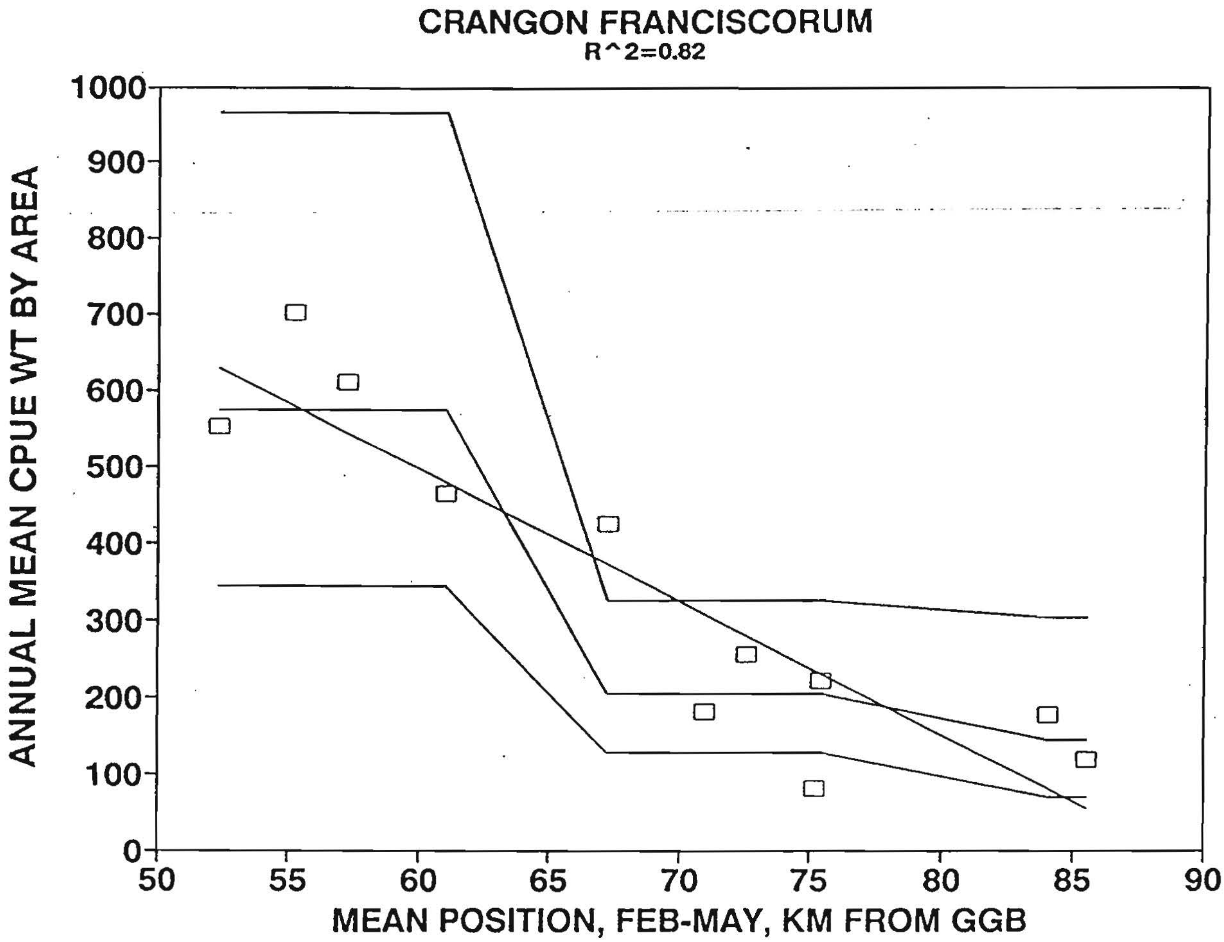


Figure 7. Crangon fransiscorum. Annual mean area-weighted CPUE vs. position of the near-bottom 2 ‰ isohaline. The linear regression has an r^2 of 0.82. The broken lines represent an alternative analysis using "binning" of the data.

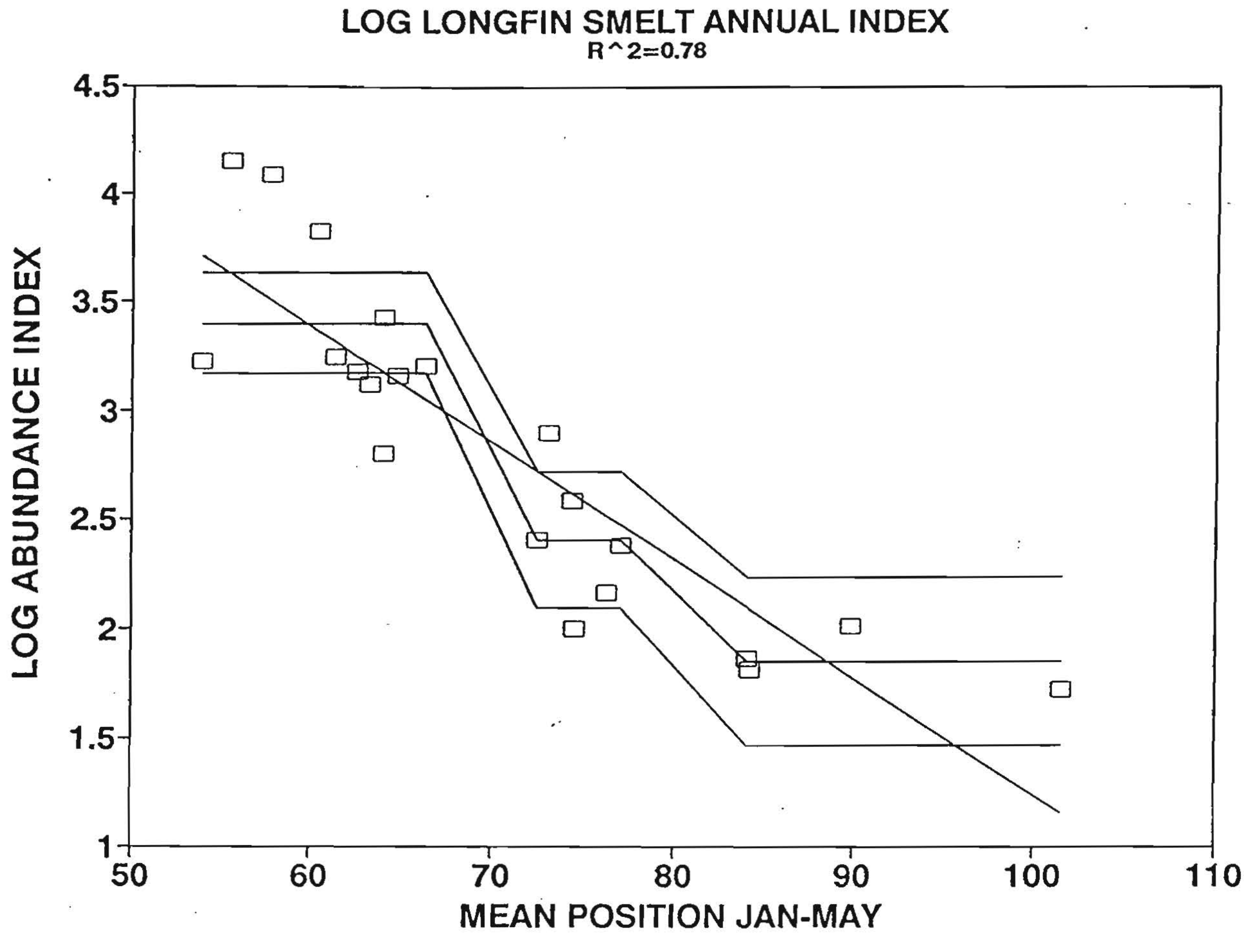


Figure 8. Longfin smelt. Annual index of abundance vs. position of the near-bottom 2 ‰ isohaline. The linear regression has an r^2 of 0.78. The broken lines represent an alternative analysis using "binning" of the data.

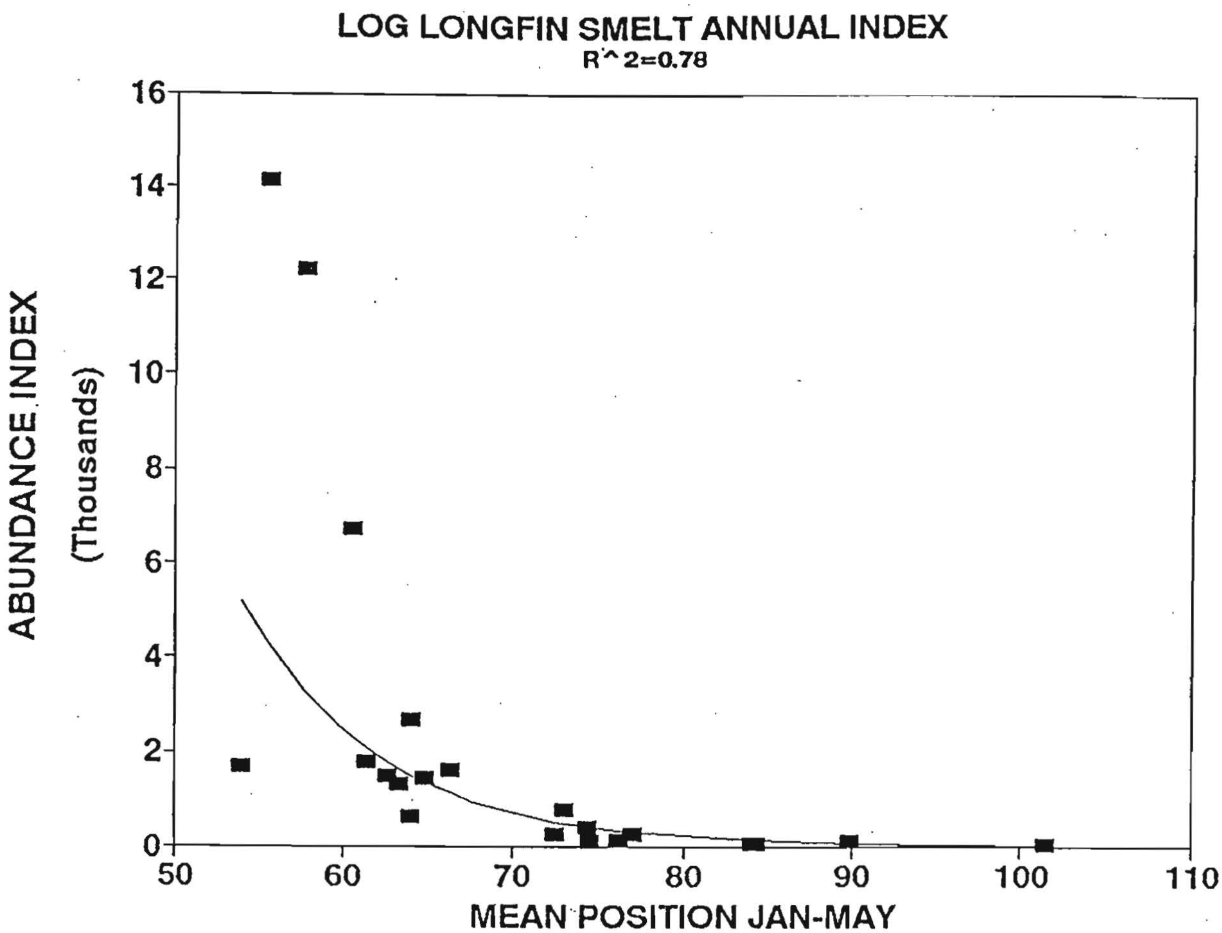


Figure 9. Longfin smelt. Data from Figure 8 recast as antilogs.

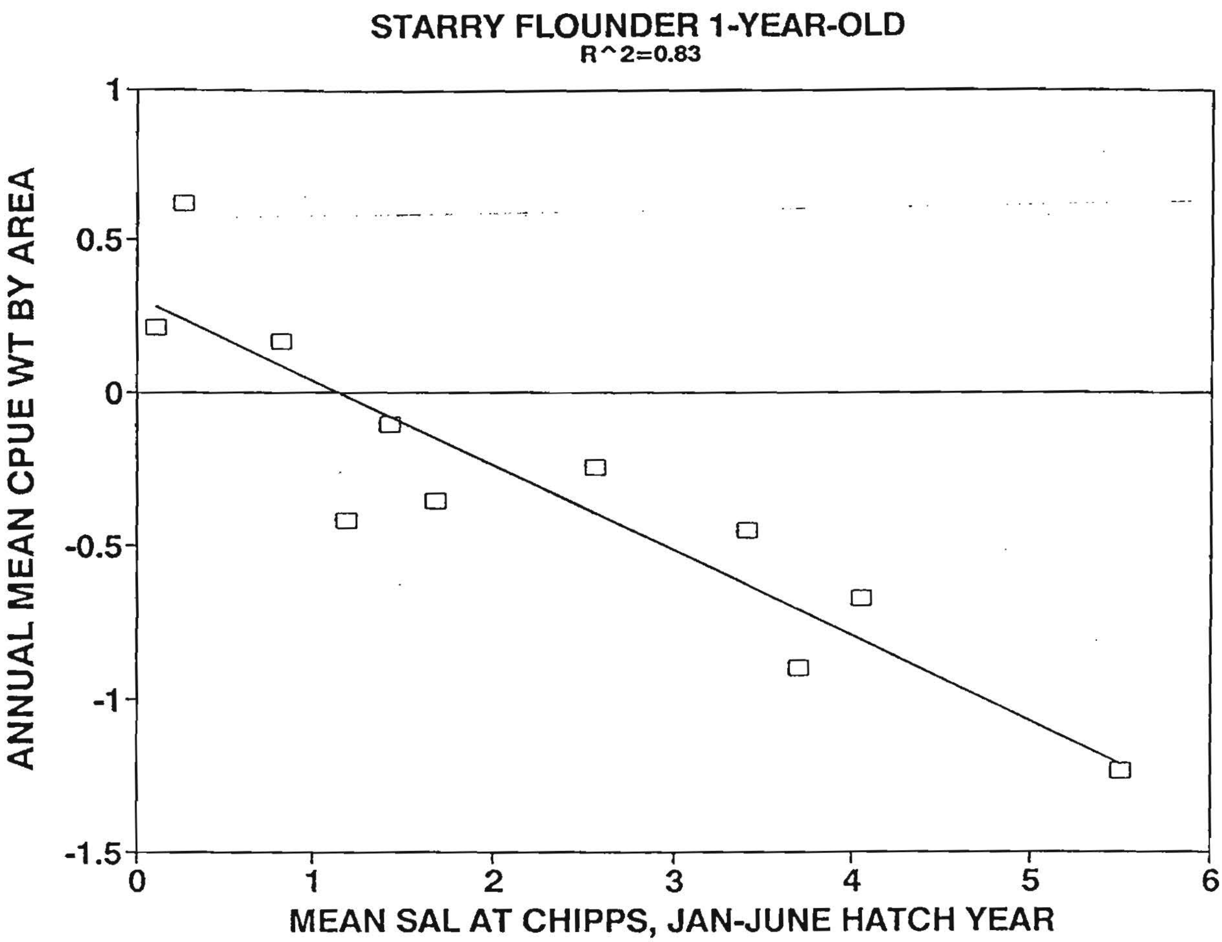


Figure 10. Starry flounder 1-year-olds. Annual index of abundance vs. position of the near-bottom 2 ‰ isohaline in the previous year.

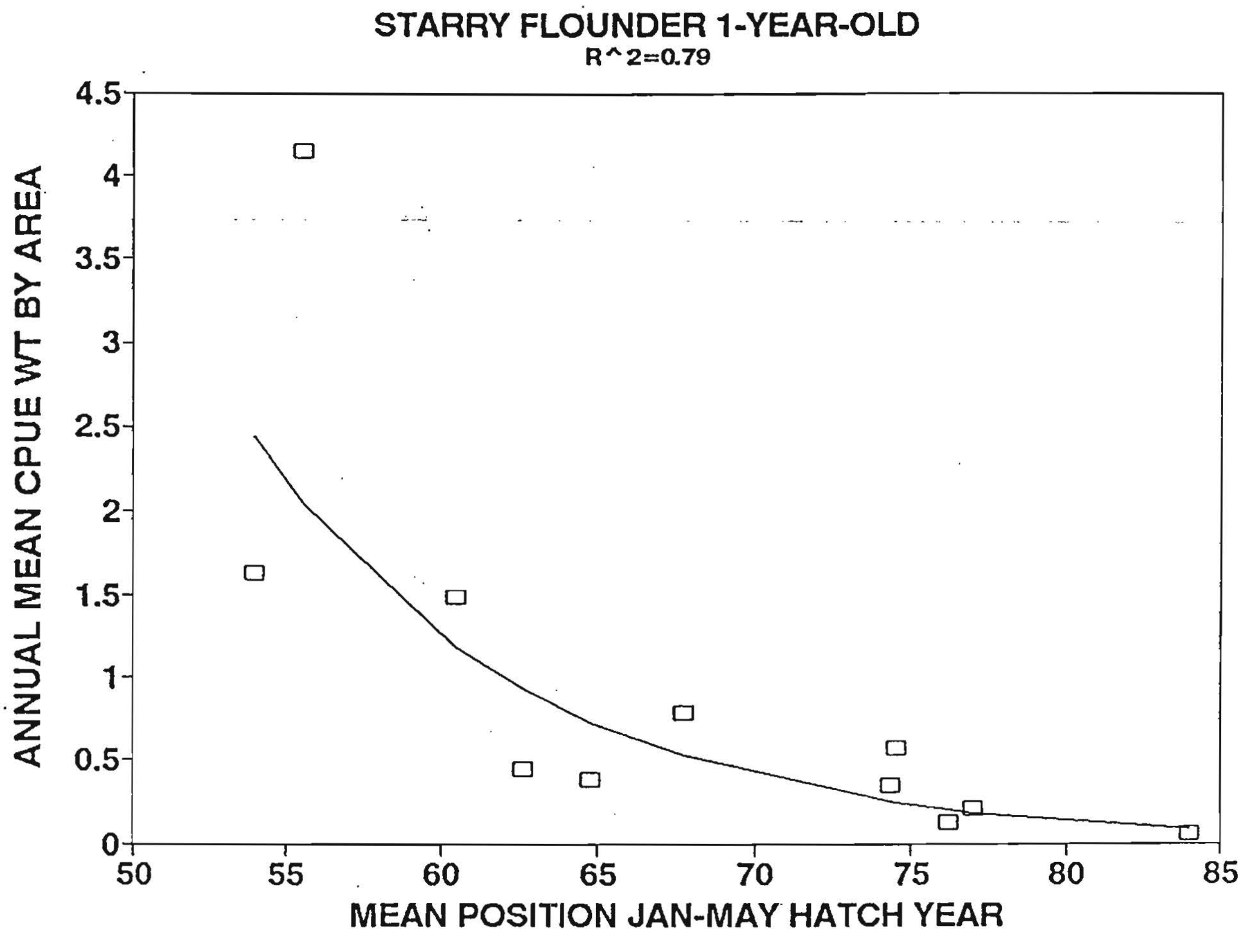


Figure 11. Starry flounder. Annual index of abundance vs. position of the near-bottom 2 ‰ isohaline in the previous year. Data from Figure 10 recast as antilogs.

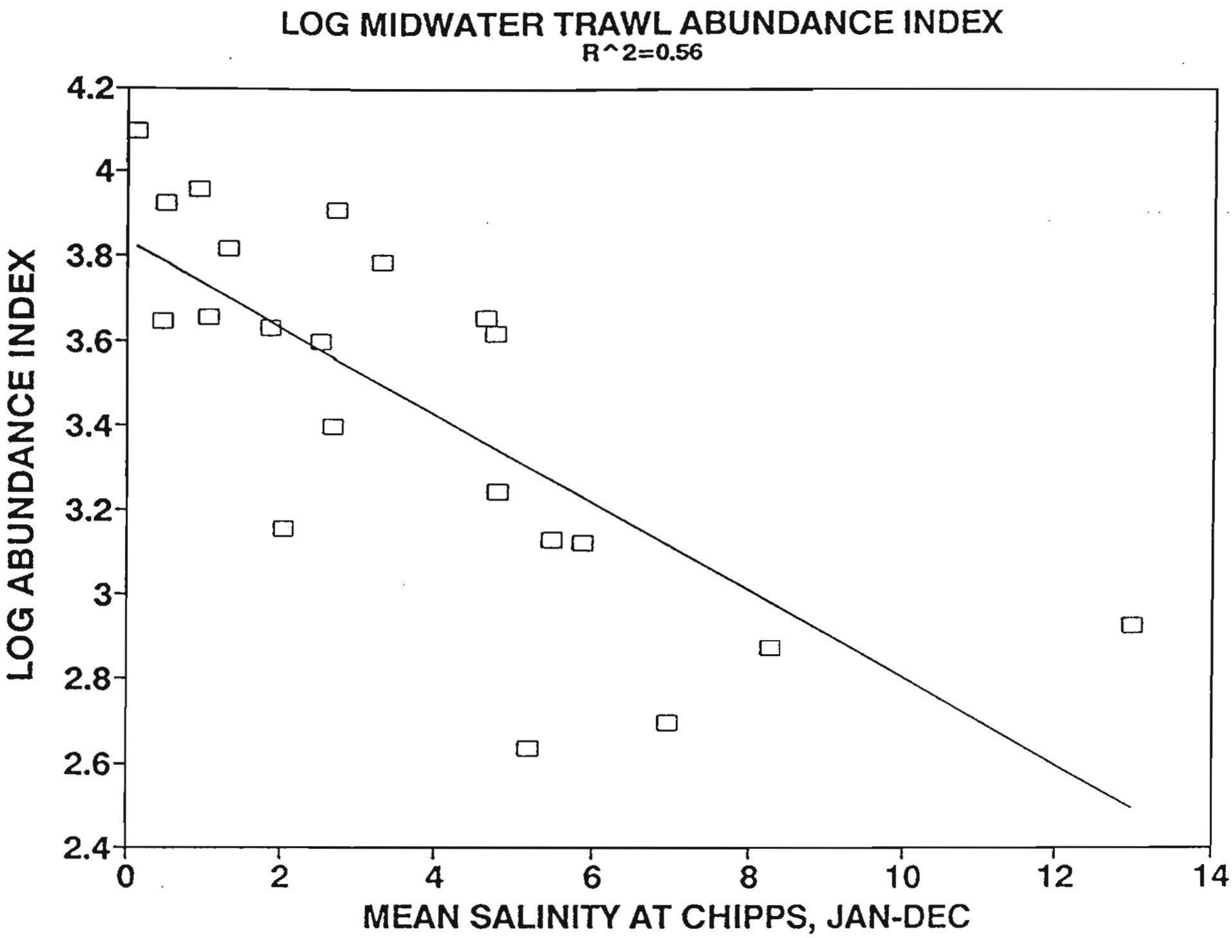


Figure 12. Striped bass midwater trawl index vs. position of the near-bottom 2 ‰ isohaline in that year.

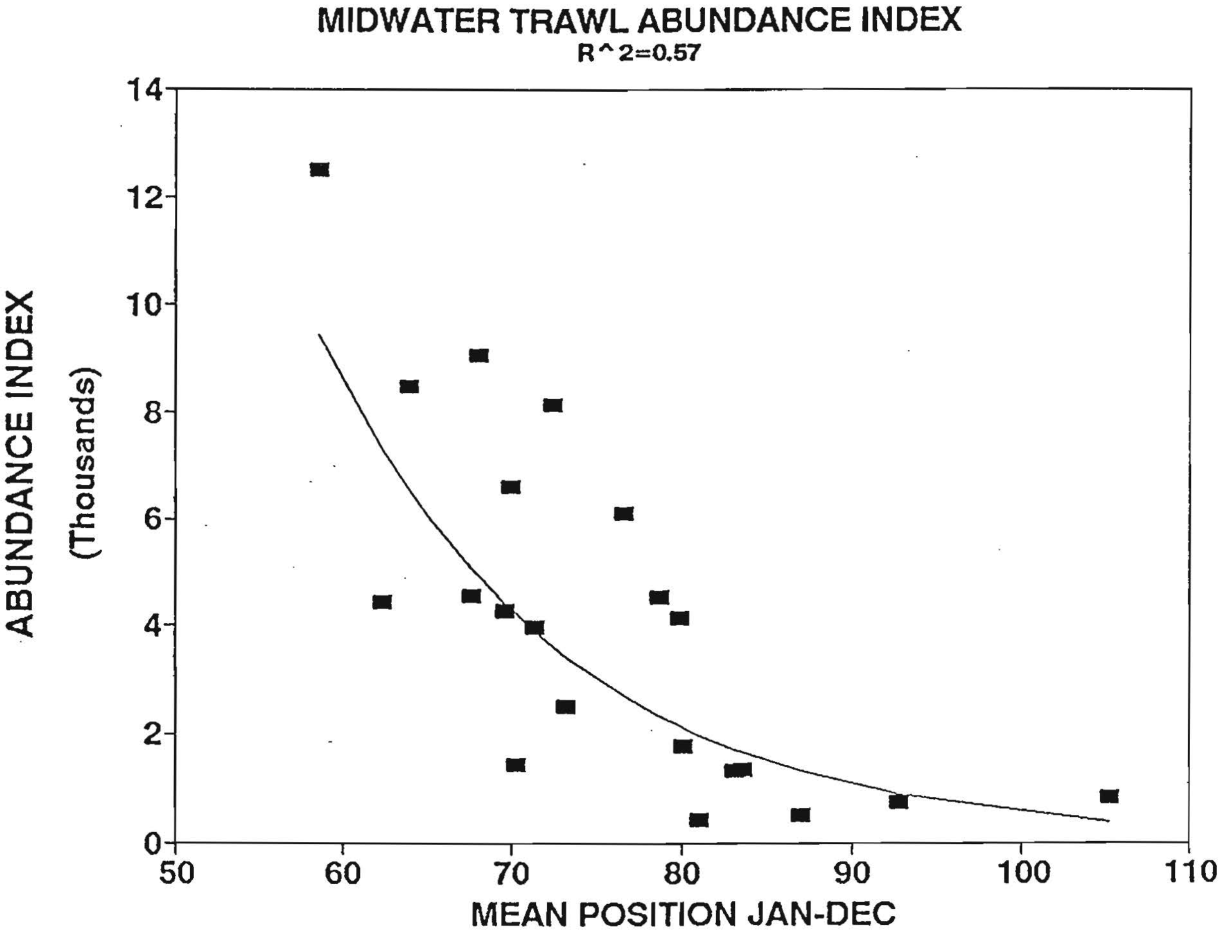


Figure 13. Striped bass midwater trawl index vs. position of the near-bottom 2 ‰ isohaline in that year. Data from Figure 12 recast as antilogs.

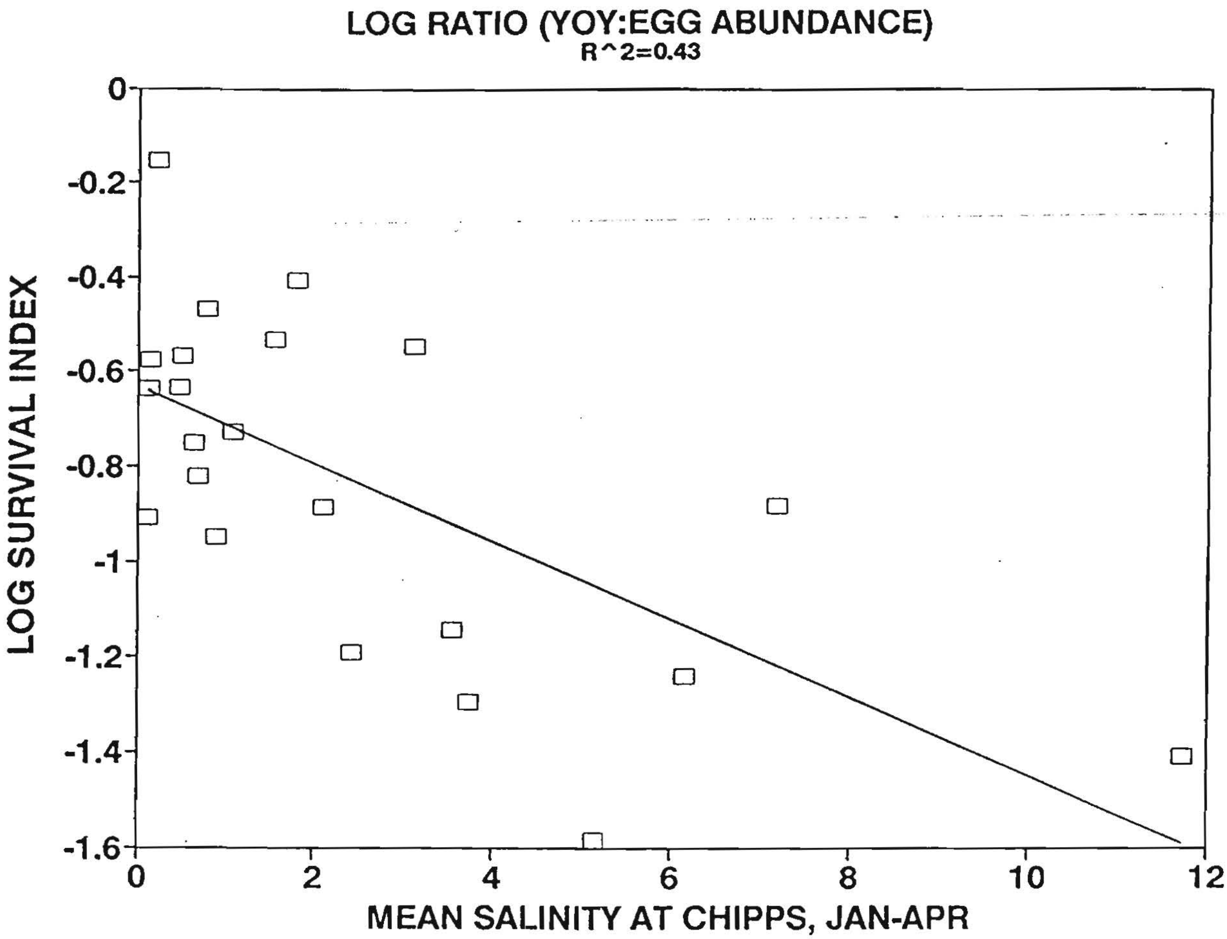


Figure 14. Striped bass survival index from egg (Petersen estimate) to young-of-the-year vs. position of the near-bottom 2 ‰ isohaline in that year.

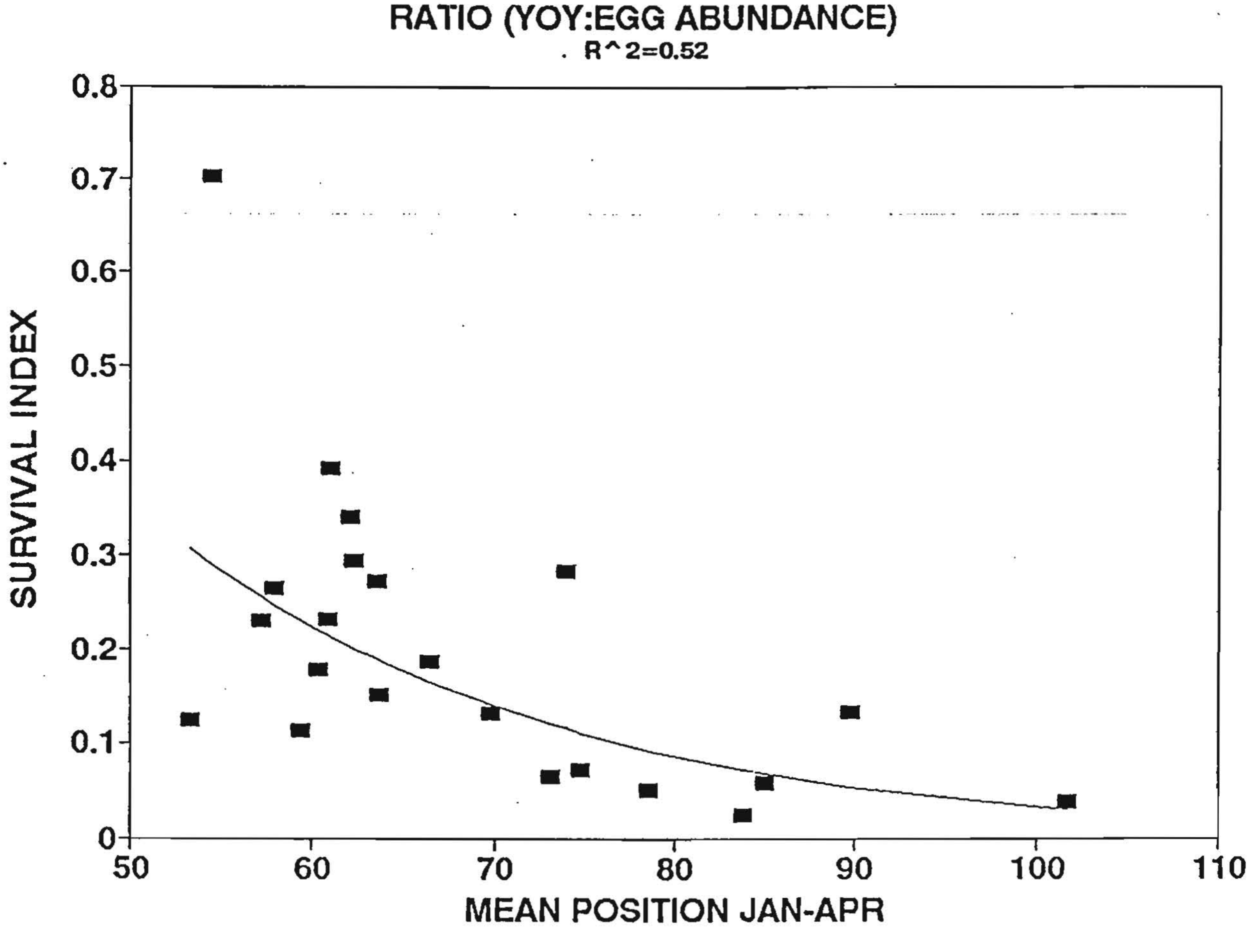


Figure 15. Striped bass survival index from egg (Petersen estimate) to young-of-the-year vs. position of the near-bottom 2 ‰ isohaline in that year. Data from Figure 14 recast as antilogs.

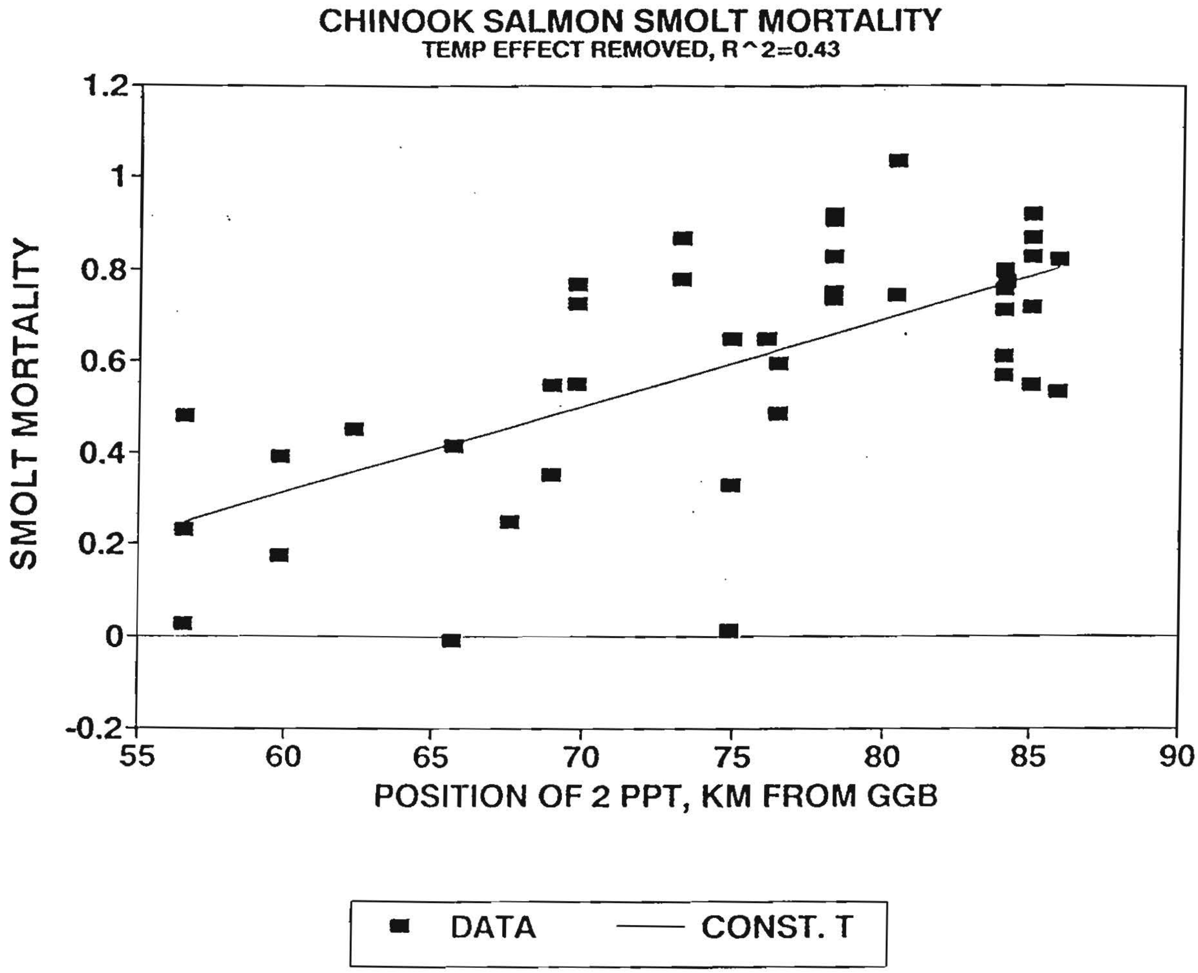


Figure 16. Chinook salmon smolt mortality through the delta vs. position of the near-bottom 2 ‰ isohaline. The temperature effect has been removed from the analysis.

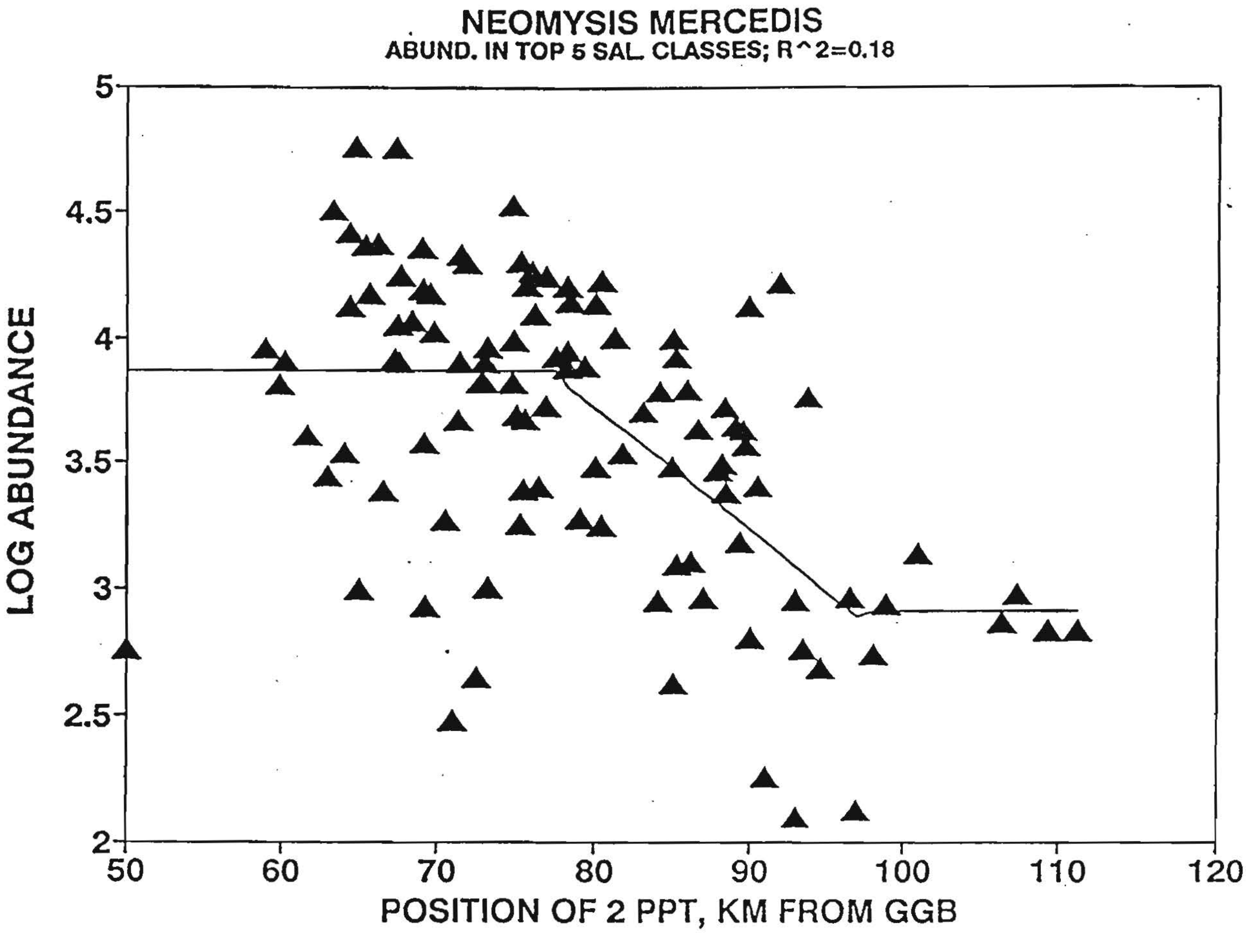


Figure 17. Neomysis mercedis. Abundance in the five salinity classes with the highest abundance vs. position of the near-bottom 2 ‰ isohaline. Each point is a monthly mean. The broken line, chosen by eye, was fitted by calculating successive means starting from each end until- three successive points had 95% confidence intervals not including the line. This was then filled-in with a linear interpolation. The r^2 value is based on the fit of the entire line except for the values at 50 km, for which we believed the population was incompletely sampled.

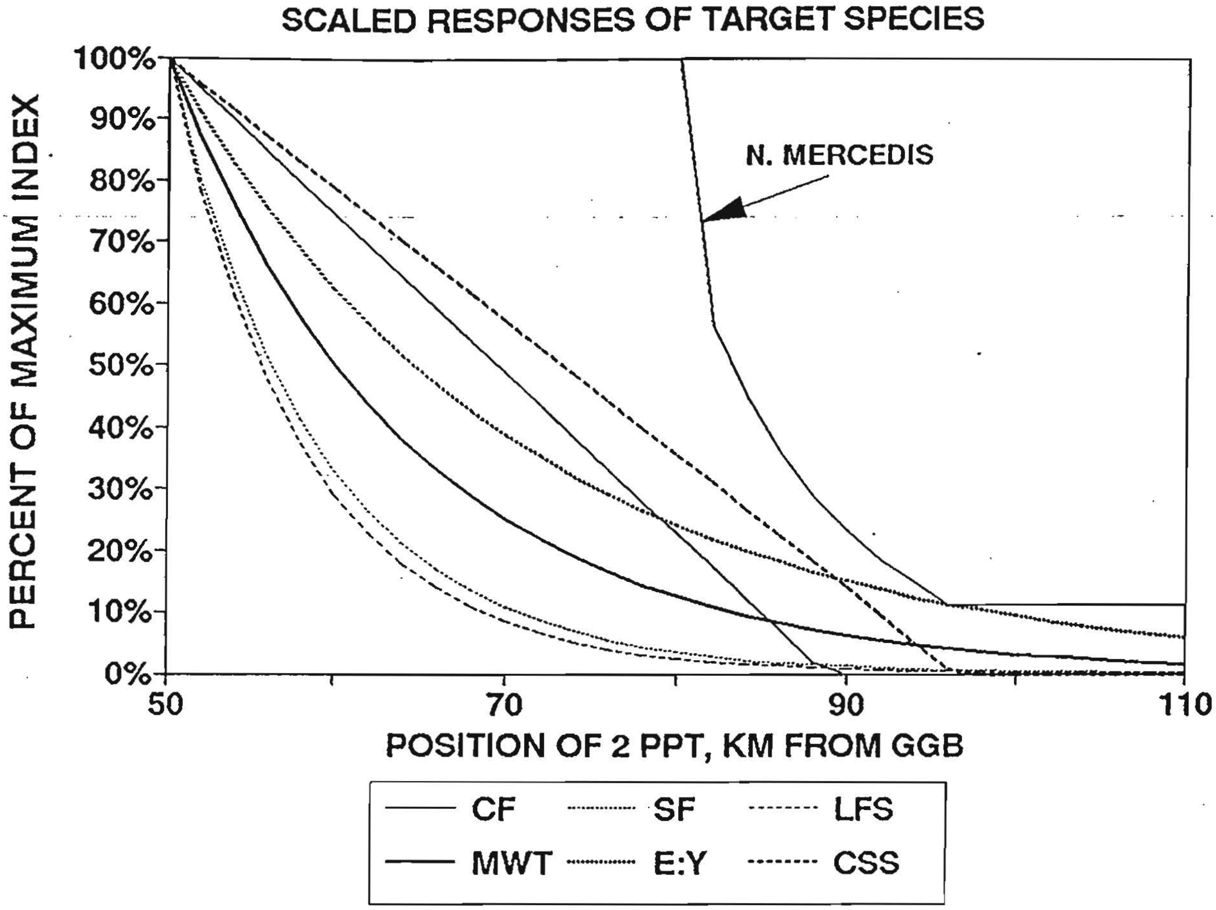


Figure 18. Responses of all of the target species/life stages scaled to 100% of maximum vs. position of the near-bottom 2 ‰ isohaline. at the bottom. CF, C. franciscorum; SF, starry flounder; LFS, longfin smelt; MWT, striped bass midwater trawl index; E:Y, egg: YOY survival of striped bass; CSS, chinook salmon smolt survival.

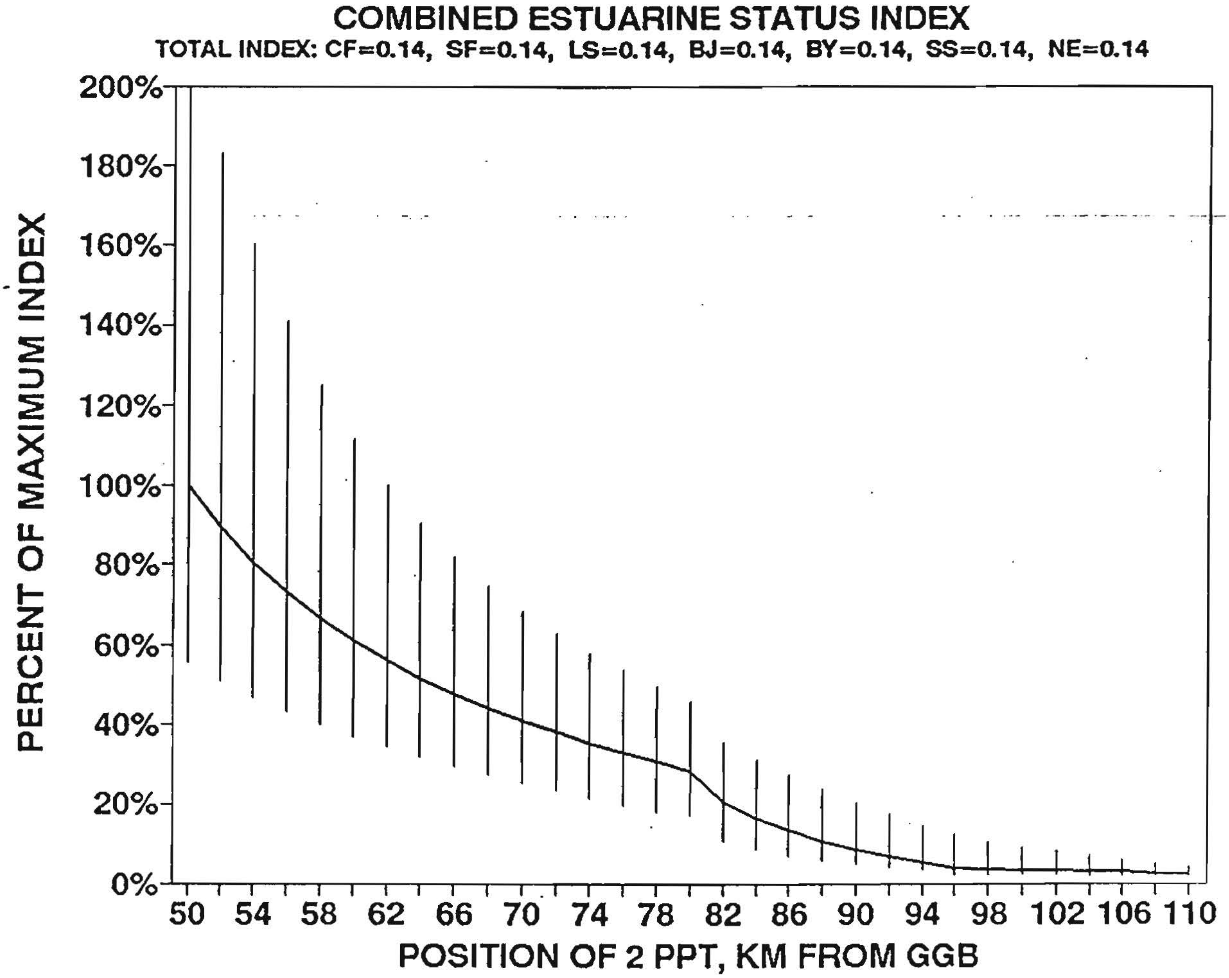


Figure 19. Combined status index consisting of a weighted linear combination of the curves in Figure 18. The weighting factors, entered in the spreadsheet depicted in Table 1, were 1 for all 7 species/stages, and all seasons were included, resulting in equal weighting. Error bars are standard errors, and are truncated at +200%.

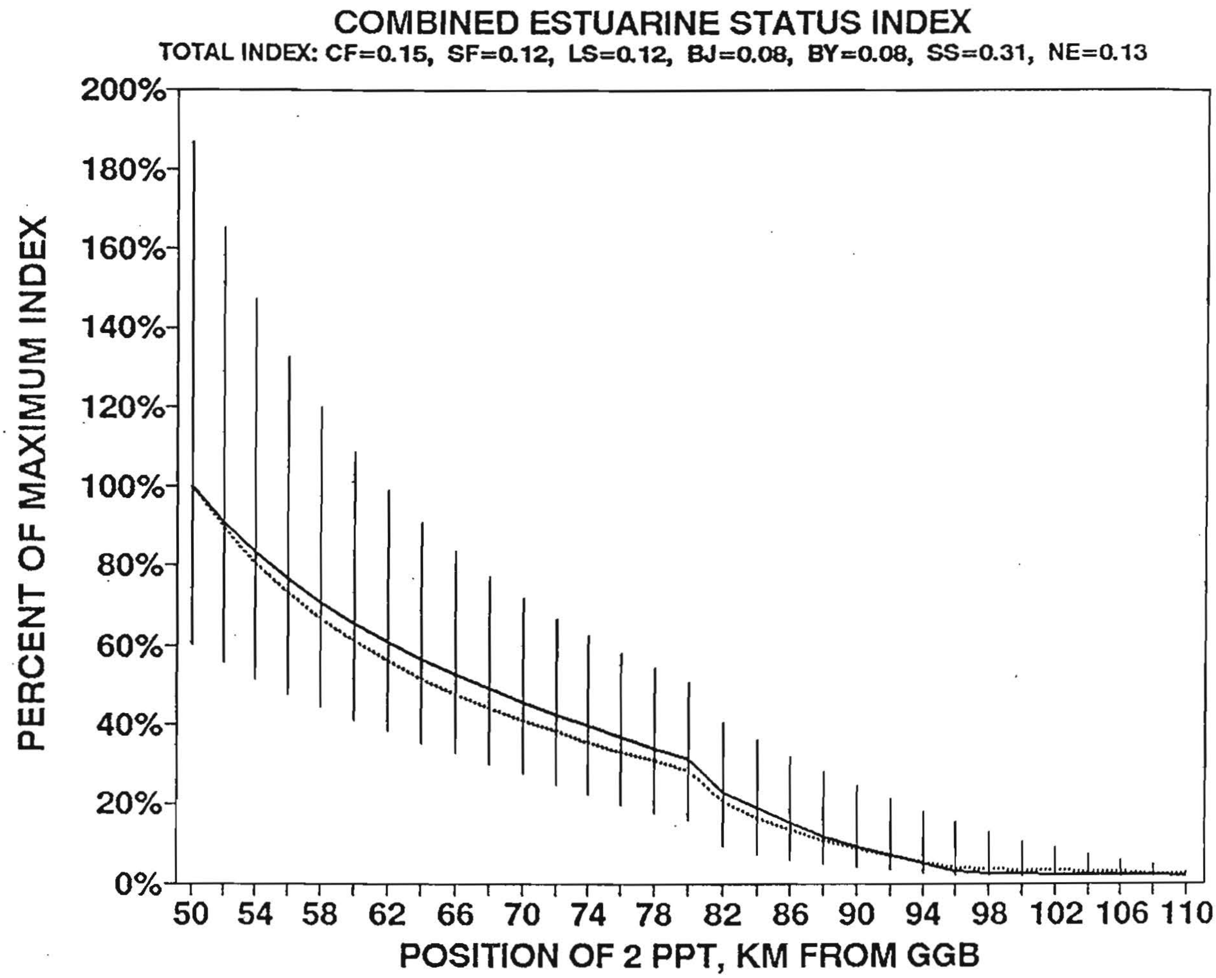


Figure 20. As in Figure 19 -- the combined status index consisting of a weighted linear combination of the curves in Figure 18 -- **<u>for spring only</u>**. Note that this alters the weighting factor according to the seasons selected in Table 1. -The dotted line gives the previous curve for comparison (i.e. that from Figure 20).

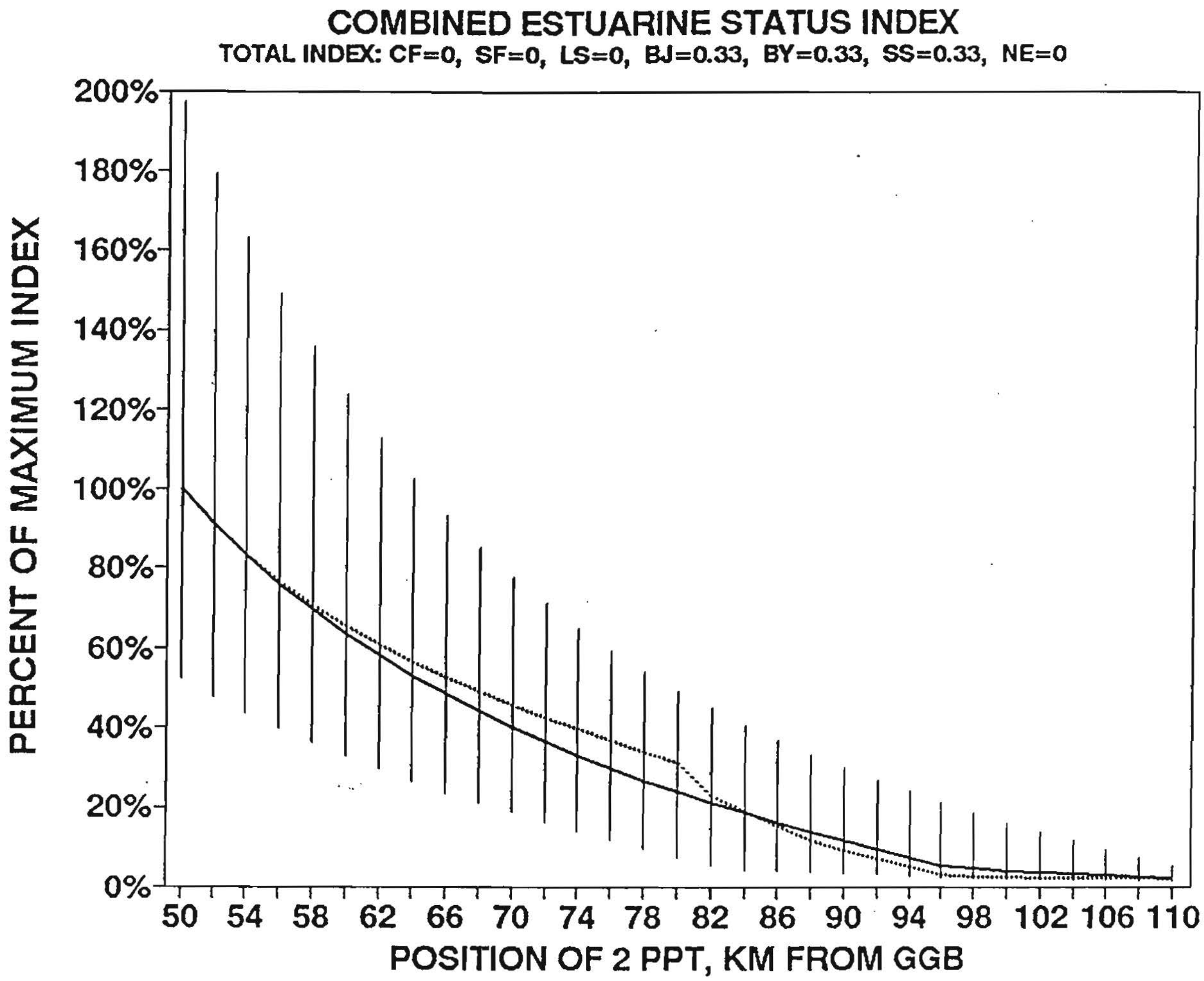


Figure 21. Combined status index f<u>or striped bass and salmon only</u>, consisting of a weighted linear combination of appropriate curves in Figure 18, <u>all seasons.</u>

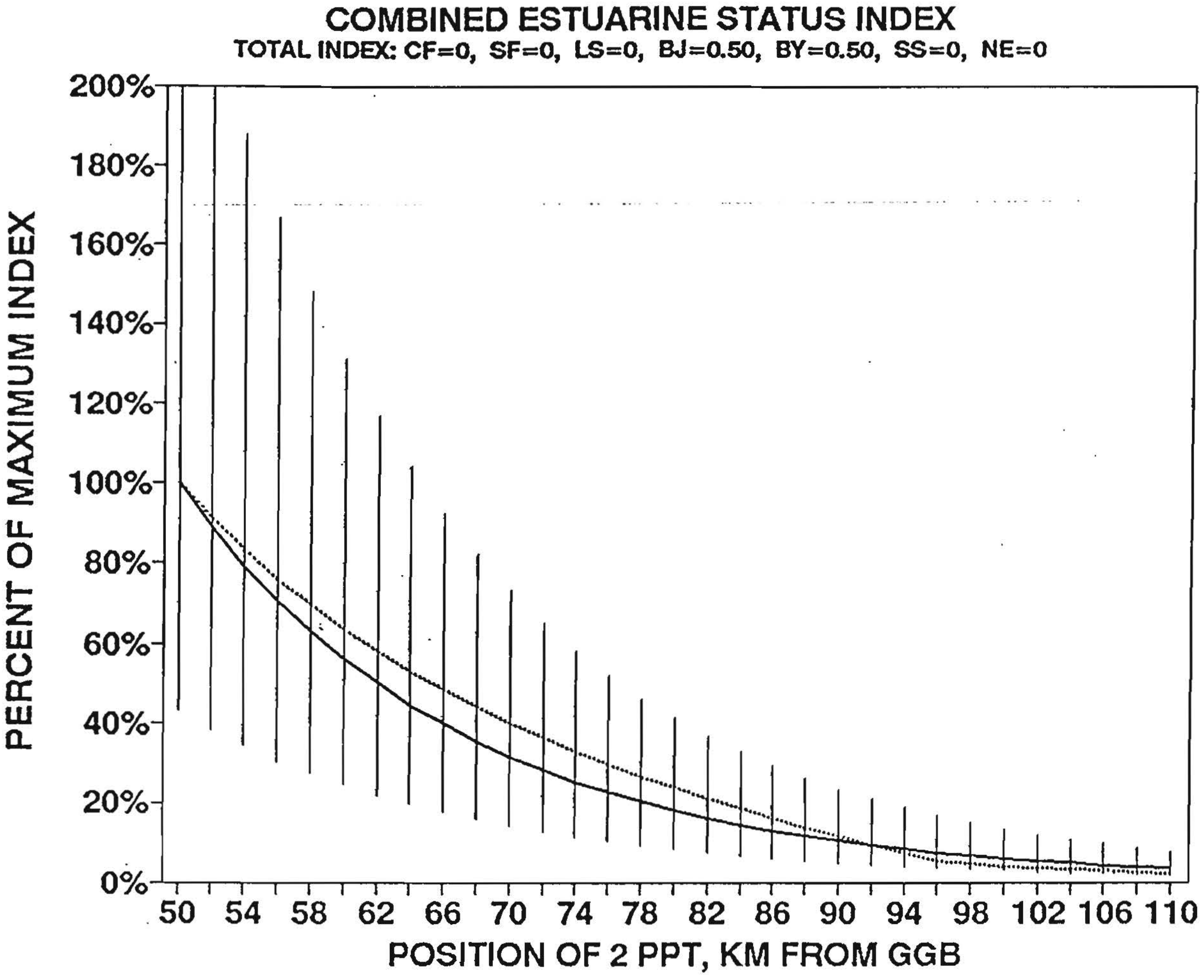


Figure 22. Combined status index <u>for striped bass only,</u> consisting of a weighted linear combination of appropriate curves in Figure 18, <u>all seasons</u>

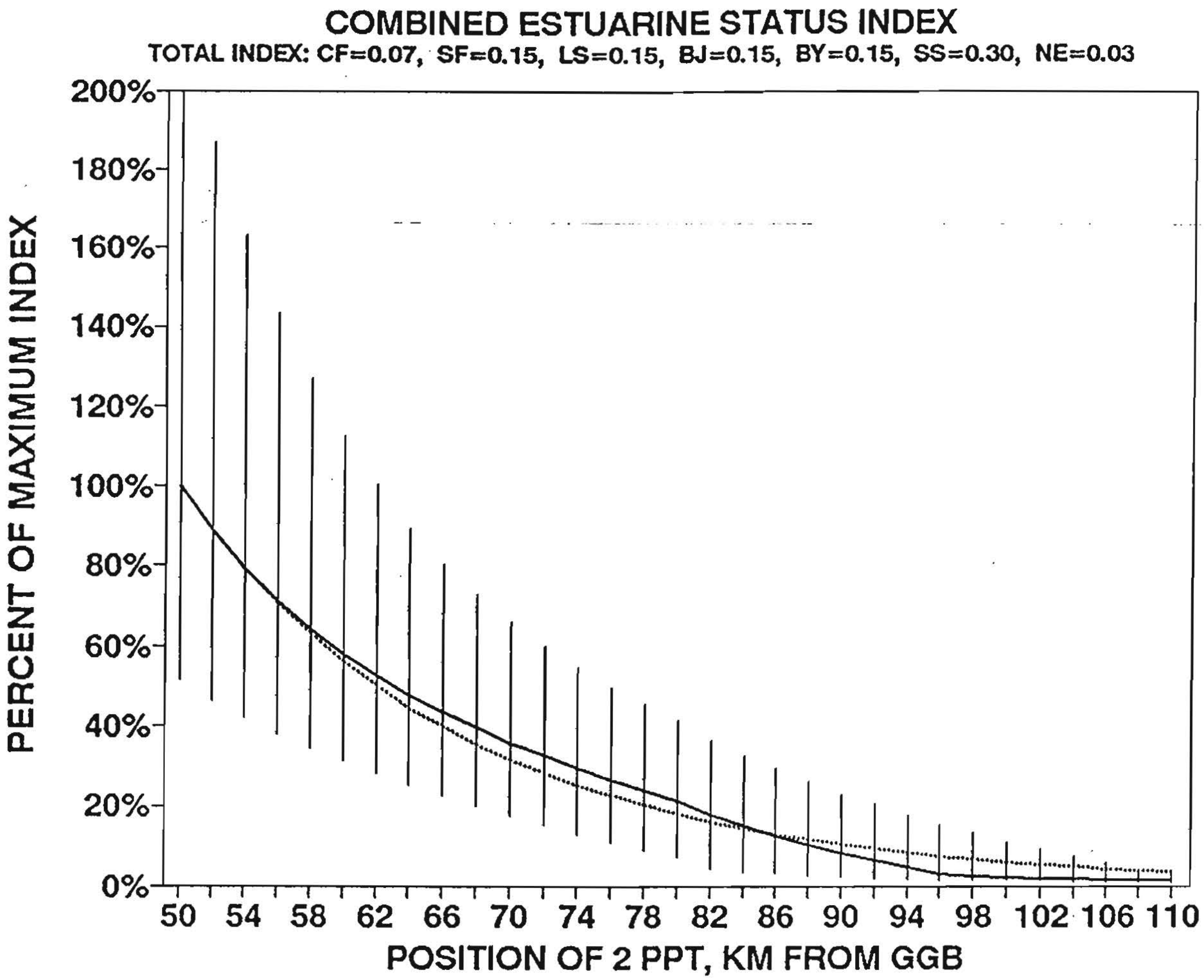


Figure 23. Combined status index consisting of a weighted linear combination of the curves in Figure 18. The weighting factors are those entered in the spreadsheet depicted in Table 1, and all seasons are included. Error bars are standard errors and are truncated at +200%.

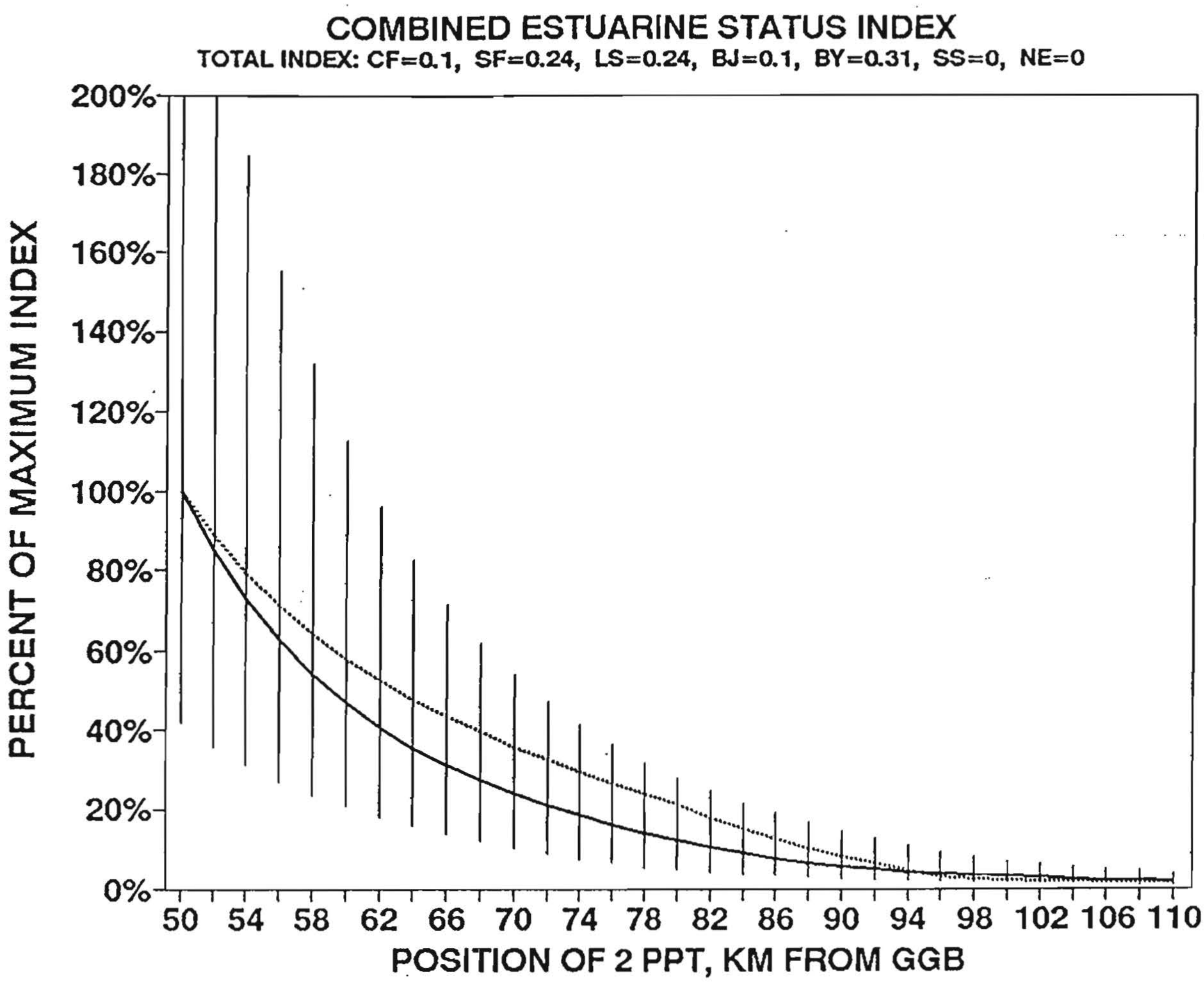


Figure 24. Combined status index consisting of a weighted linear combination of the curves in Figure 18. The weighting factors are those entered in the spreadsheet depicted in Table 1, **for winter only**.

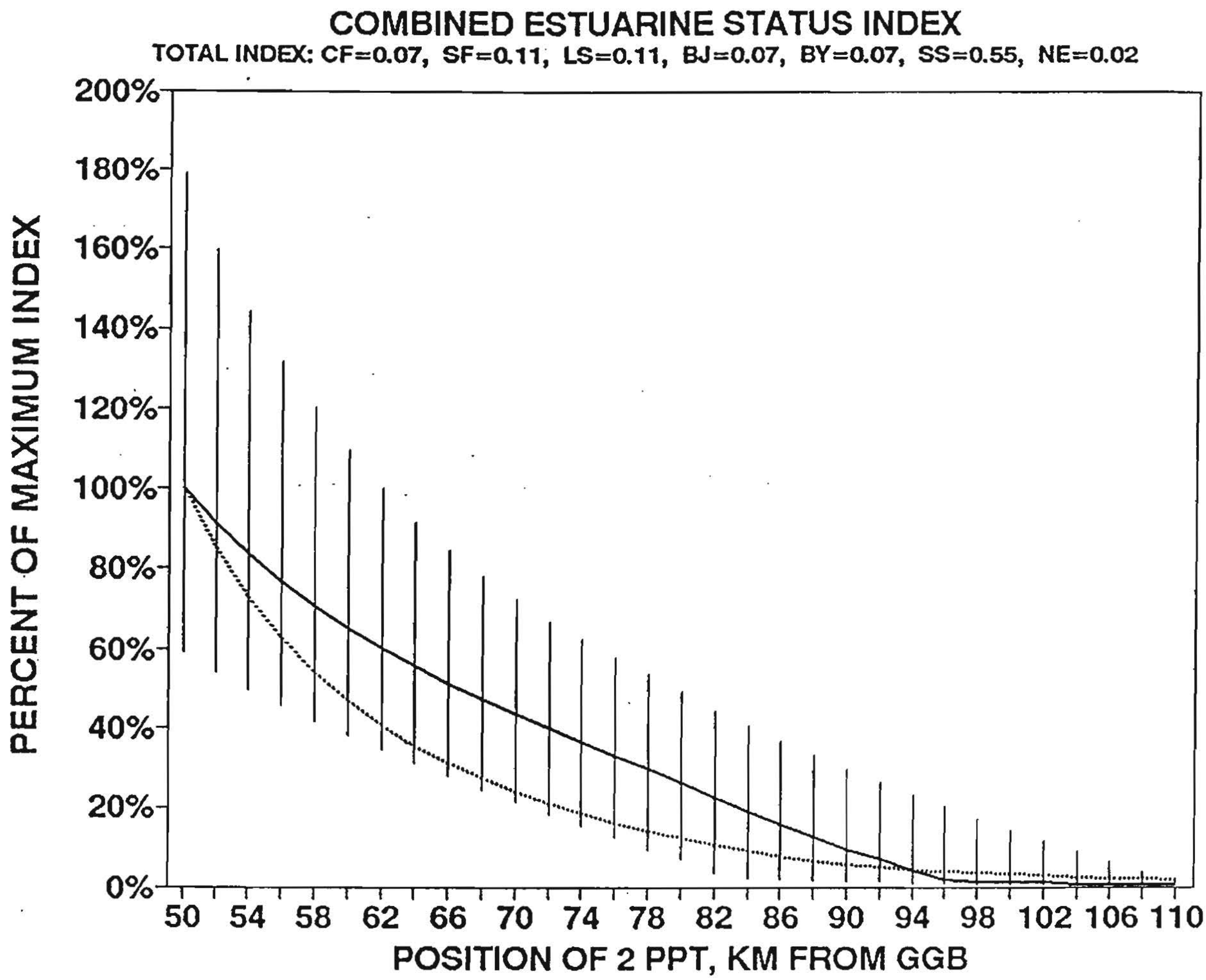


Figure 25. Combined status index consisting of a weighted linear combination of the curves in Figure 18. The weighting factors are those entered in the spreadsheet depicted in Table 1, **for spring only**. Error bars are standard errors and are truncated at +200%.

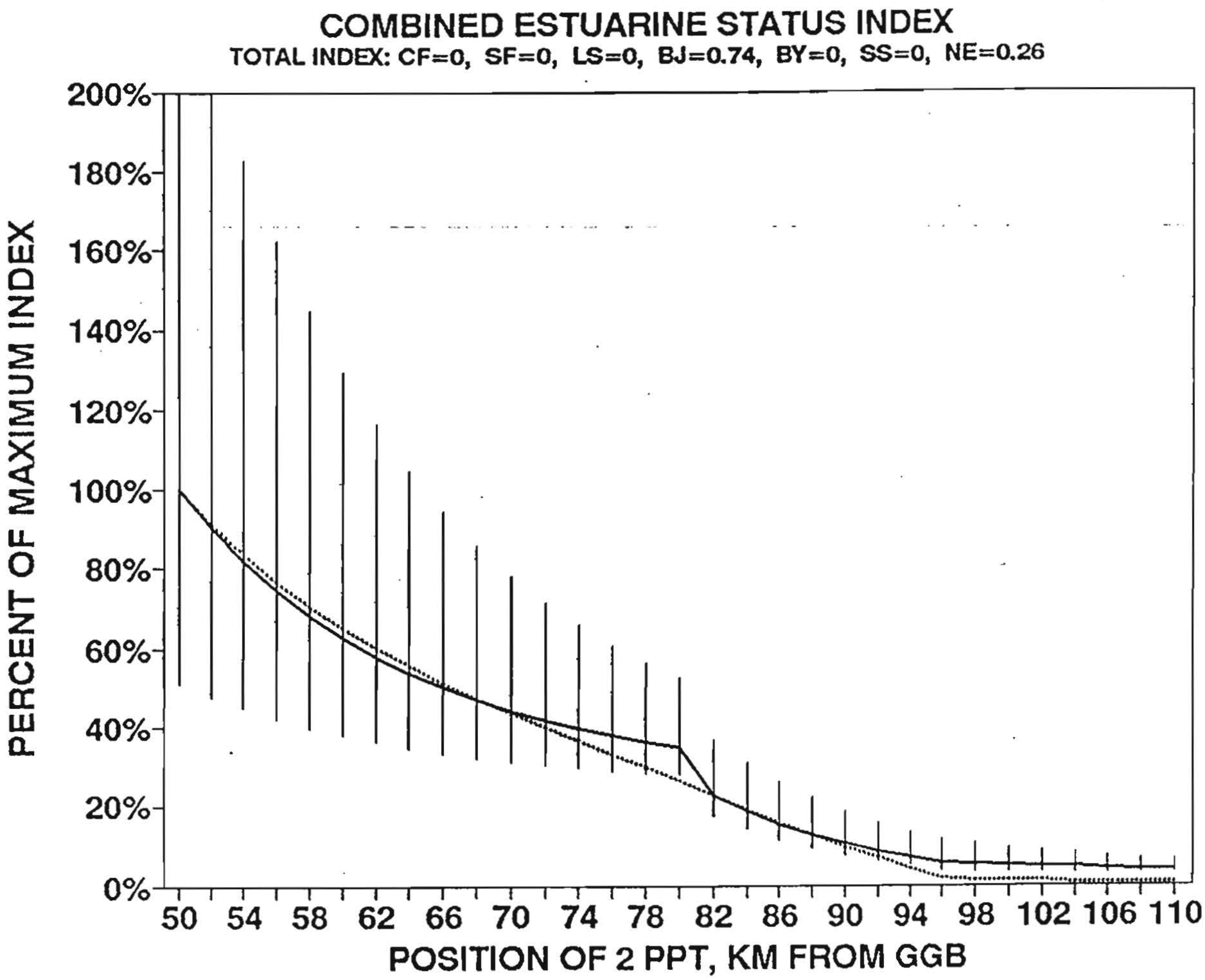


Figure 26. Combined status index consisting of a weighted linear combination of the curves in Figure 18. The weighting factors are those entered in the spreadsheet depicted in Table 1, **for summer only**. Error bars are standard errors and are truncated at +200%.

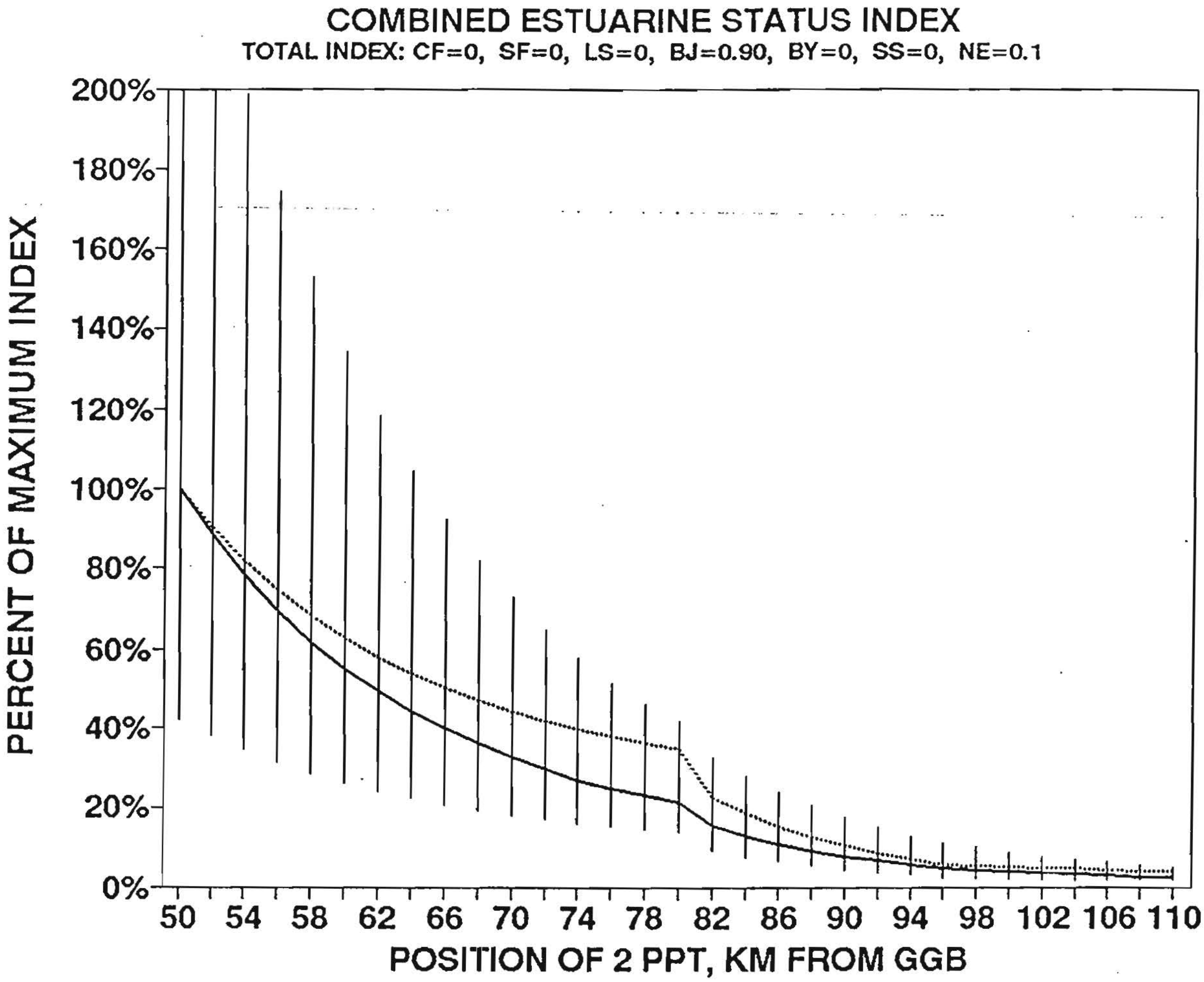


Figure 27. Combined status index consisting of a weighted linear combination of the curves in Figure 18. The weighting factors are those entered in the spreadsheet depicted in Table 1, **<u>for fall only</u>**. Error bars are standard errors and are truncated at +200%.

FOLLOW-UP TO W. KIMMERER'S PRESENTATION

Following Wim Kimmerer's presentation of the relationships of biological success of important species to position of the 2 ‰ near-bottom isohaline the workshop divided into two working groups: one chaired by Tom Powell, the other by David Jay. The Powell group was charged with answering the following questions: Is the approach taken by W. Kimmerer useful? Was it given a fair test? Were the best -- most appropriate -- data used? Were the best -- most appropriate -- methods of analysis used? How could the approach be enhanced? The Jay group was charged with answering the following questions: What averaging period should be used to define the position of the 2 ‰ near-bottom isohaline? What are the key elements of a monitoring program for the position of the near-bottom 2 ‰ isohaline?

The principal conclusions and recommendations of the Powell working group are summarized in Exhibit 5; those of the Jay working group in Exhibit 6.

EXHIBIT 5

PRINCIPAL CONCLUSIONS OF THE POWELL WORKING GROUP

This group was charged with answering the following questions:

- *Is the approach taken -- relating biological success to position of the near-bottom 2 ‰ isohaline -- useful?*
- *Was it given a fair test?*
- *Were the best -- most appropriate -- data used?*
- *Were the best -- most appropriate -- methods of analysis used?*
- *How could the approach be enhanced?*

Principal Conclusions

- The general approach is useful, but needs refinement.
- Salinity is an appropriate measure upon which to base a standard for managing freshwater inflow. The choice as the standard of a position of the 2 ‰ isohaline at 1m above the bottom for each season is appropriate.
- A salinity standard should be used in combination with some measure of freshwater inflow; the most appropriate measure would be Delta outflow; the most attainable measure is the Dayflow.

EXHIBIT 5

CONTINUED

- A salinity standard based on location of the 2 ‰ isohaline is an index of the extent of low salinity habitat. This is one of its major values. The expansion and contraction of low salinity habitat provides important information to managers in terms of protecting those species that depend upon this habitat.
- Others challenged the value added by using salinity instead of flow directly. Still others felt that salinity is too simplistic; that it is not always the controlling factor; sometimes it's flow, sometimes salinity, sometimes a combination of factors.
- Some contended that management actions should be based on causal relationships, not on statistical data.
- Others stated that these relationships of biological success and position of the 2 ‰ isohaline can help managers formulate goals which are grounded in science.
- The approach conceals much of the important biology. The effective time scale of the aggregated data is not congruent with the time scale needed to set meaningful seasonal salinity standards.

EXHIBIT 5

CONTINUED

- The strategy should be expanded to include more species.
- There was a strong consensus particularly among academic scientists that a renewed effort should be made to refine and fill-in the matrix developed at the first workshop.
- Greater effort should be made to exchange data and analyses among the various individuals and groups actively working in the Bay.
- A decision needs to be made as to which species society wants to protect or restore and to what levels?
- Any standards that are promulgated should be consistent with these priorities (goals).
- Many felt that a priority should be given to restoring and protecting the habitat of anadromous species. Increases in the diversion of freshwater have produced a compression of this habitat. The goal might be stated in terms of enhancing the abundance of communities that exploit low salinity habitat.

EXHIBIT 5

CONTINUED

If the 2 ‰ near-bottom isohaline is upstream of 75km (Chipps Island), anadromous species do not do well.

- The focus of management should be more on enhancing biological diversity and less on enhancing success of a single species.

- If a priority is placed on enhancing low salinity habitat and communities that exploit this habitat, the effects of such a priority on other habitats should be understood.

- It's clear that present standards are not protecting anadromous and semi-anadromous species. Striped bass, Delta smelt, salmon and a number of other species have declined significantly over the past 10-15 years. Striped bass are down 70%. Delta smelt are down 90%. The late fall run of salmon has been eliminated, spring run salmon -- once the dominant race throughout the Central Valley -- survive only in scattered remnants and winter run numbers are so low that this race received emergency listing as threatened under the Federal Endangered Species Act. Only the fall-run chinook salmon of the Sacramento River basin has been maintained. Its survival is attributed to its tolerance of warmer, low elevation stream habitats and to extensive state and Federal hatchery programs.

EXHIBIT 5

CONTINUED

- The quality of the Delta environment as habitat for anadromous species has deteriorated.

- For some species -- striped bass is the most notable -- declines are correlated with freshwater diversion.

- Other changes that have occurred in the system may compromise the benefits of increasing freshwater inflow. The anticipated benefits of increasing freshwater inflow may not be realized and this could lead to anger and disillusionment.

- A series of "what if" scenarios... a series of if, then scenarios should be developed.

EXHIBIT 6

PRINCIPAL CONCLUSIONS OF THE JAY WORKING GROUP

The group was charged with answering the following questions:

- *What averaging period should be used to define the position of the near-bottom 2 ‰ isohaline?*
- *What are the critical elements in a monitoring program to track compliance with a salinity standard?*

Principal Conclusions

- The appropriate averaging period for defining the position of the 2 ‰ isohaline is a function of geography. The farther east (upstream) the 2 ‰ isohaline is, the shorter the averaging period needed. At the western (downstream) end of the range of plausible positions, the appropriate averaging period might be as long as 28 days; at the eastern (upstream) end, it might be as short as 3 days.

- At the eastern (upstream) end, the average position should perhaps be accompanied by a not-to-exceed (NTE) upstream limit that takes into account the normal tidal excursion.

EXHIBIT 6

CONTINUED

- A diagnostic network of monitoring stations should consist of at least 8 stations, 6 in the channel and 2 in the Flats on the north side of Suisun Bay. Channel stations should record conductivity, temperature and optical backscattering near the surface and near the bottom; stations on the flats should make these same measurements at mid-depth only. Measurements should be made at a frequency of at least 2/hr and data should be telemetered to a shoreside facility.

CONCLUSIONS

The workshop participants reaffirmed the importance of developing a seasonal salinity standard that takes the form of a position of the near-bottom 2 ‰ isohaline. The salinity standard should be used in conjunction with a flow standard to protect the Bay ecosystem and important human values and uses. The workshop reaffirmed the two approaches outlined in the first workshop report for selecting the most appropriate location of the 2 ‰ isohaline for each season -- the seasonal salinity standard. The preliminary analysis carried out by Wim Kimmerer should be refined and a renewed effort should be made to develop a matrix for each season that relate biological and environmental properties and processes to different flows and associated positions of the near-bottom 2 ‰ isohaline. These activities are described in the next section, "Follow-up Assignments."

FOLLOW-UP ASSIGNMENTS

The following assignments were agreed to by workshop participants.

Filling-In The Matrix Developed at the First Workshop

- By mid-January 1992, Jim Cloern will convene a group consisting of Chuck Armor, Alan Jassby, Steve Monismith, Fred Nichols, Dave Peterson and Tom Powell. Their tasks are (1) to review and refine the elements of the matrix developed in the first workshop -- to add cells, remove cells or modify cells, (2) to specify what data are needed to complete the matrix and, to the extent possible, where they exist, (3) to specify what analyses of the data are needed to provide the required information to fill-in the matrix, and (4) to recommend scientists who are in the best position to analyze the data and make the first cut at filling in the matrix for different seasons.

Applying More Sophisticated Analytical Tools to Biological Response Data

- By mid-January 1992, Wim Kimmerer will provide Alan Jassby with one of the data sets he presented at the workshop on biological success of a species as a function of position of the 2 ‰ isohaline. Alan Jassby will make a preliminary assessment to determine whether, or not, the application of more sophisticated analytical and statistical tools to these data might reveal more information.

Clarifying the Flow-Salinity Relationship

- Wim Kimmerer will take the several flow-salinity relationships that exist for the Bay and produce a single relationship that best describes the salinity of the Bay over the full range of flows. No deadline was set.

Scenario Planning for the San Francisco Estuary

Scenario planning may be a useful strategy for shaping the future of the San Francisco Bay estuary. The strategy proved to be useful in the Long Island Sound estuary program (Schubel and Pritchard 1991). Other useful references include Wack (1985 a, b) and Schwartz (1991).

Scenario planning concentrates on perceiving possible futures in the present, rather than on predicting the future. Scenarios are stories of how things might turn out and they do not simply extrapolate present trends. The purpose of scenarios is to gather and transform information of strategic significance into fresh perceptions. A good set of scenarios consists of a few alternative and internally consistent pathways to the future. Once these scenarios have been developed, decision makers are in a better position to make choices now that will determine -- or at least influence -- which scenario is actually played out.

Key decision makers should be actively involved in the development of the scenarios. The scenarios should be portrayed clearly and persuasively and disseminated broadly to gain the support and commitment needed to make decisions consistent with the desired set of future conditions."

Tim Vendlinski and J.R. Schubel will develop a mechanism for creating scenarios for the San Francisco Bay estuary.

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Schubel, J.R. and D.W. Pritchard, 1991. Some Possible Futures of Long Island Sound. Marine Sciences Research Center Working Paper 55; Ref. No. 91-17.

Schwartz, Peter, 1991. The Art of the Long View. A Curreny Book of Doubleday, New York, NY. 258 p.

Wack, Pierre, 1985a. Scenarios: Uncharted Waters Ahead. Harvard Business Review Sept.-Oct. 1985:73-89.

Wack, Pierre, 1985b. Shooting the Rapids. Harvard Business Review Nov.-Dec. 1985:139-150.

APPENDICES

APPENDIX A

A WORKSHOP TO REVIEW, REVISE AND REFINE THE USE OF THE 2 ‰ NEAR-BOTTOM ISOHALINE AND DELTA OUTFLOWS TO PROTECT IMPORTANT LIVING RESOURCES OF THE SAN FRANCISCO ESTUARY

Bay Conference Center

Tiburon, California

Tuesday,
December 17, 1991

AGENDA

0830	Registration and Continental Breakfast	
0900 Sharp	I. Welcome	Tim Vendlinski
	II. A Brief Recap Of How We Got To Where We Are; And What Remains To Be Done	J.R. Schubel
	• Goals and Objectives of the Workshop • Procedures • Products	

0930	**III. Flow - Salinity Field Relationship** • What data were used and how were they "processed"? • Historical trends and position of 2 ‰ isohaline • Historical trends in salinity at specific locations, e.g. Antioch and Carquinesz • Relationship between salinity and net Delta outflow • Tidal effects on the position of the 2 ‰ isohaline	**Wim Kimmerer**
1030	**Break**	
1045	**IV. Discussion**	**J.R. Schubel, Facilitator**
1115	**V. Coupling the Reproductive Success and Abundance of Various Life Stages of Key Aquatic Species with the Position of the 2 ‰ Isohaline and Salinity at Standard Monitoring Sites.**	**Wim Kimmerer**
1145	**VI. Discussion; Formation of Working Groups and a Challenge to Scientists** **Objective:** Review and refine the recommended locations of the 2 ‰ isohaline in different seasons.	**J.R. Schubel, Facilitator**
1215	**Working Lunch**	

1430		**VII. Workshop Groups Report to Plenary Session** • A comparison by season of the recommendations for positioning of the 2 ‰ Isohaline • Resolving the differences (Getting to Yes.)	**J.R. Schubel, Facilitator**
1600		**VIII. Development of a Strategy and Recommendations for Monitoring the Position of the 2 ‰ Isohaline** • Identification of alternatives • Evaluation of alternatives • Selection of the best - - most appropriate - - alternative	**J.R. Schubel, Facilitator**
1700	IX	**Brief Recap**	
1730	X	**Adjourn**	

APPENDIX B

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