Progress Report on Physical Habitat Trend Analyses for Fall Midwater Trawl

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Fred Feyrer (ffeyrer@water.ca.gov), Matt Nobriga, Ted Sommer

Introduction

We are midway through an in-depth analysis of the Fall Midwater Trawl (FMT) data to answer the following question: Has physical habitat suitability for delta smelt and age-0 striped bass declined over the period of record? The analysis was based on the following assumptions: (1) Delta smelt and young striped bass are generally pelagic fishes. Thus, their physical habitat can be adequately defined in terms of water quality parameters. (2) The available water quality parameters (water temperature, Secchi disk depth, and specific conductance) are sufficient to characterize habitat quality for these species. (3) All three water quality variables constrain distribution in an additive manner. We made this assumption because we did not have data to the contrary.

The basic approach used was somewhat comparable to instream flow methods (IFIM) that have been applied to rivers and streams. 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 area units based on the location of FMT sampling sites. Third, we applied the habitat criteria (step 1) to long-term water quality monitoring data for each FMT site to determine which provided suitable habitat. Finally, the area units (step 2) based on suitable habitat at FMT sites were summed 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.

Methods

The FMT has sampled approximately 100 stations across four months - September, October, November, and December – since 1967. Each site is sampled once per visit each month. Each monthly collection of samples is termed a survey, thus four surveys are completed each year. Mean water temperature decreases from approximately 20 ˚C to 10 ˚C over the course of the four surveys because of the seasonal transition from fall to winter (Figure 1). Secchi depth and specific conductance also exhibit some seasonal variability but the gross differences are obscured by spatial variability across the wide geographic area encompassed by the sites (Figure 1). Due to this seasonal variability, distributions of delta smelt and striped bass shifted to cooler temperatures across surveys, while shifts in Secchi depth and specific conductance were less apparent (Figure 2). Due to these differences across surveys, physical habitat suitability criteria for delta smelt and striped bass were developed separately for each survey.

Physical habitat suitability criteria were developed from a subset of 97% of FMT samples collected from 1967 to 2004 that had both fish catch and physical environmental data (N = 14,017 samples). Analyses such as IFIM are often highly sensitive to what types of habitat suitability criteria are selected. To address this issue, we developed four different criteria that we believed “bracketed” the habitat of the target fishes (Table 1). Each method was devised such that data from each survey in each year contributed equally to setting habitat suitability criteria. In other words, interannual and inter-survey abundance differences did not influence our results.

Overall, the constructed physical habitat criteria for temperature was similar for delta smelt and striped bass however, striped bass exhibited broader criteria for Secchi depth and specific conductance (Figure 3). Further, for each species, methods A and D produced similar physical habitat suitability criteria across all environmental variables, while methods B and C were similar and typically produced a narrower range of criteria. There was a seasonal downward shift in temperature across the surveys for both species under all three criteria methods. Secchi depth criteria across surveys appeared relatively stable. Specific conductance criteria for delta smelt under methods A and C appeared to increase across surveys. Specific conductance criteria for striped bass exhibited subtle shifts across surveys but all criteria appeared to remain within a similar range of what could be considered biologically relevant.

Due to variability in the number of sites sampled among years, we standardized the amount of total habitat available to a core set of stations used to establish the FMT fish abundance indices. The list of core stations and associated surface areas (Table 2) were obtained directly from California Department of Fish and Game staff. Estimates of surface area meeting suitability criteria are based relative to 347.37 km^2, which is the estimated total available surface area per survey and was derived from the sum of the surface areas associated for each FMT index station. Because not all index sites were sampled in all years, estimated surface area sampled also varied among years (Figure 4). To correct for this problem, a nearest neighbor extrapolation was used to assign environmental variables to stations with missing data. Sites with missing data and those used for extrapolation are given in Table 3. Due to time constraints, the present surface area analyses are limited to survey 3 for the time period 1982-2004, and 1994 was omitted from the analyses because of an extensive number of missing sites.

Results

Delta smelt

Overall, there appears to be some evidence of a decreasing time trend in the proportion of sites sampled meeting suitable habitat criteria (Figure 5) for delta smelt but not for the total suitable surface area (Figure 6). The proportion of samples meeting suitable habitat criteria appears to have decreased since about 1990, as has the variability in sites meeting the criteria. These contrasting results suggest there is likely an interaction between suitable sites and time periods that requires further investigation. There is some indication using Methods A and D that suitable habitat area since 2001 has been below average; however, these trends are within the range of variability of previous years. It does not appear that total suitable surface area influences September FMT or the following year's Summer Townet index (Figures 9 and 11). However, it should be clearly noted that statistical characterization of these time series and relationships needs to be completed before conclusions should be drawn from these data.

Striped bass

Overall, the results for striped bass are similar to those for delta smelt. There appears to be some evidence of a decreasing time trend in the proportion sites sampled meeting suitable habitat criteria (Figure 7) but not for the total suitable surface area

(Figure 8). Methods B and C suggest that the proportion of samples meeting suitable habitat criteria may have decreased since about 1990, as has the variability in sites meeting the criteria. Unlike delta smelt, none of the methods suggest that the past four years have shown below average levels of suitable habitat. It does not appear that total suitable surface area influences September FMT or the following year's Summer Townet index (Figures 10 and 12). Again, however, it should be clearly noted that statistical characterization of these time series and relationships needs to be completed.

Next Steps

- Complete the surface area analyses for all possible years and surveys.
- Statistically characterize all time series.
- Examine all time series in more detail relative to other factors (e.g., delta inflow) to elucidate mechanisms of variability. This will include investigating possible interactions between regions meeting suitable habitat criteria and time periods.
- Re-do the analysis by developing the habitat criteria using the top 50% of years with highest fish abundance, then testing the probability that the 50% of years with lowest fish 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.
- 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.).

Table 1. Basic description of the four methods used to develop physical habitat suitability criteria for delta smelt and age-0 striped bass.

Method	Type	Data and conceptual framework
A	Least conservative	Derived from samples with highest abundance for each survey in each year. Assumes maximum observed abundances reflect preferred habitat combination of temperature, transparency, and salinity. The range of physical habitat conditions across these maximum abundances represents the range for the suitability criteria.
B	Most conservative	Derived from samples with highest abundance for each survey in each year. Also assumes maximum observed abundances reflect preferred habitat conditions but is more restrictive than method A in setting criteria. A centrally distributed subset (mean ± one standard deviation) of the range of physical habitat conditions at these maximum abundances represents the range for the suitability criteria.
C	Most conservative	Derived from samples in which cumulative abundance reached 50% for each survey in each year for each variable. Assumes independence of variables in determining preferred habitat conditions. A centrally distributed subset (mean ± one standard deviation) of the range for each variable represents the range for the suitability criteria.
D	Least conservative	Derived from samples in which cumulative abundance reached 50% for each survey in each year for each variable. Assumes independence of variables in determining preferred habitat conditions but is less restrictive than method C in setting criteria. Minimum and maximum values for each variable represent the range for the suitability criteria.

Table 2. Representative surface areas (km^2) for Fall Midwater Trawl stations used to establish abundance indices.

Station	Surface area	Station	Surface area	Station	Surface area	Station	Surface area
305	2.82	407	2.12	601	4.48	902	16.51
306	2.35	408	2.40	602	12.15	903	1.36
307	8.70	409	1.61	603	3.71	904	3.94
308	2.81	410	1.74	604	5.16	905	2.44
309	2.88	411	3.21	605	1.00	906	2.83
310	2.65	412	4.07	606	2.81	908	2.99
311	2.43	413	4.34	608	1.39	909	2.08
314	13.55	414	2.64	701	5.10	910	1.63
315	13.24	415	2.27	703	5.08	911	0.82
321	3.19	416	4.19	704	1.78	912	2.42
322	3.16	417	4.99	705	1.82	913	6.49
323	6.96	418	5.88	706	2.61	914	3.00
325	2.48	501	3.16	707	2.82	915	3.65
326	5.26	502	2.58	708	1.86		
327	7.68	503	1.95	709	1.54		
328	7.93	504	2.22	710	1.31		
329	2.81	505	3.10	711	1.72		
334	2.37	507	2.26	802	4.70		
335	2.16	508	1.11	804	3.46		
336	0.65	509	1.46	806	3.58		
337	3.06	510	1.62	807	4.65		
338	3.50	511	2.15	808	2.36		
339	2.71	512	1.81	809	2.13		
340	1.86	513	3.99	810	1.86		
401	3.77	515	4.53	811	1.68		
403	2.47	516	3.11	812	1.86		
404	3.20	517	2.27	813	1.57		
405	2.39	518	6.10	814	1.94		
406	0.91	519	6.10	815	2.18		

Table 3. Sites used for extrapolation (replacement site) for those missing environmental data (missing site), 1982-2004. 1994 was omitted because of extensive missing sites.

Year	Missing site	Replacement site
2004		
2003	412	413
2002	315	314
2001		
2000		
1999		
1998		
1997	407,408	406
	703	704
1996	310	309
	806	807
1995	306	305
	512	513
1993	414	415
	509	510
	703,704	705
	709	710
1992	338	337
	339	337
	909	910
1991	329	328
	501	502
	516	516
1990	329	334
	501	502
	815	814
	913,914,915	Average of 902,908
1989	314,315	321
	327,328	329
	913,914,915	Average of 902,908
1988	414,415	416
	913,914,915	Average of 902,908
1987	309	310
	815	814
	913,914,915	Average of 902,908
1986	413	412
	815	814
	913,914,915	Average of 902,908
1985	323	322
	603	602
	815	814

	913,914,915	Average of 902,908
1984	305,306	307
	327	328
	404	405
	408	407
	815	814
	913,914,915	Average of 902,908
1983	913,914,915	Average of 902,908
1982	310	309
	334	335
	339	338
	602	601
	813,815	814
	913,914,915	Average of 902,908

Figure headings

Figure 1. Mean values for environmental variables per survey per year. Error bars are one standard deviation.

Figure 2. Distribution of delta smelt and age-0 striped bass across surveys for each environmental variable. Bars represent total number of observations and lines represent the cumulative percentage of observations.

Figure 3. Range of values encompassed for each physical habitat suitability method across species and surveys. Details regarding analyses used to derive values for methods A, B, C, and D are presented in the text and in Table 1.

Figure 4. Estimated total surface area sampled across surveys and years.

Figure 5. Proportion of sites sampled that met suitable habitat criteria for delta smelt under each method.

Figure 6. Total surface area that met suitable habitat criteria for delta smelt under each method. This time series is limited to Survey 3 for the time period 1982-2004, with 1994 excluded because of extensive missing sites.

Figure 7. Proportion of sites sampled that met suitable habitat criteria for striped under each method.

Figure 8. Total surface area that met suitable habitat criteria for striped bass under each method. This time series is limited to Survey 3 for the time period 1982-2004, with 1994 excluded because of extensive missing sites.

Figure 9. Total September suitable delta smelt habitat area plotted against September FMT delta smelt index.

Figure 10. Total September suitable delta smelt habitat area plotted against following year's Summer Townet delta smelt index.

Figure 11. Total September suitable striped bass habitat area plotted against September FMT striped bass index.

Figure 12. Total September suitable striped bass habitat area plotted against following year's Summer Townet striped bass index.

Figure 1.

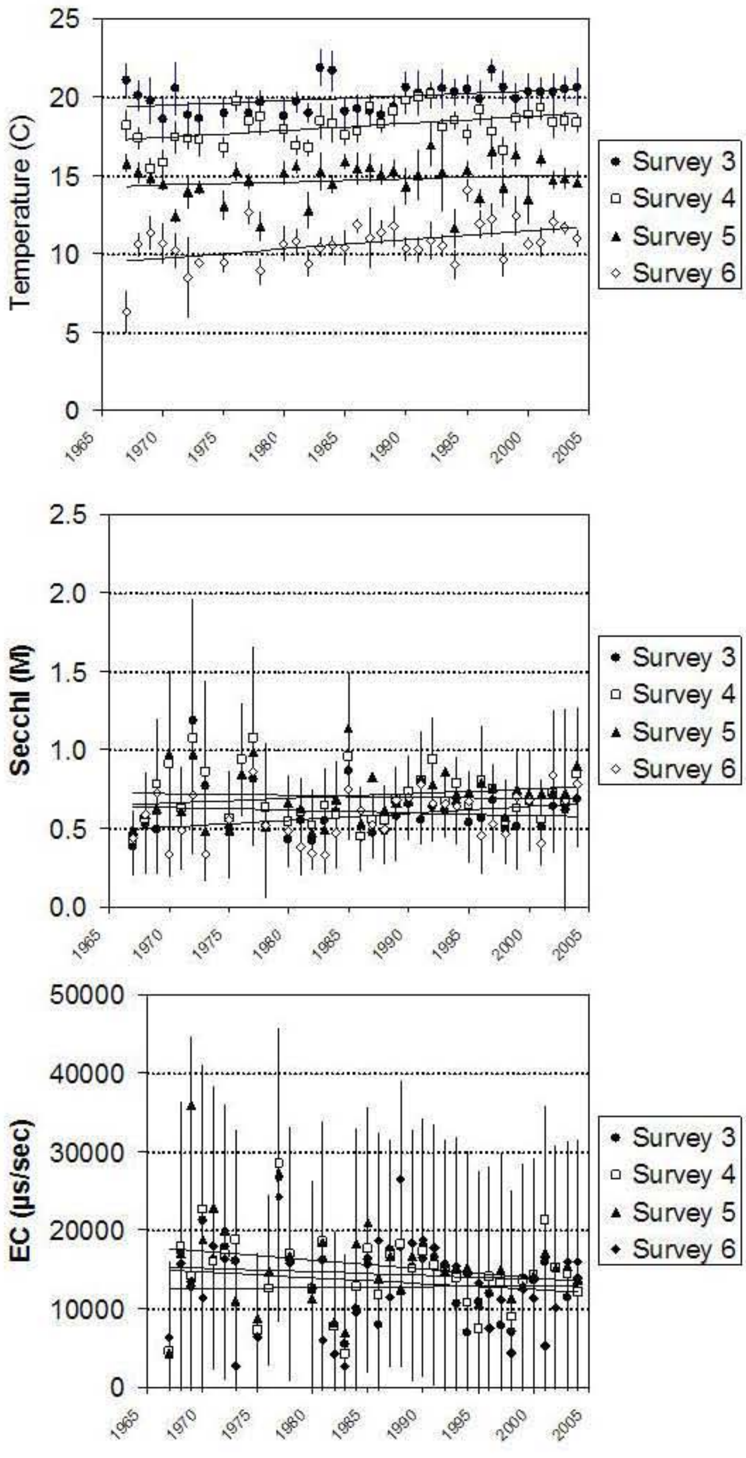
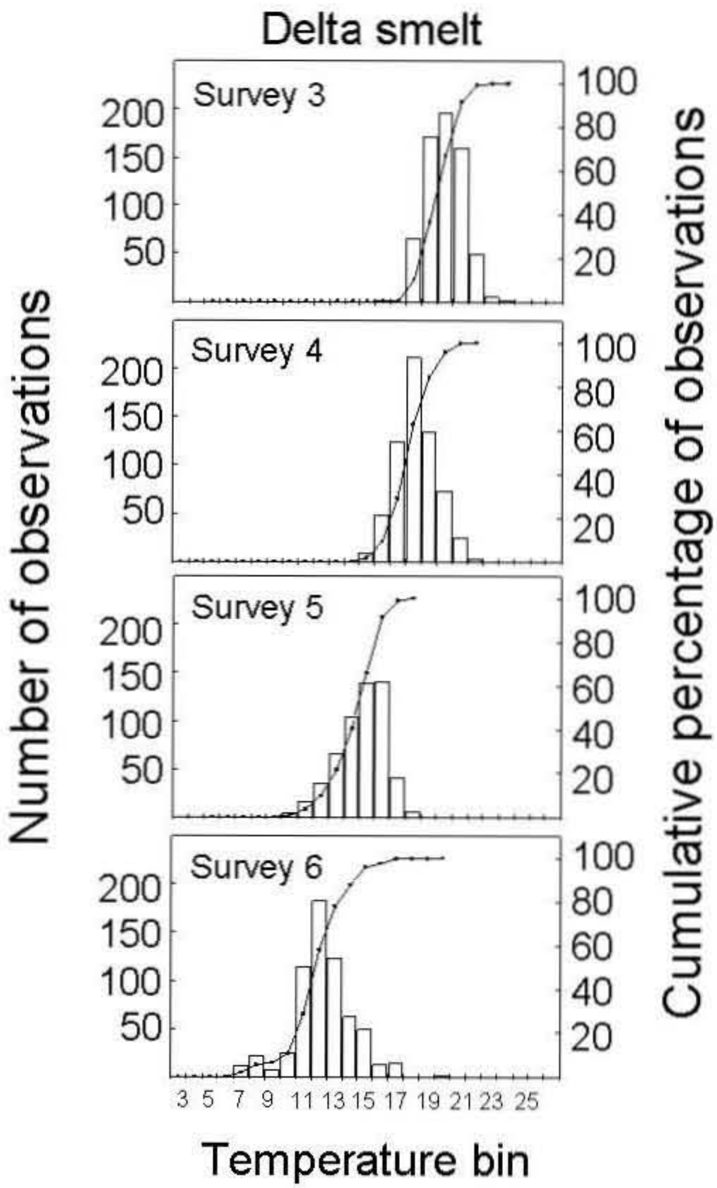
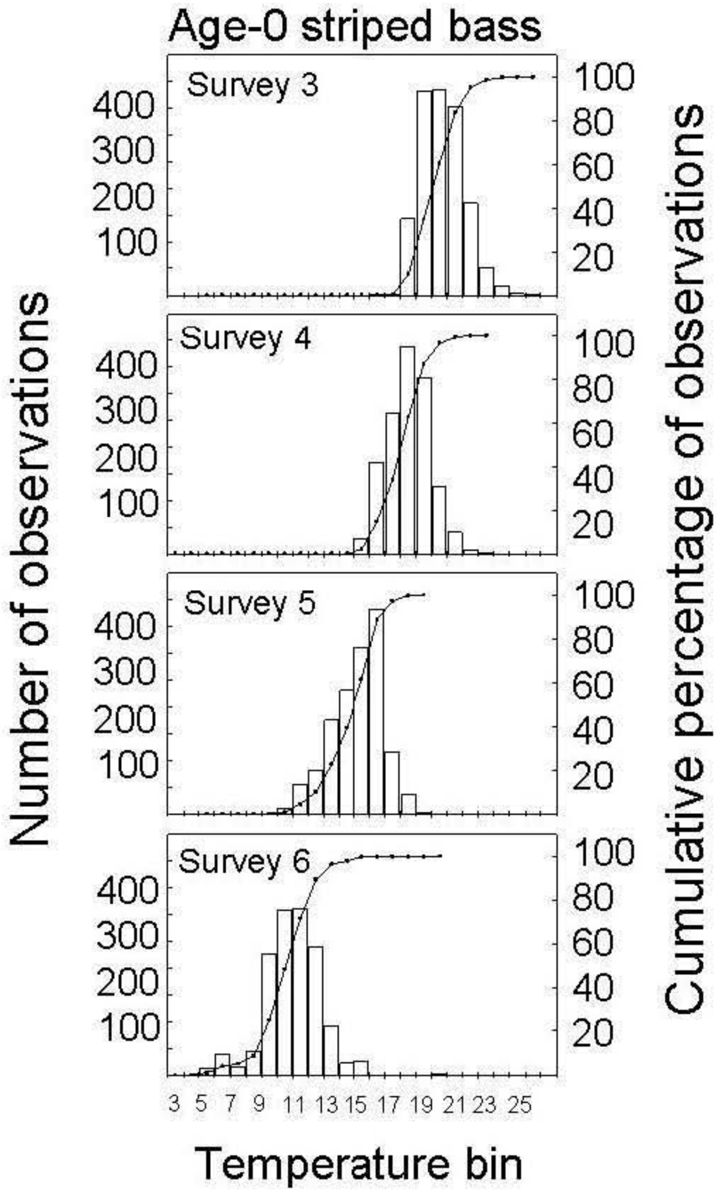

Temperature (C)
25
20
15
10
5
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
Survey 3
Survey 4
Survey 5
Survey 6
Secchi (M)
2.5
2.0
1.5
1.0
0.5
0.0
1965
1970
1975
1980
1985
1990
1995
2000
2005
Survey 3
Survey 4
Survey 5
Survey 6
EC (µs/sec)
50000
40000
30000
20000
10000
0
1965
1970
1975
1980
1985
1990
1995
2000
2005
Survey 3
Survey 4
Survey 5
Survey 6

Figure 2.



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

Figure 2, continued.



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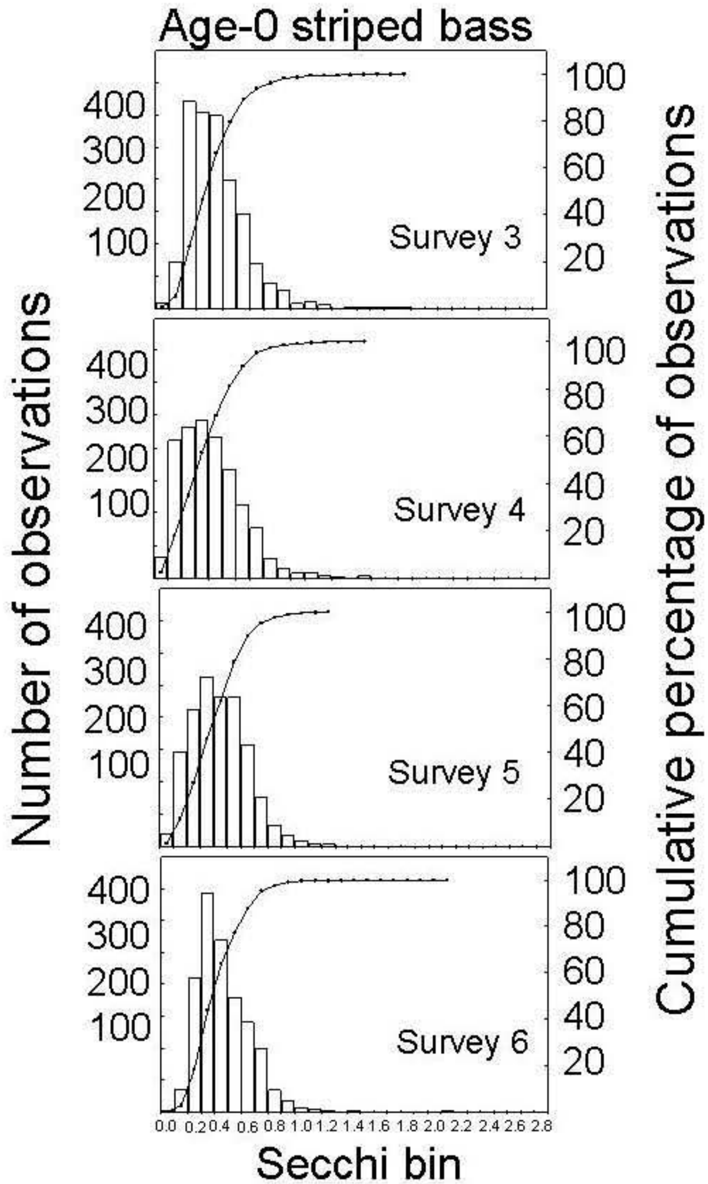

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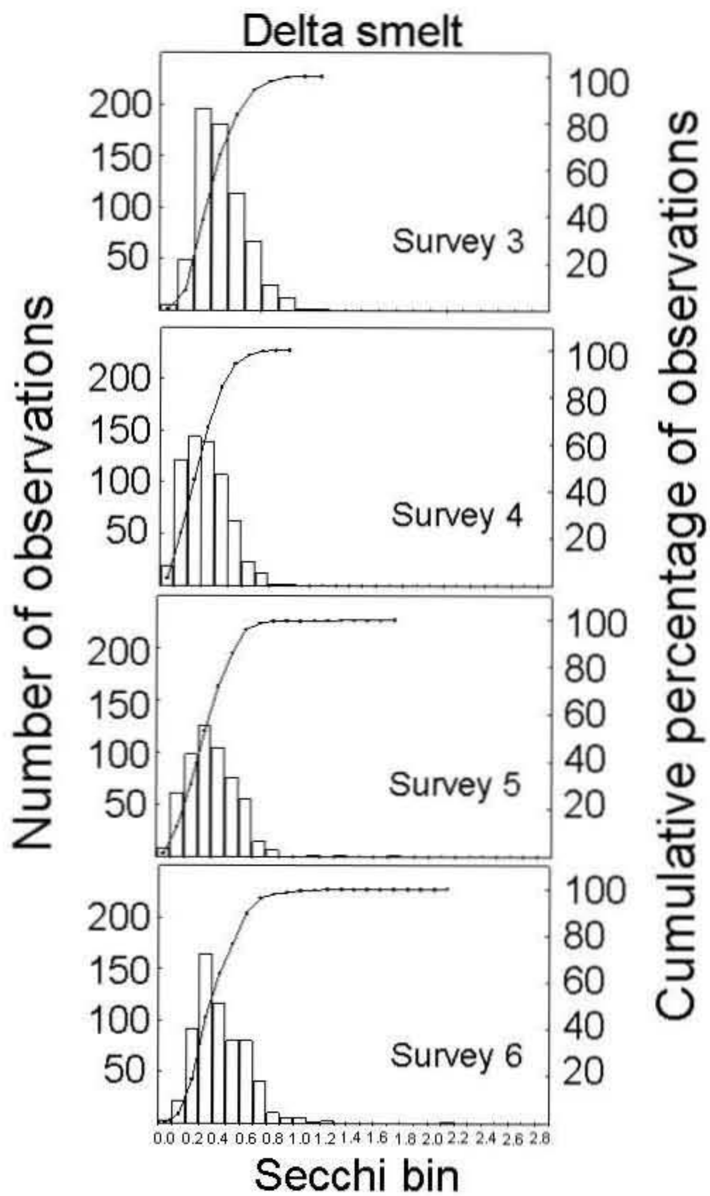

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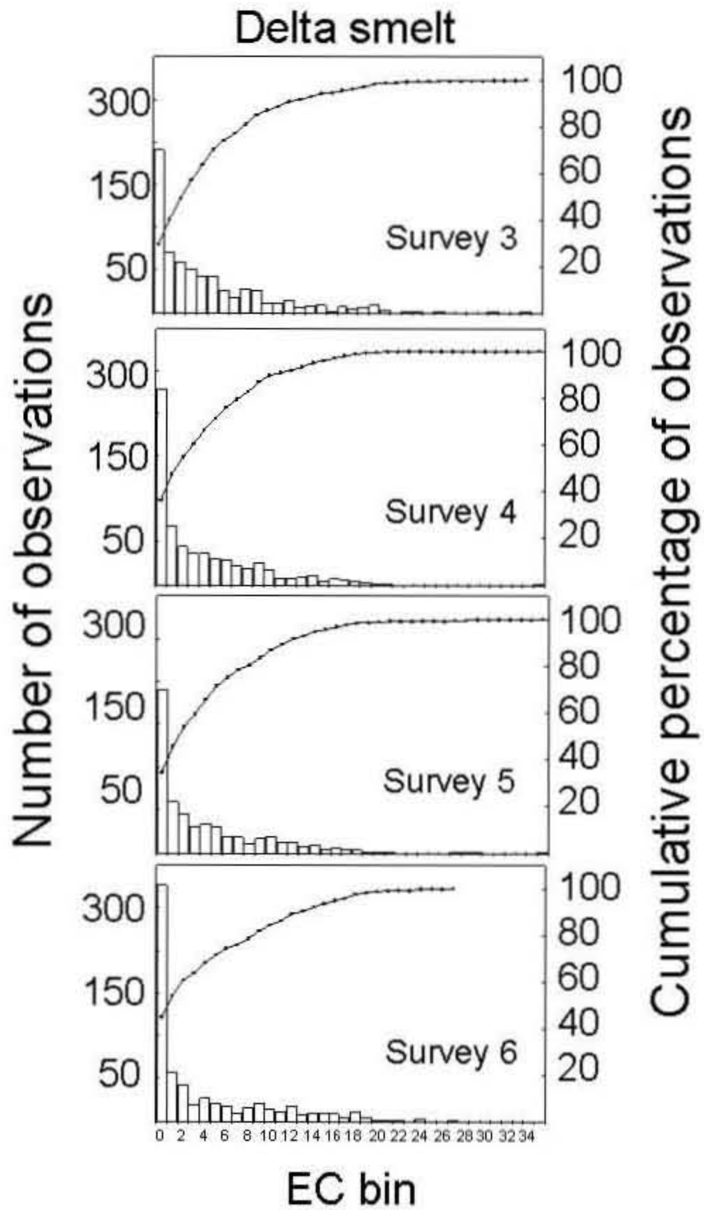

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Figure 2, continued.

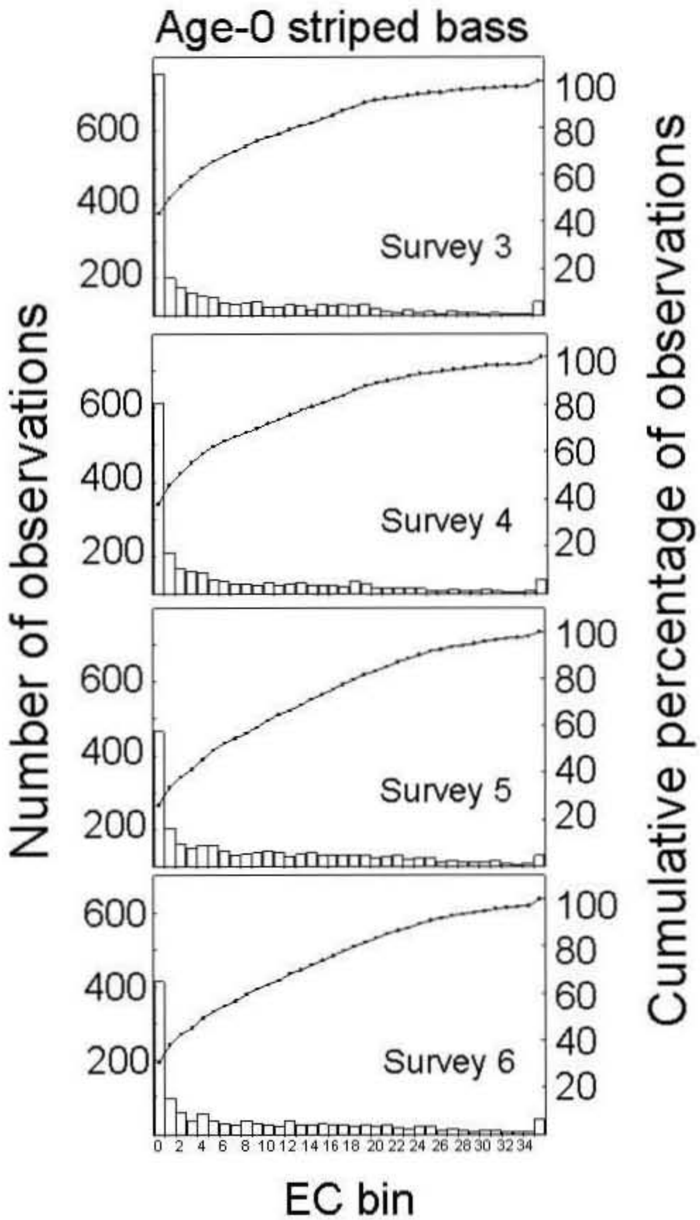


Figure 3.

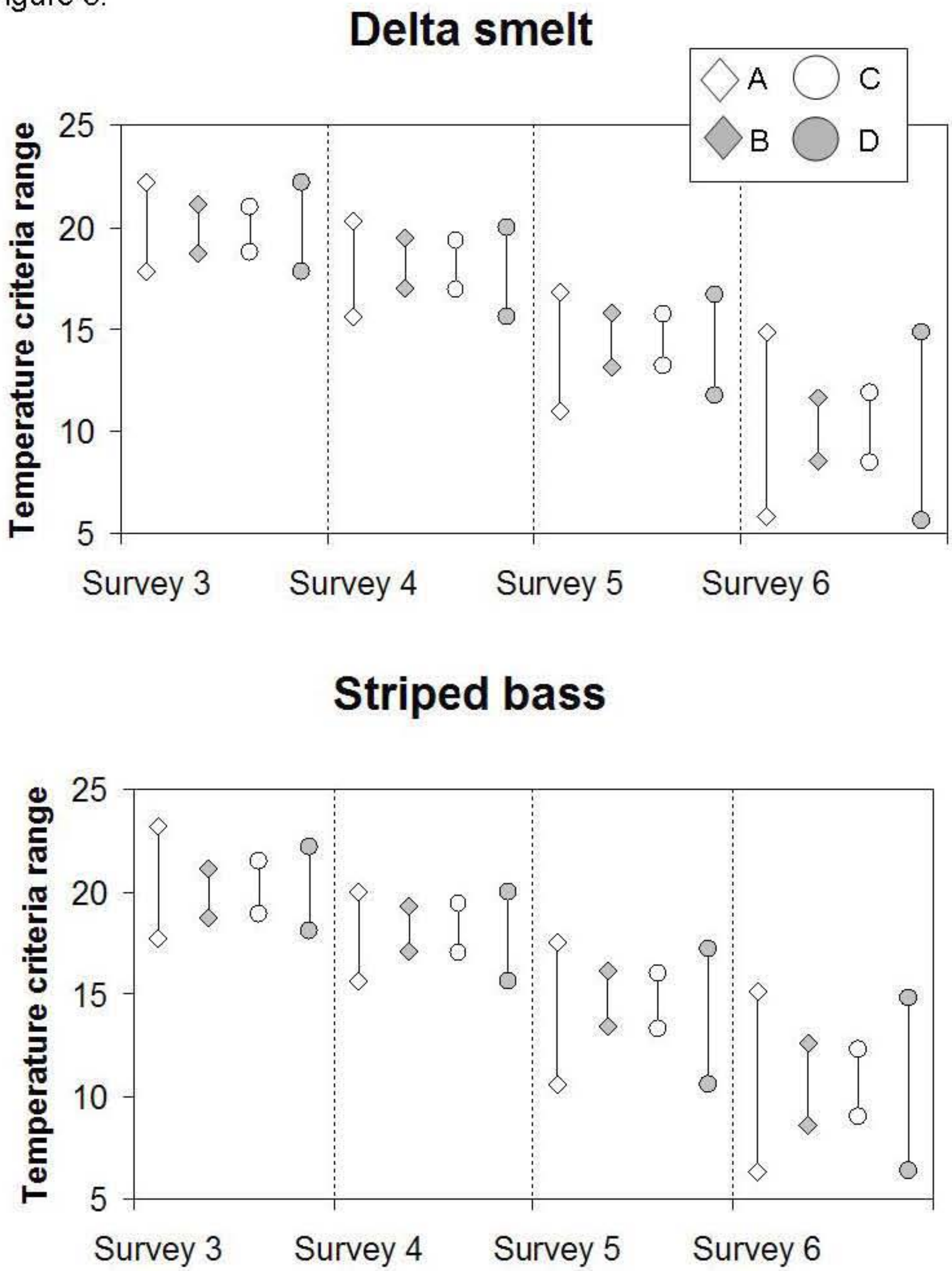
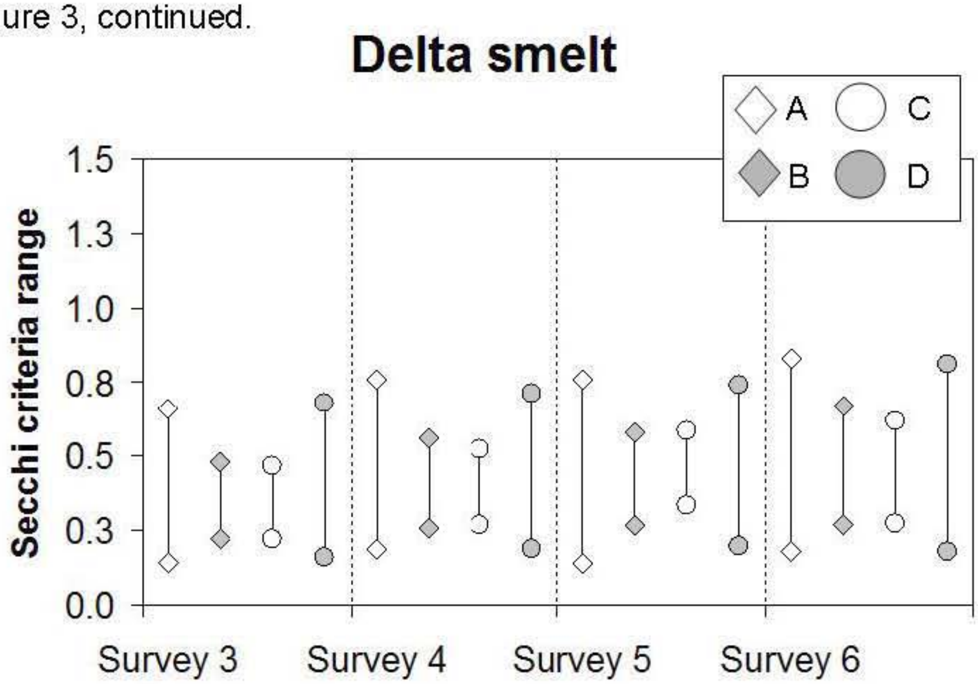
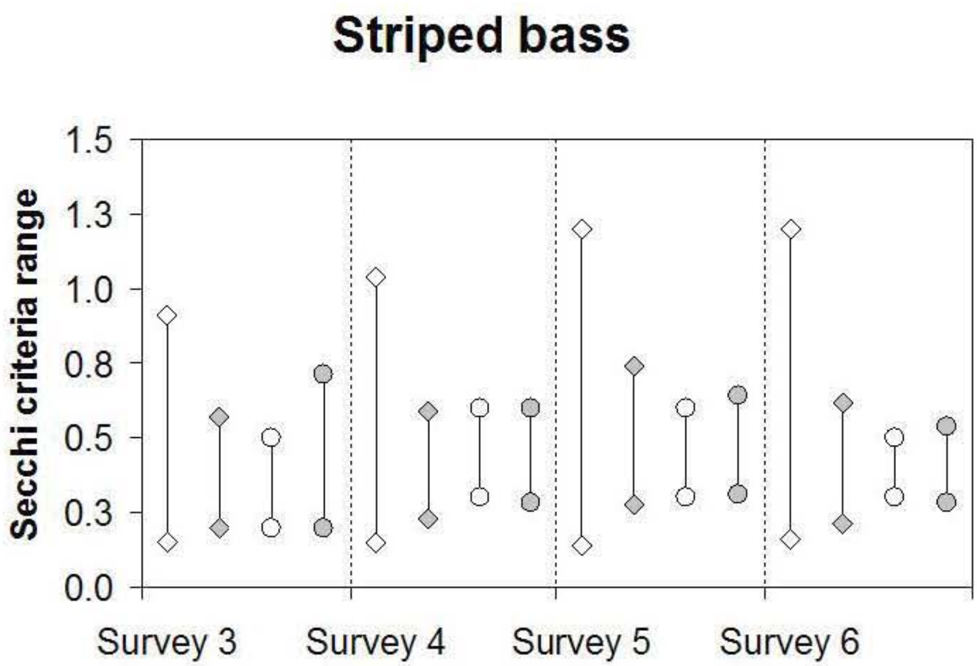

Delta smelt
A
B
C
D
Temperature criteria range
25
20
15
10
5
Survey 3
Survey 4
Survey 5
Survey 6
Striped bass
Temperature criteria range
25
20
15
10
5
Survey 3
Survey 4
Survey 5
Survey 6

Figure 3, continued.





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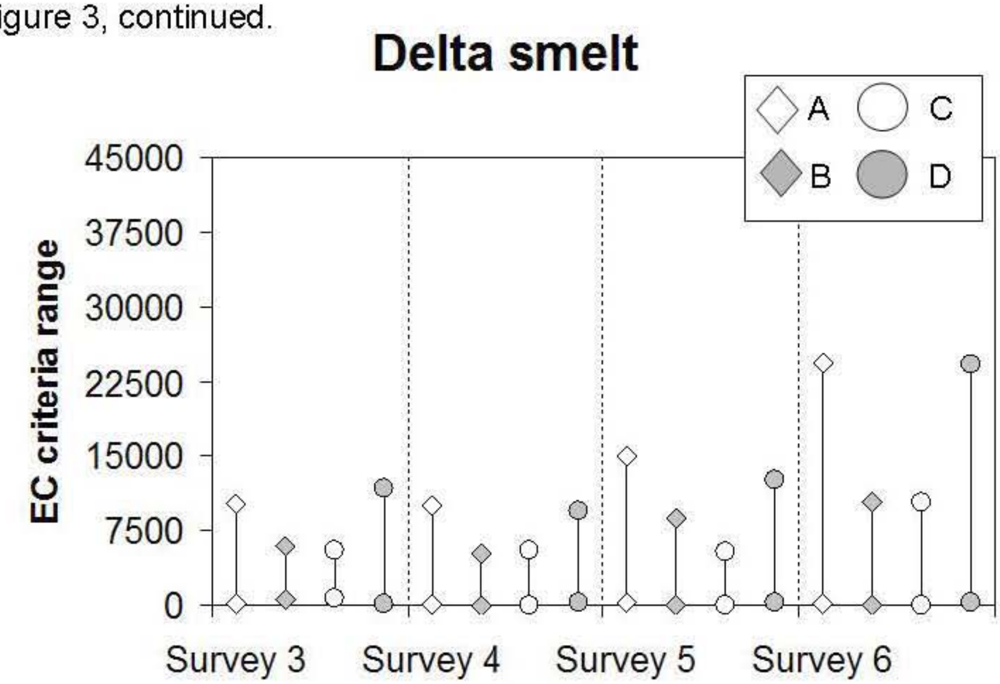

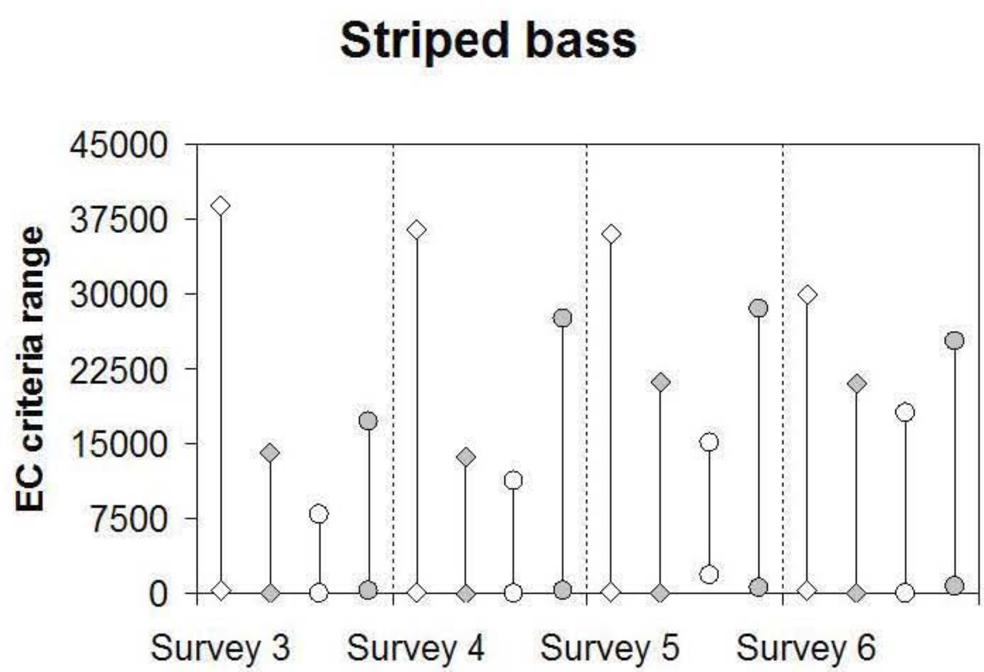

Figure 4.

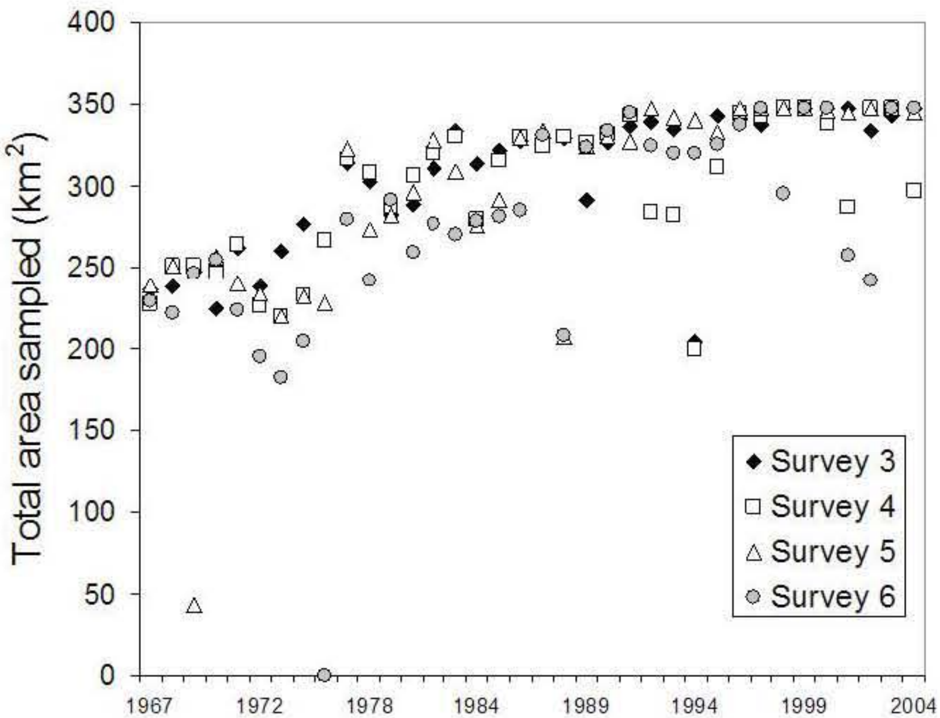

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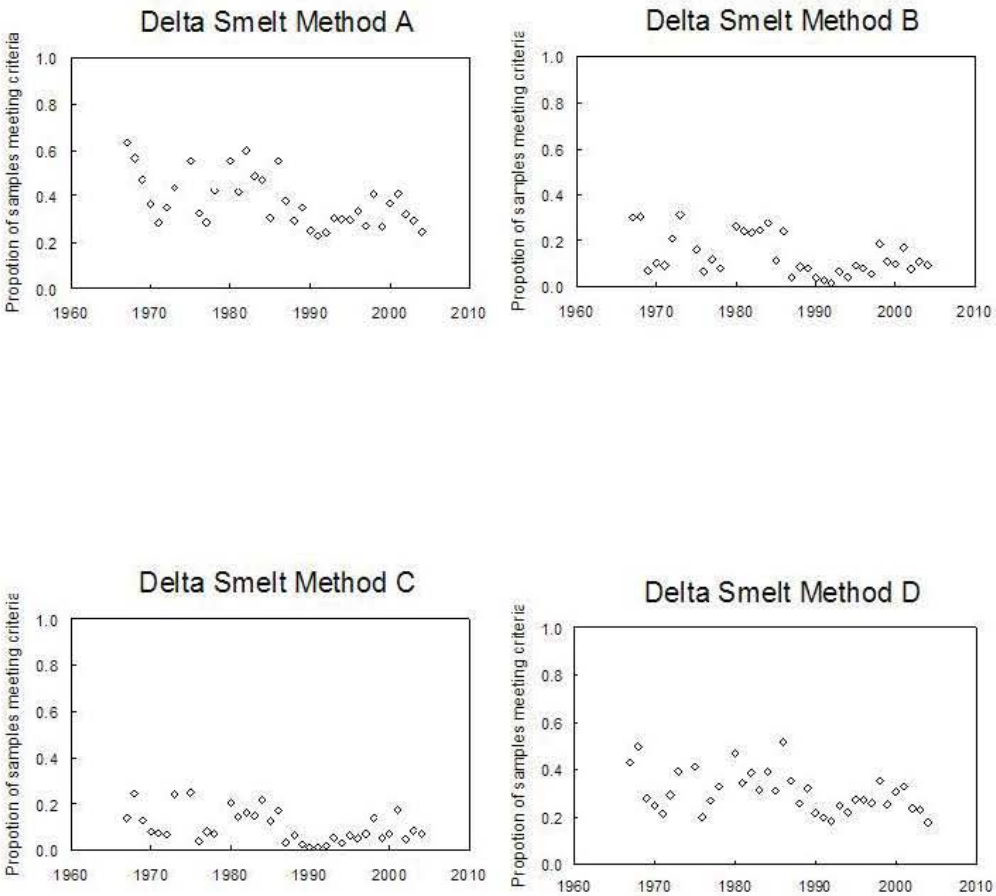
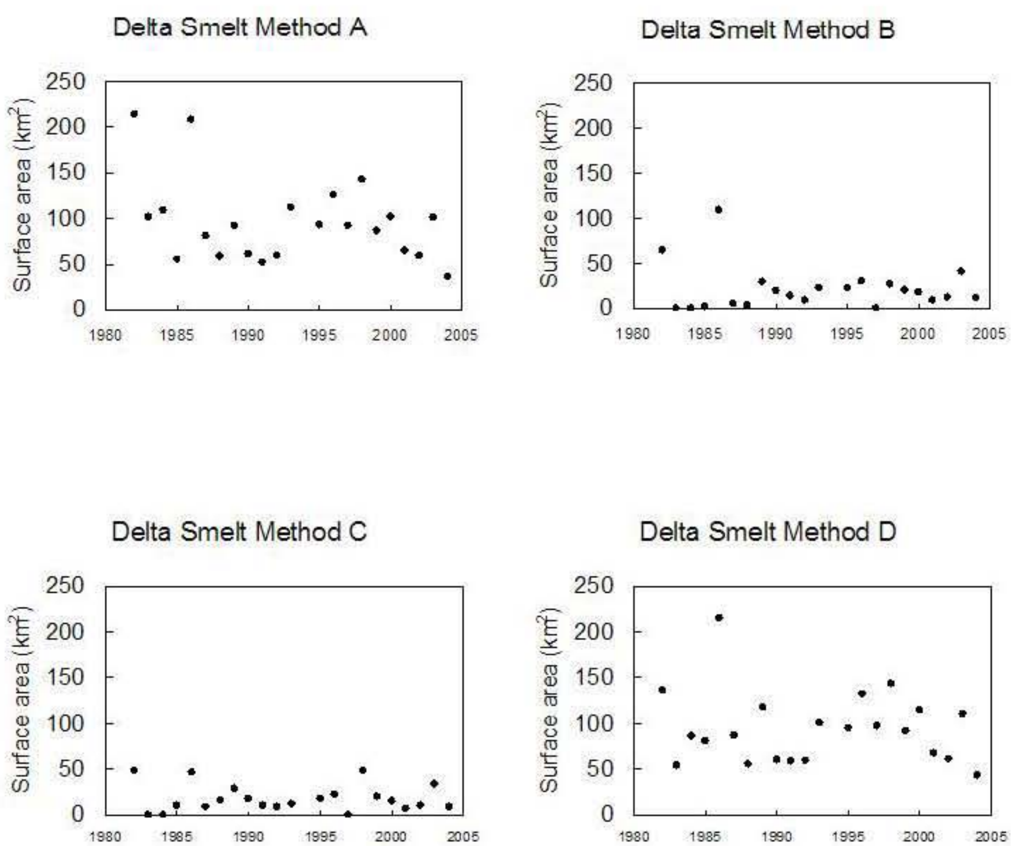
Figure 5.



Delta Smelt Method A
Delta Smelt Method B
Delta Smelt Method C
Delta Smelt Method D
Propotion of samples meeting criteria
Propotion of samples meeting criteria
Proportion of samples meeting criteria
Propotion of samples meeting criteria
0.0
0.2
0.4
0.6
0.8
1.0
1960
1970
1980
1990
2000
2010

Figure 6.



Delta Smelt Method A
Delta Smelt Method B
Delta Smelt Method C
Delta Smelt Method D
Surface area (km²)
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005

Figure 7.

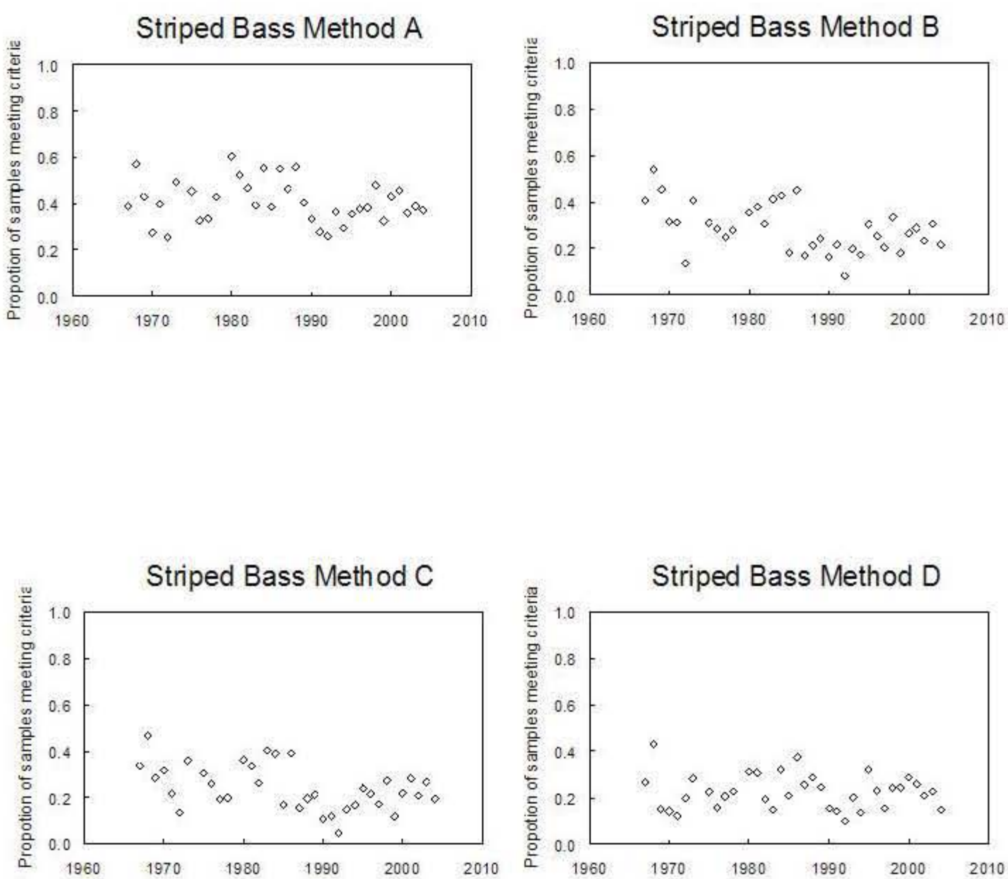

Striped Bass Method A
Propotion of samples meeting criteria
1.0
0.8
0.6
0.4
0.2
0.0
1960
1970
1980
1990
2000
2010
Striped Bass Method B
Propotion of samples meeting criteria
Striped Bass Method C
Propotion of samples meeting criteria
Striped Bass Method D
Propotion of samples meeting criteria

Figure 8.

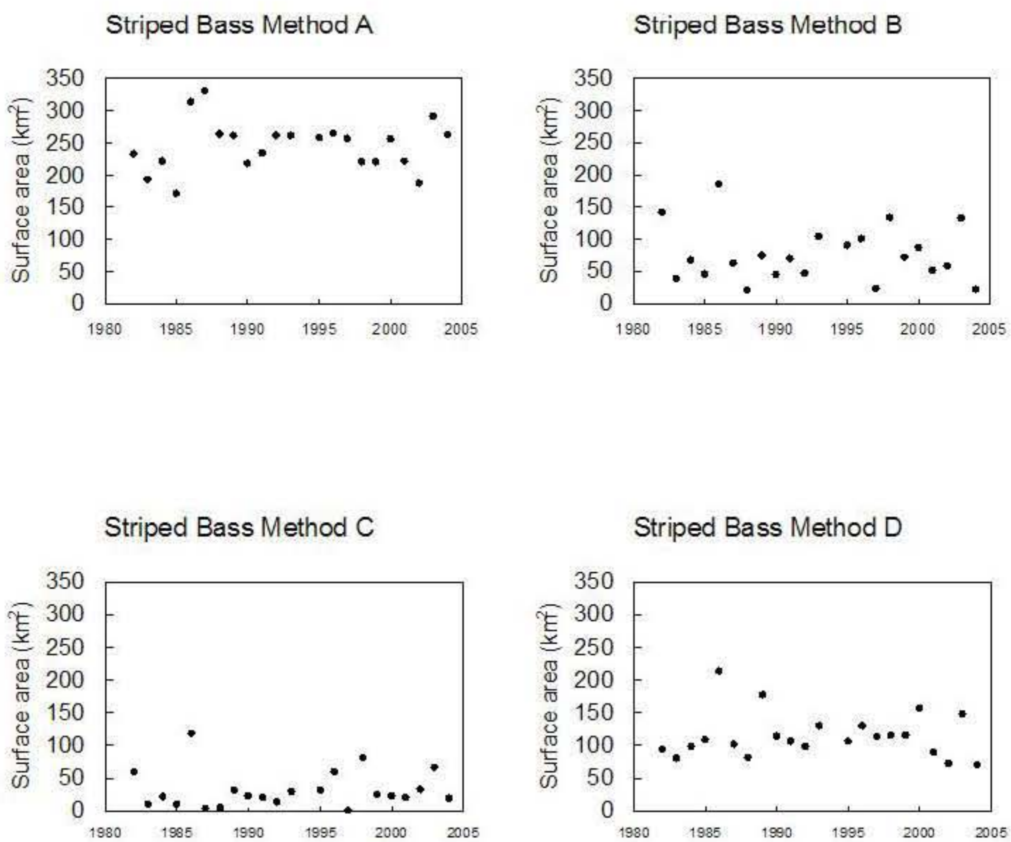

Striped Bass Method A
Striped Bass Method B
Striped Bass Method C
Striped Bass Method D
Surface area (km²)
350
300
250
200
150
100
50
0
1980
1985
1990
1995
2000
2005

Figure 9.

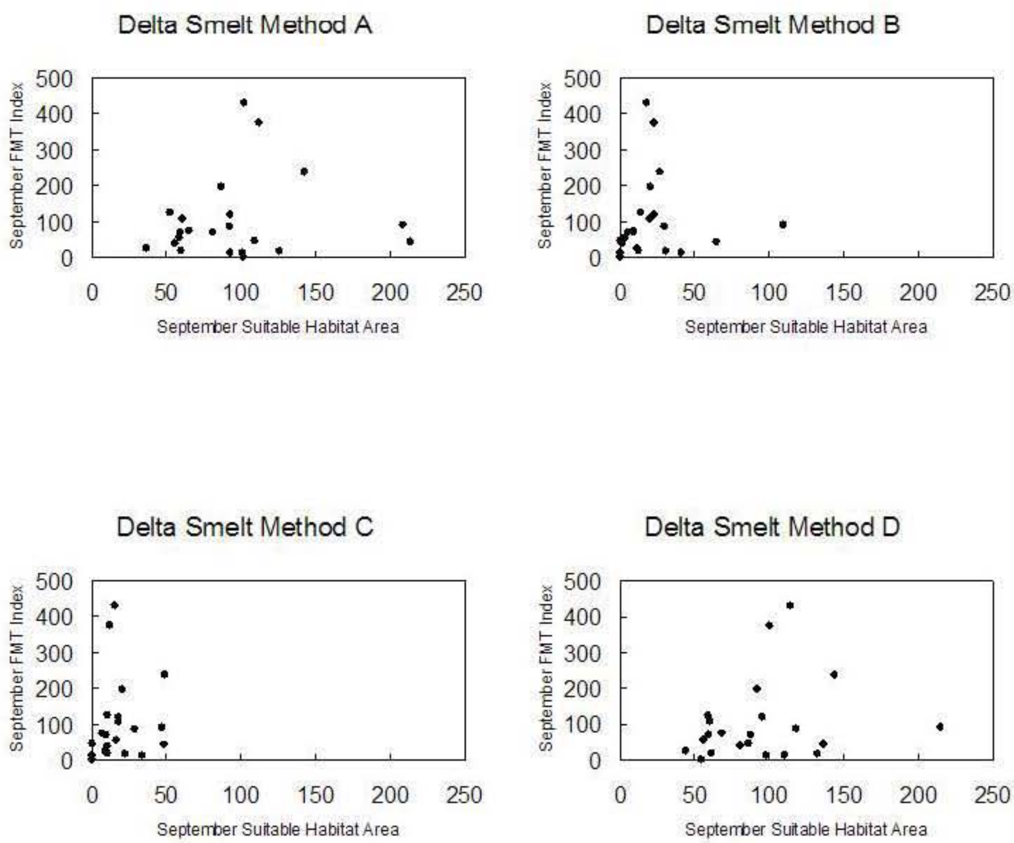
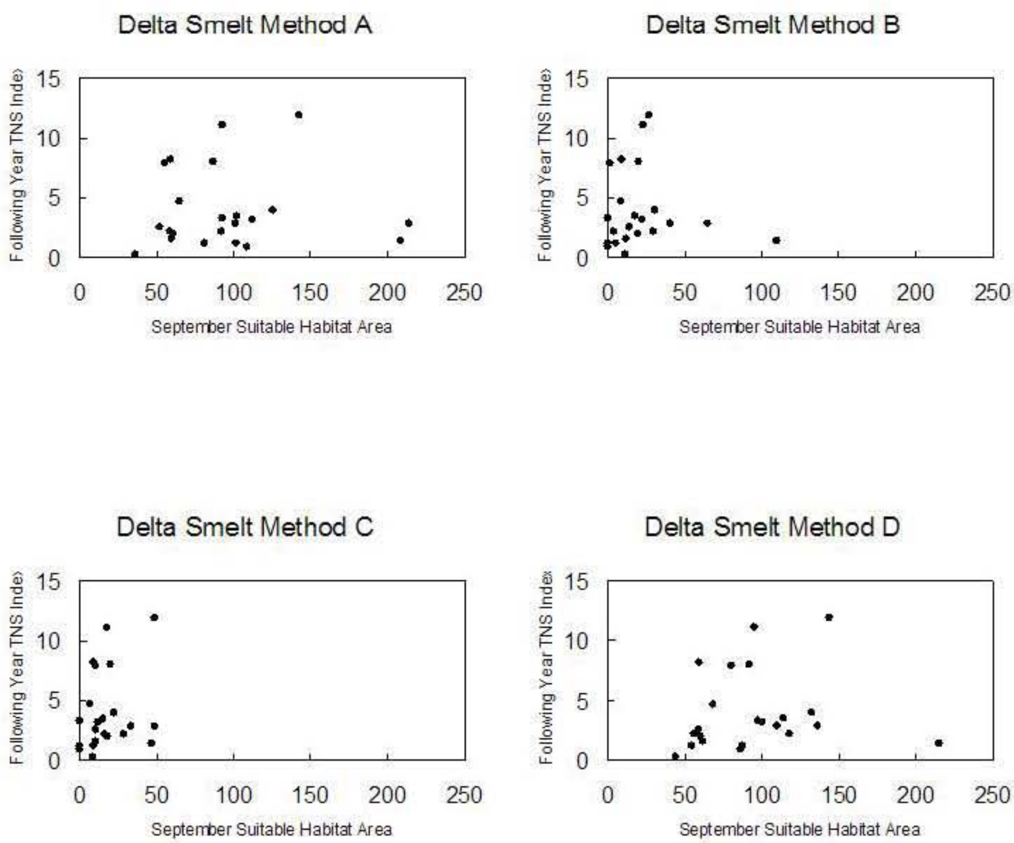

Delta Smelt Method A
Delta Smelt Method B
Delta Smelt Method C
Delta Smelt Method D
September FMT Index
September Suitable Habitat Area
0
100
200
300
400
500
0
50
100
150
200
250

Figure 10.



Delta Smelt Method A
Delta Smelt Method B
Delta Smelt Method C
Delta Smelt Method D
Following Year TNS Index
September Suitable Habitat Area
0
5
10
15
50
100
150
200
250

Figure 11.

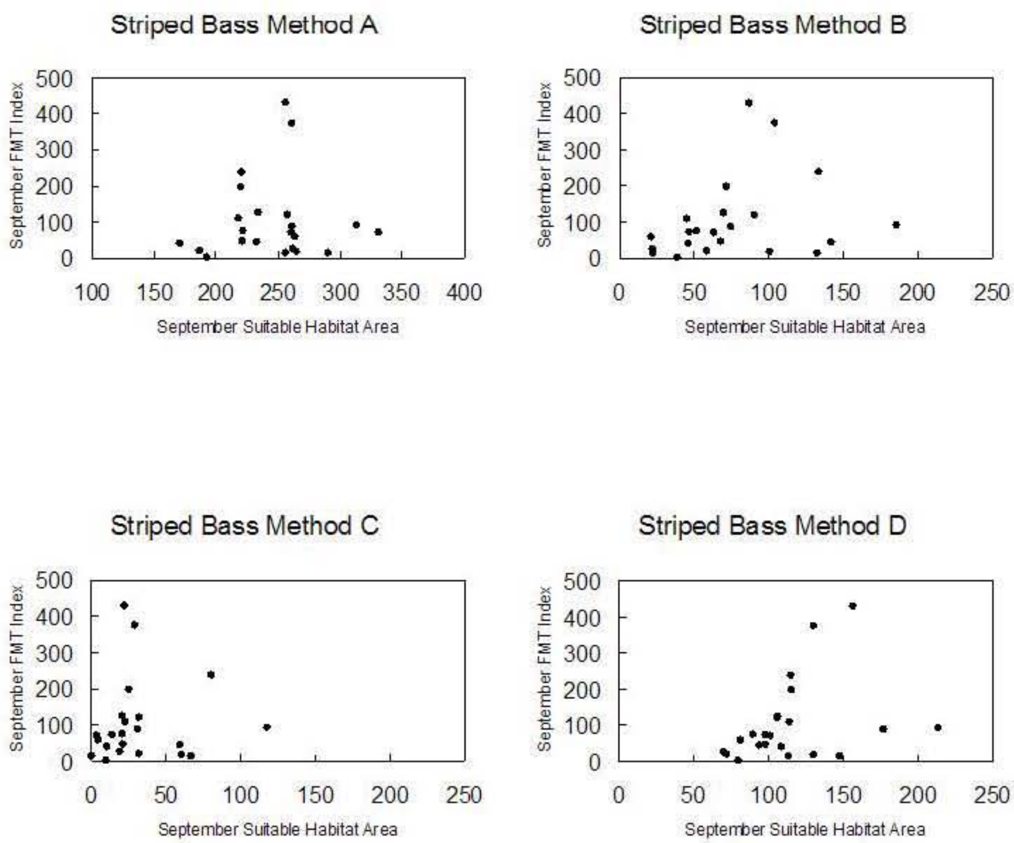
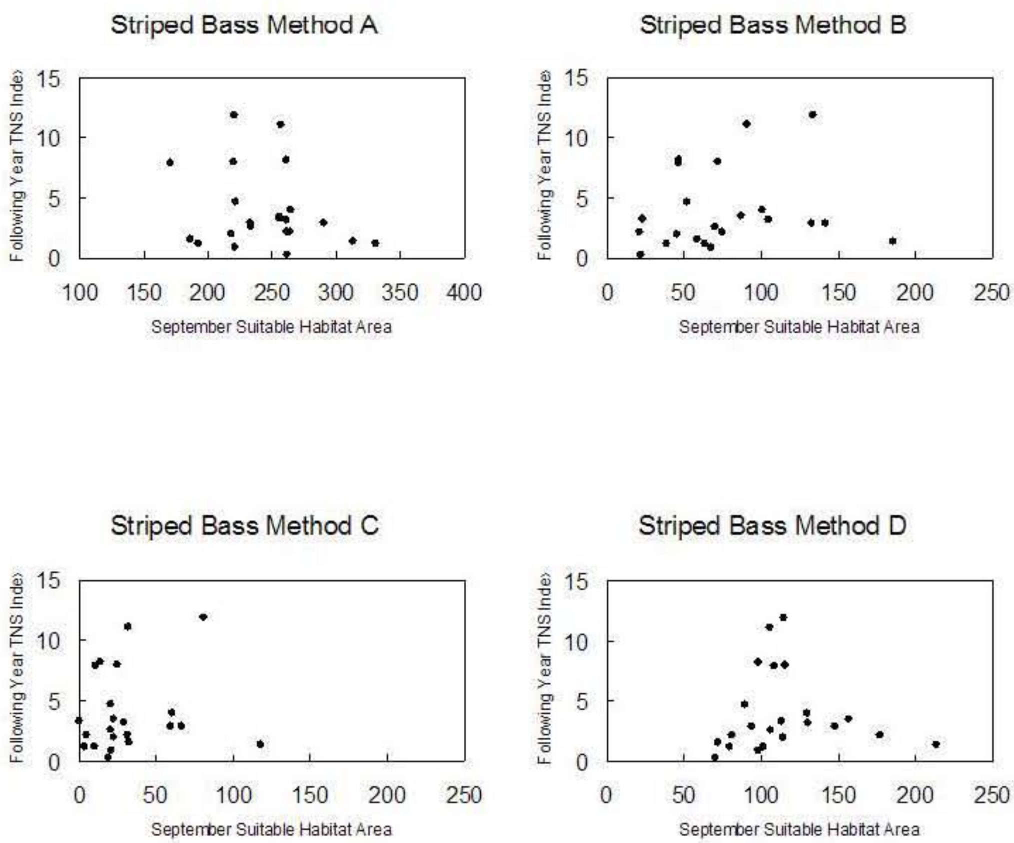

Striped Bass Method A
September FMT Index
500
400
300
200
100
0
100 150 200 250 300 350 400
September Suitable Habitat Area
Striped Bass Method B
September FMT Index
500
400
300
200
100
0
0 50 100 150 200 250
September Suitable Habitat Area
Striped Bass Method C
September FMT Index
500
400
300
200
100
0
0 50 100 150 200 250
September Suitable Habitat Area
Striped Bass Method D
September FMT Index
500
400
300
200
100
0
0 50 100 150 200 250
September Suitable Habitat Area

Figure 12.



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