Trend Analysis of Delta Smelt and Striped Bass Physical Habitat Based on the Summer Townet Survey

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Study Rationale: We conducted an in-depth analysis of the Summer Townet Survey (TNS) data to answer the following question: has physical habitat suitability for delta smelt and striped bass declined over the period of record? This analysis was based on the following assumptions:

- Delta smelt and young striped bass are generally pelagic fishes. Thus, their physical habitat can be adequately defined in terms of water quality parameters.
- The available water quality parameters (water temperature, Secchi disk depth, and specific conductance) are sufficient to characterize habitat quality for these species.
- All three water quality variables constrain distribution in an additive manner. We made this assumption because we did not have data to the contrary.

Fish habitat quality in the upper San Francisco Estuary has been indexed by "X2", the distance in km from the Golden Gate to the position of the 2‰ salinity isohaline (Jassby et al. 1995). The mean location of X2 varies greatly among years due to interannual variation in watershed precipitation. Water management in California's Central Valley also has influenced the average position of X2 during some months (Figure 1). We hypothesized these long-term deviations in mean X2 position could influence physical habitat quality for delta smelt and striped bass.

Unlike several other San Francisco Estuary fishes, adult delta smelt abundance does not respond strongly to interannual variation in X2 position during spring (Jassby et al. 1995). However, there is a statistically significant influence of springtime X2 position on juvenile abundance during summer since the species declined in the early 1980s (Kimmerer 2002). Delta smelt distribution is influenced by X2 position (Moyle et al. 1992; Sweetnam 1999). However, the core juvenile distribution, regardless of water year type, is usually centered upstream of X2 in eastern Suisun Bay and the lower Sacramento River to about Three-Mile Slough (Sweetnam 1999; Dege and Brown 2004).

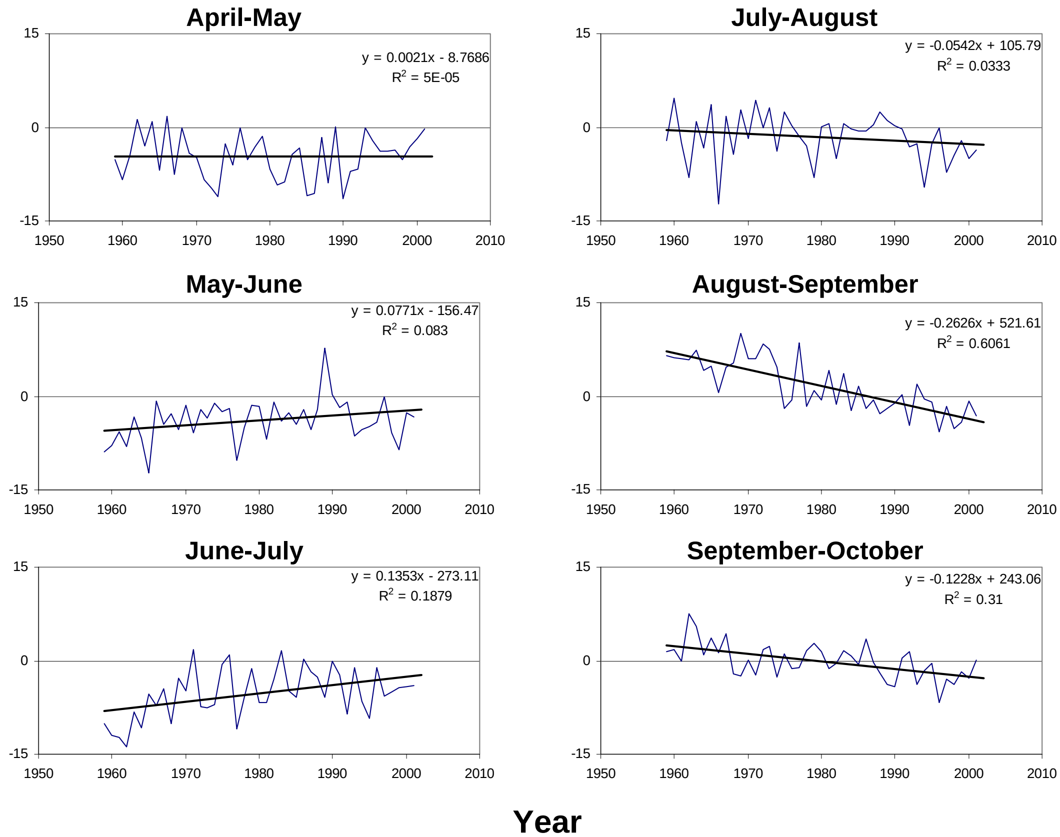


Figure 1. Annual deviation in X2 position from the 1959-2002 means for successive two-month periods, April-May through September-October. The x-axes are years and the y-axes are km deviations in X2 position from its 1959-2002 mean for each period. Negative values in the y-axes denote landward movement of X2. Source: Kevin Fleming (DFG) and Matt Nobriga (DWR) unpublished data.

The Summer Townet Survey: DFG has conducted the summer Townet Survey annually since 1959. The survey was first described in the peer-reviewed literature by Turner and Chadwick (1972). The survey was designed to index the relative abundance of 38-mm striped bass, but delta smelt have always been collected incidentally. A delta smelt abundance index based on the survey was developed by Moyle et al. (1992). Replicate hauls (up to 3/station) are done at 30-40+ stations from San Pablo Bay through the Sacramento-San Joaquin Delta. Water quality data are taken at each station simultaneously. This procedure has been repeated at least twice each year since 1959.

Although the TNS has been conducted since 1959, the suite of three water quality parameters was not measured until 1970 and these data were not taken consistently until 1973. The following catch records were not included in this analysis.

- 1959-1969: no or incomplete water quality data
- 1971-1972, 1975: no or very incomplete water temperature data
- 26 July 1973, Survey 3, Station 602: Secchi disk depth was recorded as 1 cm
- 26 July 1993, Survey 3, Station 405: Water temperature was recorded as 3.3°C

- 30 July 1994, Survey 4, Station 340: Water temperature was recorded as 3.6°C
- Other particular dates/locations where a water quality parameter was missing. In total, only 14% of the 1970-2004 dataset was removed due to missing data.

General Approach: The basic approach used was similar to instream flow methods (IFIM) that have been applied to rivers and streams (Bovee 1982). First, we developed habitat criteria to define the physical and chemical conditions that were suitable for striped bass and delta smelt. Second, we divided the study region into smaller area units based on the location of TNS stations. Third, we applied the habitat criteria (step 1) to long-term water quality monitoring data for each TNS station to determine which stations provided suitable habitat. Finally, we summed the area units (step 2) representing suitable habitat to provide an estimate of total suitable area. Note that a major difference between our approach and traditional IFIM methods is that we relied on actual water quality monitoring data at sampling stations to calculate suitable habitat, while IFIM typically uses model simulations to generate data for each station. We assumed that error attributable to tidal time scale variation from taking point measurements of water quality would be effectively averaged out given the large amount of data (> 30 years).

***Habitat Suitability Criteria*:** Analyses such as IFIM can be highly sensitive to the habitat suitability criteria chosen (Bovee 1982). Therefore, we developed four different criteria that we believed "bracketed" the habitat of the target fishes (Table 1). Each method was devised such that each year's or each survey's data contributed equally. In other words, interannual and inter-survey abundance differences did not influence our results. Each species was analyzed separately.

Table 1. Four methods developed to define physical habitat for delta smelt and striped bass.

Method #	Description
Method 1	Cumulative catch for the mid-July survey each year[1] was sorted and plotted separately against each water quality variable. The interpolated value of each water quality variable where cumulative catch equalled 50% was taken as a habitat metric. The range of each water quality variable denoting habitat was derived as ± 1 SD from the mean of 32 observations (1970, 1973-1974, 1976-2004).
Method 2	Same as for Method 1, except that the range of each water quality variable denoting habitat was derived from the minimum and maximum values at which 50% of the cumulative catch had occurred in some year. The range was roughly equivalent to ± 2 SDs.
Method 3	Water quality data from where the maximum catches/tow for each survey, each year (ties included) were used as habitat indicators. The range of each water quality variable denoting habitat was

Table 1. (concluded)

	derived as ± 1 SD from the mean of 117 observations based on the same years as described for Method 1.
Method 4	Same as for Method 3, except that the range of each water quality variable denoting habitat was derived from the minimum and maximum values where a max catch/tow had occurred[2]. The range was roughly equivalent to ± 2 SDs.

[1]Usually Survey 2, Survey 3 in 1987, 1992, 1994, 2001-2004

[2]A max delta smelt catch/tow of 34 was reported at a specific conductance of 28,454 µs • cm on 16 July 1991 at station 704. This was an order of magnitude higher than at any station near 704 and was much higher than any other specific conductance where a maximum delta smelt catch had occurred. Thus it was considered an error. The second highest specific conductance value for a maximum catch/tow was used to define the upper range.

***Area Represented by Each Station*:** Staff from the DFG Central Valley/Bay-Delta office used GIS software to develop surface area estimates (acreages) for the more than 100 stations in the DFG Fall Midwater Trawl. We combined FMWT area estimates as needed to represent the approximately 40 TNS stations. Our TNS area estimates were linked to our datasets via look-up tables in Microsoft Access.

Water Quality Data: Habitat suitability criteria were applied to the water quality monitoring data for each TNS station. The suitability criteria were based on ranges of water temperature, Secchi disk depth, and specific conductance meeting the criteria described in Table 1. This provided a means of categorizing stations as 'suitable habitat' using four different sets of criteria. We applied these criteria to each year's mid-July survey data (as described in Table 1 for method 1) to characterize habitat area based on a standardized time of year. The surface area of habitat meeting the suitability criteria for each of the four methods was divided by the total area sampled each year during mid-July to provide four habitat area indices per year.

Results: Delta smelt distribution was constrained relative to total survey ranges of all three water quality variables. A detailed spreadsheet containing these preliminary analyses is available upon request. We have opted to report only the key results here.

Methods 1 and 3 provided the most conservative habitat definitions for each species (Tables 2 and 3). Method 4 provided the most liberal habitat definitions. Habitat ranges for delta smelt and striped bass were very similar. Both species have tended to be collected in low clarity, low salinity water that is less than 24°-25°C. The striped bass data were not analyzed further because it was unlikely they would provide a different result.

Table 2. Summary of delta smelt TNS habitat definitions. Note that means and standard deviations of specific conductance data were developed based on $\log_{10}$-transformed data. The untransformed specific conductance ranges, which are asymetric around the mean, are presented for clarity.

	Method 1	Method 2	Method 3	Method 4
Water temperature (°C)	21 ± 1	19-23	21 ± 1	19-26
Secchi disk depth (cm)	32 ± 8	18-54	31 ± 9	13-57
Surface EC (µs/cm)	571-3967	251-11288	355-4965	125-19,620

Table 3. Summary of striped bass TNS habitat definitions.

	Method 1	Method 2	Method 3	Method 4
Water temperature (°C)	22 ± 1	20-24	21 ± 1	18-25
Secchi disk depth (cm)	34 ± 8	18-53	29 ± 11	10-62
Surface EC (µs/cm)	563-3401	218-7985	698-9449	146-14,076

Based on all four methods, there has been no significant trend in the surface area of delta smelt habitat over the period of record (Figure 2; all $P \geq 0.39$). The delta smelt summertime habitat indices are non-linearly related to average X2 position during spring and early summer (Figure 3). The shape of these relationships varied depending on method. The conservative habitat definitions (Method 1 and Method 3) did not respond strongly to X2. The comparatively liberal habitat definitions (Method 2 and Method 4) suggested that habitat area may decrease as X2 moves upstream. Method 3 also suggested habitat area may decrease under very wet conditions. None of the habitat area estimates are significant predictors of delta smelt relative abundance (Figure 4; all $P \geq 0.07$). However, the several lowest habitat area estimates were consistently associated with very low delta smelt abundance using all four methods. Overall, the data indicate that physical habitat availability, as we were able to describe it, does not contribute strongly to the population dynamics of delta smelt.

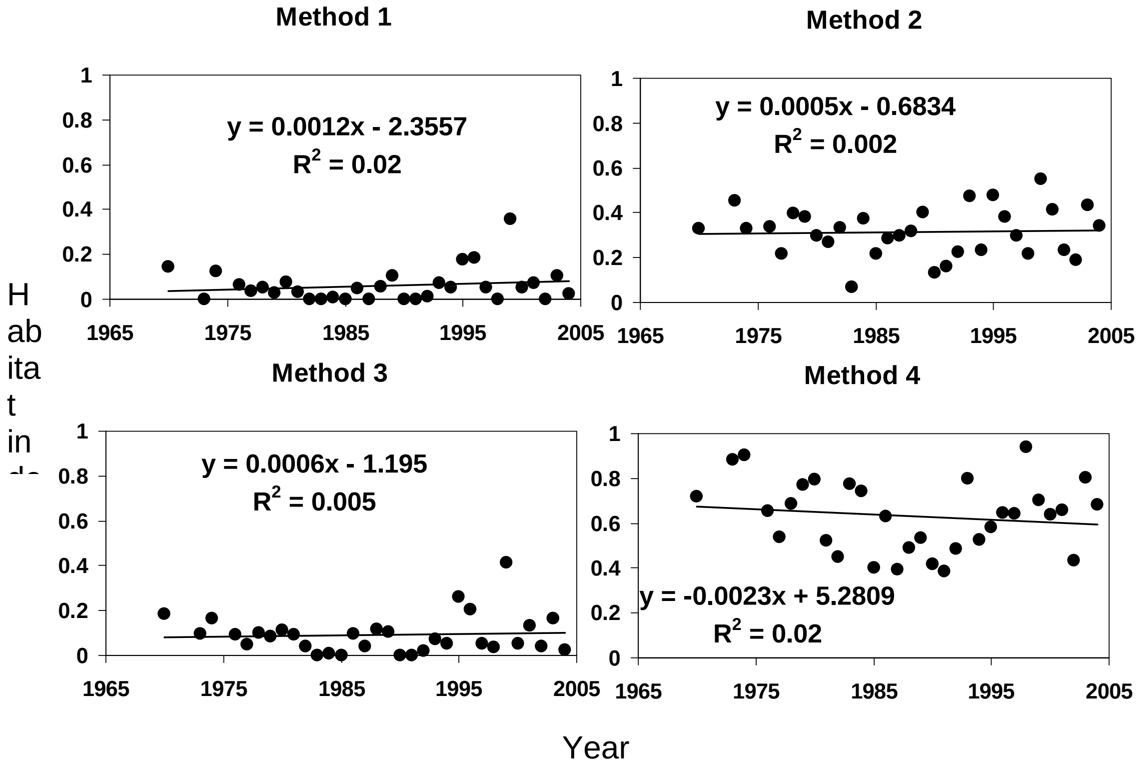
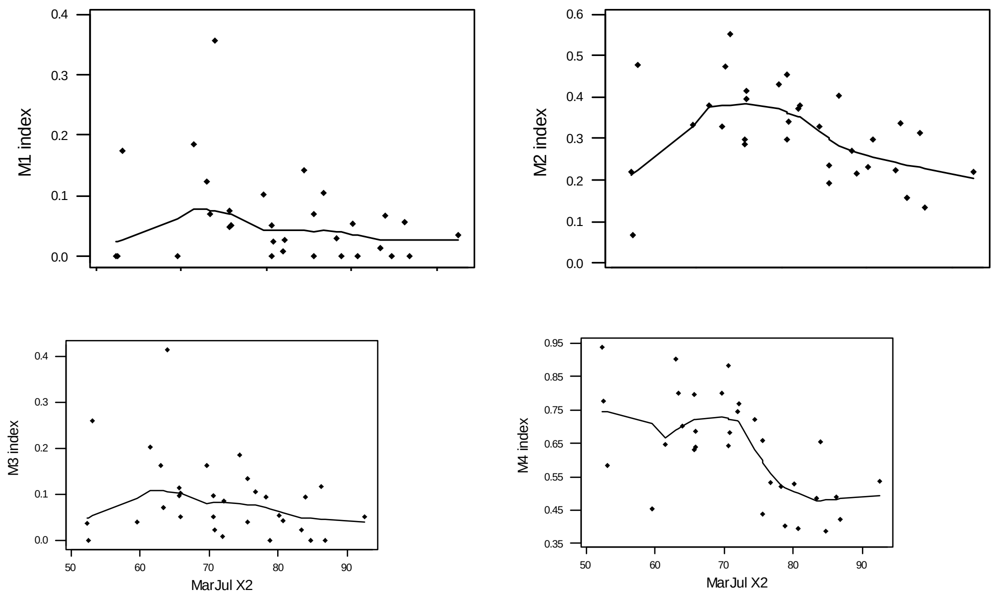


Figure 2. Time series plots of delta smelt summertime habitat area based on four methods described in Table 1. The x-axes depict years and the y-axes depict the proportion of sampled area (acres) meeting the habitat definitions.



Mean March1 – July 31 X2 position (km)

Figure 3. Scatterplots of mean March 1 – July 31 X2 position (x-axes; km; 1970, 1973-1974, 1976-2004) versus delta smelt summertime habitat area indices (y-axes) based on four methods described in Table 1.

This is a draft work in progress subject to review and revision as information becomes available.

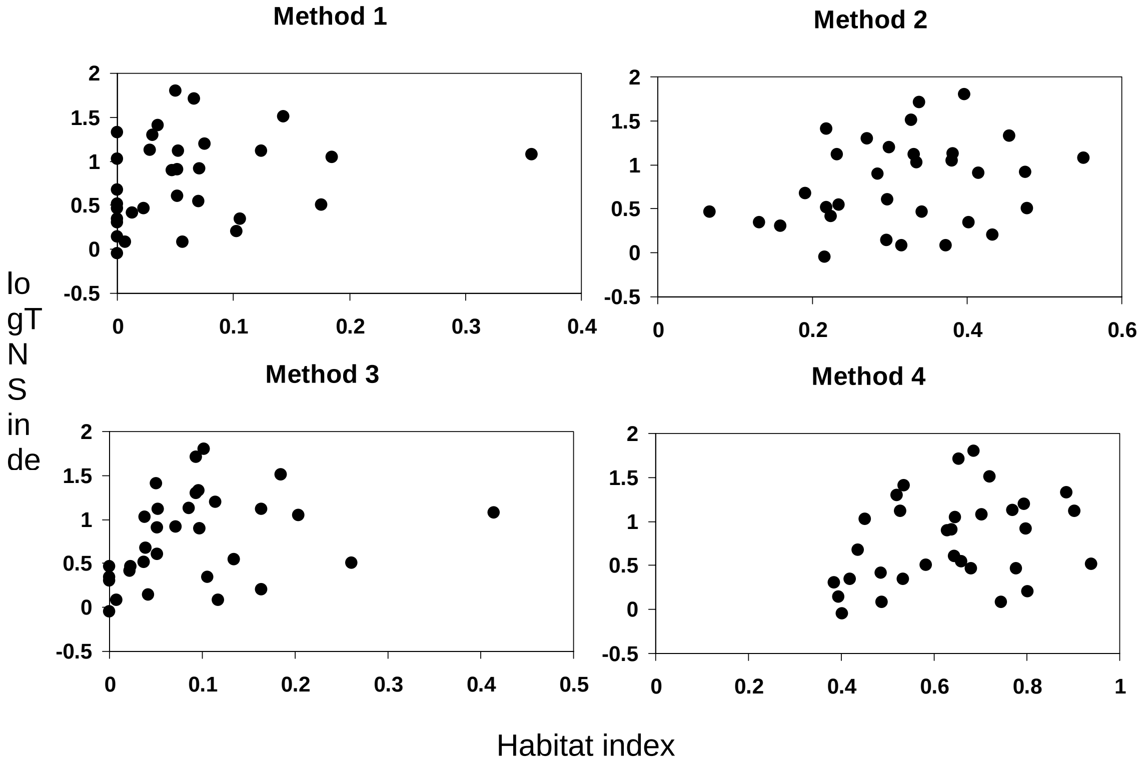


Figure 4. Scatterplots of proportion of sampled habitat meeting four definitions of delta smelt habitat (Table 1; x-axes) versus the $\log_{10}$-transformed delta smelt Townet Survey abundance indices (y-axes; 1970, 1973-1974, 1976-2004).

Conclusions:

- There is no evidence that delta smelt physical habitat quality has decreased since 1970. By extension, this also applies to age-0 striped bass, which were distributed very similarly to delta smelt with regard to the available water quality data.
- There is no evidence that variation in physical habitat quality significantly influences delta smelt population dynamics.
- The relationship between delta smelt physical habitat area and hydrodynamic conditions indexed by X2, is uncertain because it varied substantially among methods. The conservative habitat definitions did not respond strongly to flow variation. This is likely due to several factors. Geographically, delta smelt occur in and near the mixing zone where water clarity is consistently low. Summertime water temperatures are probably driven more by summer air temperatures than river flow. Delta smelt distribution is not tightly constrained by EC in the region of the estuary sampled by the TNS.

Next Steps:

- We would like to re-do the analysis by developing the habitat criteria using the top 50% of years with highest delta smelt abundance, then testing the probability that the 50% of years with lowest delta smelt abundance come from the same multivariate distribution of habitat variables. This would provide further assurance that our results are robust by testing the probability that pooling all years for analysis was an appropriate choice.

- We would like to use GIS software to examine the distribution of predicted 'optimal' habitat and the empirical distribution of the population. This might provide insight into other distribution-constraining variables that we have not accounted for (zooplankton abundance, water depth, etc.).

References:

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