Delta Smelt Analyses by BJ Miller and Tom Mongan
and implications of these analyses
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We have performed a number of analyses over the last several years. This is a summary of those analyses, along with findings and implications. Supporting data can be obtained by emailing BJ Miller (bj_miller@sbcglobal.net).

Analysis: Correlations between the Summer Townet index of juvenile abundance and the Fall Midwater Trawl index of sub-adult abundance

Findings:

- Through 2005, there was no correlation between the STN and subsequent FMWT for the period 1981-2004 (the delta smelt "post decline" period).
- Addition of the 2005 data point produces a weak correlation between LOG STN and LOG subsequent FMWT.
- Using all years STN and FMWT data, that is data from 1969-2004, there is a correlation between STN and subsequent FMWT, but accounting for regime change in the 1980s eliminates this correlation.
- There is a correlation between FMWT and subsequent STN.
- Checked by Manly

Implications:

- The essential lack of a correlation between the STN and subsequent FMWT indicates that factors acting prior to the Summer (especially, export effects) cannot be important to the subsequent FMWT.
- The lack of correlation between the STN and subsequent FMWT is explained by the importance of smelt-prey co-occurrence in the Summer.
- The correlation between the FMWT and subsequent STN (over one generation, several life stages, and at least six months) indicates that the lack of correlation between the STN and subsequent FMWT (over a couple of months) is not the result of poor quality indices.
- The lack of correlation between the STN and subsequent FMWT, coupled with the reasonably good correlation between the FMWT and subsequent Kodiak approximate adult abundance indicates that factors acting before the Summer are not having important effects on subsequent spawning population of smelt.

Analysis: Estimation of areas and volumes of delta habitat from eastern San Pablo Bay upstream to Stockton and Cache Slough and the upper reach of the Sacramento Ship Channel

Findings:

- Areas and volumes estimated for 14 areas used in co-occurrence and Kodiak population analyses (see below), for both the entire water column and the upper 12 feet where most adult delta smelt are thought to reside.
- Areas and volumes associated with each 20 mm survey station
- Data can be transformed into area-volume estimates for any desired set of sampling stations.

Implications:

- Volume data can be combined with catch or catch per unit effort data to estimate relative abundance of species.
- Reasonably good agreement between these estimates and those from a recently developed computer program by USGS, based on their extensive bathymetry data, that allows selection of areas to produce area and volume estimates except in areas with extensive tributary sloughs, such as Suisun Marsh and Cache Slough. Presumably, the USGS program could be expended to deal with these areas as well.

Analysis: co-occurrence of delta smelt and prey in July

Findings:

- Strong correlation between various measures of co-occurrence of delta smelt and primary prey, zooplankton Pseudodiaptomus and Eurytemora, in July and subsequent FMWT index.
- Decline in prey abundance in core Summer habitat (near confluence and downstream) similar to decline in smelt FMWT index
- Findings checked by Manly

Implications:

- Problem with delta smelt is primarily prey in the Summer.
- If prey problems cannot be solved and/or smelt do not thrive on alternative food source, extinction or continuing very low abundance seems likely.

Analysis: Correlations between exports or various measures of salvage and subsequent Summer and Fall delta smelt abundance in years when smelt are "close to the pumps"

Findings:

- No correlation between either salvage measures or Dec-Mar exports and subsequent FMWT abundance even in years when smelt are close to the pumps.

- Correlations between December-March exports and subsequent juvenile abundance, but inclusion of common factors (previous FMWT, for example) in both variables raises concerns about the validity of the correlations.
- Checked by Manly

Implications:

- Such correlations between salvage and subsequent FMWT index are the basis for the Delta Smelt Risk Assessment Matrix. Lack of such correlations calls the DSRAM into question.
- The primary basis of the POD emphasis on exports has been the coincidence of higher measures of adult salvage (adult salvage, adult salvage/previous FMWT index, adult salvage/previous FMWT index/Dec-Mar exports) and lower delta smelt abundance. This analysis indicates that this coincidence is simply that, a coincidence. The real cause of the smelt decline is the decline in prey density (co-occurrence) in the core Summer habitat area.
- Correlations between exports and subsequent Summer juvenile abundance, subject to concerns about common variables above, suggest that exports could be affecting juvenile abundance, but these effects are not important enough to bridge the important juvenile smelt-prey co-occurrence and affect sub-adult abundance in the Fall.

Analysis: Estimate of approximate adult population using Kodiak Spring Trawl data, assuming 100% gear efficiency, all adult smelt in upper 12 feet of water column, and no adult smelt in Motezuma Sl. tributaries

Findings:

- Approximate adult abundance is well-behaved; that is, in all but February of 2002, the data show an exponentially declining population for each month's estimates in all years (2002-2005)
- Adult abundance estimates correlate with previous FMWT index.
- Significant percentage of adults found in Sacramento Ship Channel (not regularly sampled) in several years.
- Checked by Manly

Implications:

- FMWT index is a reasonably good measure of adult spawning abundance
- Exponential mortality rate in Winter, estimated from monthly population estimates, increases each year, 2002-2005.
- Kodiak data can be used to produce approximate estimates of adult smelt population and distribution.
- Checked by Manly

Analysis: Correlations between adult salvage/previous FMWT index and percent change in FMWT index over the year the salvage occurred

Findings:

- "Relative salvage," adult salvage/previous FMWT, is a measure of percentage adult entrainment (adult salvage is a measure of entrainment, previous FMWT index is a measure of adult abundance). Therefore, if relative salvage is important, it should show some correlation with the percentage change in FMWT index over the year in which adult salvage occurred. No correlations were found.
- Checked by Manly

Implications:

- Relative adult salvage is not an important factor in determining subsequent Fall sub-adult abundance.

Analysis: Estimates of relative gear efficiency for the 20 mm survey. Assumed shaped of relative efficiency curve, defined curve by four parameters, and searched for values of those parameters producing a curve that, when applied to each year's actual 20 mm data after hatching complete, produced a declining total population of juvenile smelt

Findings:

- Can estimate relative gear efficiency using this method for any species with sequential samples of the entire habitat when no recruitment is occurring and for which the general shape of the relative efficiency curve can be assumed.
- The relative efficiency of the 20 mm gear is extremely low (0.0028) for 5 mm larvae, compared to an assumed relative efficiency of 1.0 at 20 mm.
- This relative efficiency curve can be used to correct 20 mm catch for gear efficiency.

Implications:

- Correcting 20 mm catch data for gear efficiency indicates that the percentage of delta smelt in the Southeast Delta typically decreases by about half for most surveys for which smelt were caught in the Southeast Delta.
- Failure to correct 20 mm data for gear efficiency can result in overestimates of larval-juvenile entrainment.

Analysis: Estimates of water temperature at 8 stations in delta smelt habitat

Findings:

- Dates when water temperature reached 12 and 21 degrees C (approximate limits of delta smelt spawning temperatures) can be estimated for all years of 20 mm surveys (1995-present).
- Water temperature throughout the smelt habitat area is correlated with air temperature with a several-day lag.
- The Southeast Delta and other upstream areas tend to warm up first, causing smelt to spawn and hatch first in those areas, and to show up first in those areas in the 20 mm surveys.

Implications:

- Without accounting for this early warming in parts of the Delta, early 20 mm surveys can be misinterpreted to indicate that all larvae are in those areas when, in fact, only a few early hatch larvae are there.

Analysis: Correlation between monthly adult salvage and adult smelt distribution

Findings:

- Monthly adult salvage correlates well with the approximate number of adult smelt east of Franks Tract. (Checked by Manly)
- The percentage of adult smelt east of Franks Tract is very low, typically about 0% (rounded) and in the months during 2002-2005 when trawls were made, was never higher than 4%.
- The distribution of smelt in the December FMWT and the subsequent Kodiak trawls are not consistent with a high percentage of adult smelt being entrained, except for the relationship with the number of smelt east of Franks Tract, above. That is, high salvage shows up when smelt are nowhere near the pumps.
- The distribution of smelt in the Kodiak trawl is not consistent with the idea that the export pumps are "vacuuming" smelt out of the southeastern Delta. Even when salvage is relative high, there are still many smelt in the southeastern Delta.

Implications:

- Adult salvage depends on having just a small percentage of adult smelt in the Southeastern Delta.
- This indicates that adult salvage is a small percentage of the total population.

Analysis: Relationships between monthly distribution of adult smelt and various hydrologic parameters

Findings:

- There are no correlations between the percentage of adult smelt at or east of Franks Tract and the ratio, exports/inflow.
- Pete Smith, USGS, has reported correlations between adult salvage and Old and Middle River flows, but the mechanism for these correlations is unclear.

Implications:

- Maybe hydrologic conditions over periods less than a month are predictive of adult smelt distribution into the Southeast Delta, but monthly conditions are not.

Analysis: Estimation of percentage larval-juvenile entrainment using the Particle Tracking Model and catch per unit effort data from the 20 mm survey

Findings:

- Without correcting for gear efficiency or mortality, the percentages of larval-juvenile entrainment ranged from 0% to about 30% per year in 1995-2004. Correction for gear efficiency and mortality would reduce these estimates.
- There was no correlation between % larval-juvenile entrainment and subsequent FMWT abundance or percentage change in FMWT abundance.

Implications:

- Although there were no correlations with subsequent FMWT abundance, steps should be taken to prevent % entrainment as high as some of these past values.

Analysis: Relationship between the percentage of larval-juveniles in the Southeast Delta in early 20 mm surveys and March-April Delta outflow

Findings:

- Without correcting for gear efficiency or mortality, the percentages of larvae-juveniles in the Southeast Delta shows a declining exponential correlation with Mar-April Delta outflow.
- There is also a good correlation between the product of the percentage of larvae-juvenile smelt in the Southeast Delta in early surveys and Spring exports, on the one hand, and annual percentage larval-juvenile entrainment on the other hand.

Implications:

- If March-April outflow can be predicted, the percentage of larvae-juveniles in the Southeast Delta can be predicted. With this estimate and a target percentage larval-juvenile entrainment, target Spring exports can be predicted. These exports can be adjusted as each 20 mm survey provides refining data on smelt location.

Analysis: Analysis of length and length-frequency trends for sub-adult delta smelt

Findings:

- There is a statistically significant downward trend in delta smelt length in each month of the FMWT.
- The trend is somewhat more pronounced and significant the later in the year the month (that is, December is the most pronounced decline and most significant, statistically).
- However, it is apparent from the data on mean or median length that a step change of about 6 mm in length occurred around 1989-1990, and this produces the apparent long term downward trends.
- If anything, the mean length of delta smelt has increased slightly since the mid 1990s.

Implications:

- The data are not consistent with the hypothesis that a decline in sub-adult or adult delta smelt length contributed to the recent decline in delta smelt abundance.

Analysis: Relationship between the number of larger adult delta smelt, egg production of larger smelt, or egg production and increased survival of eggs from larger smelt, on the one hand, and subsequent abundance on the other hand

Findings:

- There is no correlation between the number of larger delta smelt (>59 mm) in December and any measure of subsequent abundance (sum of 20 mm CPUEs, STN, July co-occurrence abundance, FMWT).
- There is no correlation between the number of eggs produced, allowing for an exponential increase in fecundity with smelt length, and any measure of subsequent abundance.
- There is no correlation between an "enhanced" number of eggs produced, to account for the better quality of eggs from larger females, and any measure of subsequent abundance.

Implications:

- The data are not consistent with the hypothesis that large females have been a significant factor in the decline of delta smelt numbers.