Ecosystem Restoration: Delta Smelt

What Is This Indicator and Why Is It Important?

This indicator uses the adult abundance index (Figure 1) to describe trends in delta smelt abundance levels and uses the duration of the spawning window (Figure 2) to report information about trends in the suitability of the environment for delta smelt reproduction. The delta smelt occurs only in the San Francisco Estuary and is listed as a threatened species under both state and federal law. Because of its threatened status, it was targeted for restoration efforts. It is primarily an annual species, reproducing each year in the Sacramento-San Joaquin Delta, although some individuals likely reproduce as two-year-olds.

The adult index of abundance tracks trends in the number of individuals surviving the larval and juvenile life stages. It therefore integrates the species' biological response to all factors affecting the population from larval to early adult life stages (see conceptual model in Figure 3). Although the adult index is the most consistent and long-term estimate of potential spawning population size available, spawning and larval recruitment success is also strongly influenced by environmental conditions (e.g., amount of freshwater inflow, water temperature, food supply, and water quality), which must be considered when evaluating the status of the population. The influence of environmental conditions is captured by a second metric shown in Figure 2. The duration of the spawning window reflects environmental suitability at a critical point in the delta smelt life cycle and is an indicator of the potential for early recruitment success. Successful spawning earlier in the year, and a longer spawning window, are both considered advantageous to recruitment success. Together, the indicators of biological response and the suitability of environmental conditions contribute to a more complete understanding of the species' status and its trends over time.

What Has Happened To Affect the Indicator?

Concerns about the status of delta smelt arose in the 1980s when researchers noticed a precipitous decline in the adult abundance index. The decline may be attributed to both direct and indirect causes. CVP and SWP Export pumping and in-Delta agricultural diversions removed fish from the system, while upstream storage and reduced inflow to the Delta allowed the salinity field to move further upstream in the Bay / Delta, which may have reduced habitat quality for the species. As the average position of X2 (the point where the average bottom salinity is two parts per thousand) moved upstream, out of Suisun Bay and into narrower channels, the area of habitat suitable for the delta smelt was probably reduced, perhaps by a substantial amount. In addition, there is evidence that regional climate variation such as the severe El Nino winter of 1982-83 led to poor recruitment, which, combined with other stressors (entrainment losses, competition for food, predation, etc.), resulted in fewer numbers of adults. Other factors thought to adversely impact the species include contaminants (direct effects on reproduction and survivorship and indirect effects on the food supply), parasites, and introduced species competition and predation. Although there is some evidence that each of these factors adversely impact the species to varying degrees, it is impossible to quantify their absolute and/or relative effects. The environmental gauntlet (Figure 3) was thus proposed as a means of representing the combined interaction of all these sources of potential impact.

The 1993 decision to list the delta smelt as threatened under both the federal and California Endangered Species Acts was largely based on reductions in the adult abundance index. These reductions were thought to be caused by excessive entrainment losses at the CVP and SWP Delta export facilities and habitat degradation. Key habitat elements were identified as the low salinity shallow-water shoals and bays in Suisun Bay,freshwater inflows, and salinity levels required to maintain the habitat needed for adult migration and larval and juvenile transport and rearing.

Actions to mitigate what are thought to be major sources of population impact have focused on limiting CVP and SWP exports under certain conditions and placing a cap, based on historical data, on the incidental take of delta smelt permitted in the export operations. When the cap is reached, all possible actions to reduce the take are considered. For reasons that are not completely understood, incidental take exceeded the established cap in several years after the species was listed as threatened in 1993. As explained below (see Discussion), the Environmental Water Account (EWA) has provided a new source of water for responding to concerns over high incidental take levels.

What Do the Data Show?

The annual index of adult abundance (Figure 1) shows a decline in the abundance of delta smelt between 1970 and the mid-1980s, followed by an increase in abundance from the mid-1980s to the mid-1990s. Adult abundances have remained at moderately high levels in the late 1990s and early 2000s, but have not returned to levels measured in the early 1970s. Delta smelt have met both the abundance and distribution criteria of the recovery plan over the last five years (see Technical Note), further suggesting this species' status has improved.

The spawning window (Figure 2) describes one aspect of delta smelt's response to environmental conditions. The timing of optimal conditions for reproduction (see Technical Note) and their total duration are both important to spawning success. The duration relates to the period when environmental conditions are suitable for successful spawning and hatching of eggs. Natural environmental changes (e.g., rapid warming of water temperature) can affect both the timing and duration of the spawning window. The data show timing and duration of the spawning window varies on the order of one-two months. Depending on this variation, a portion of the spawning window can overlap with the late spring / early summer ramp-up in CVP an SWP exports and in-Delta agricultural diversions, thus increasing the proportion of the cohorts susceptible to entrainment loss. The data also suggest years (i.e., 1983 and 1997) when sub-optimal spawning windows may have substantially affected early recruitment. Timing of optimal conditions generally occurred earlier each successive year between 1983 and 1990 but generally occurred later each successive year between 1992 and 1999. There is no obvious trend in the duration of the spawning window.

Discussion

The incidental take of delta smelt associated with export pumping operations, combined with restrictions in amount and quality of habitat required for spawning and rearing, may have reduced the long-term sustainability of the delta smelt population, particularly following the severe winter of 1982-83.

Adults use shallow, fresh, or slightly brackish waters with suitable water quality for spawning, and are hypothesized to use substrates such as submerged vegetation and woody debris for egg attachment. Suisun Bay historically provided a shallow and food-rich environment for rearing of larvae and juveniles. However, by reducing freshwater inflows and allowing X2 to move out of Suisun Bay and into upstream channels, earlier water management practices may have substantially reduced the amount of such rearing habitat. The amount of suitable spawning habitat may also be restricted by low freshwater inflows and habitat alteration within the Delta. However, because there is no direct evidence that delta smelt are habitat limited, the causal link between the decline of the population and any reductions in habitat availability are circumstantial at best.

Adequate freshwater inflows may be required to move delta smelt larvae and juveniles out of the Delta to rearing habitat in Suisun Bay. This process may be disrupted by physical disturbances such as channel modifications, upstream reservoir operations, and changes to natural flow patterns through the Delta due to water diversions and in-channel barriers. However, as with habitat needs and availability, a definitive relationship between population size and distribution and measures of freshwater inflow has not been demonstrated.

Factors thought to have contributed to the improved state of delta smelt include an extended series of above normal and wet water years between 1995 and 2000, as well as targeted curtailment of State Water Project (SWP) and Central Valley Project (CVP) South Delta export levels in the late winter, spring and early summer. Late winter export reductions are intended to reduce the entrainment of adult delta smelt moving upstream to spawn, while spring and early summer export reductions are intended to reduce the entrainment of young delta smelt. Since 2000, these export reductions have relied on water from the Environmental Water Account (EWA) to protect the species while resulting in no net loss of water deliveries to south-of-delta water contractors. The application of EWA water to reduce the entrainment levels of delta smelt at the SWP and CVP export facilities is among the most substantial CALFED action undertaken for this species.

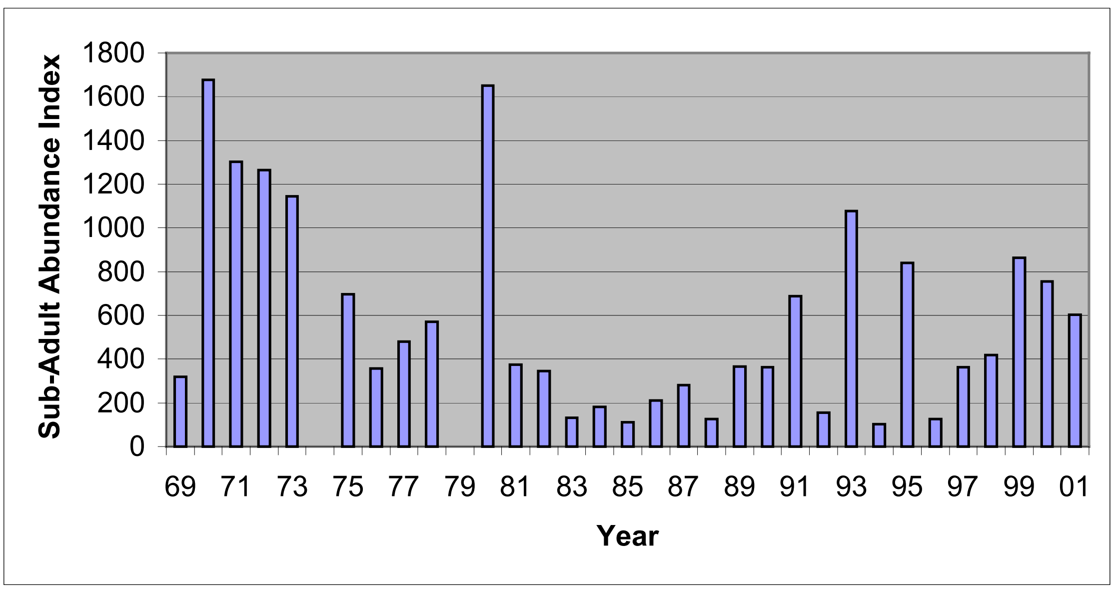
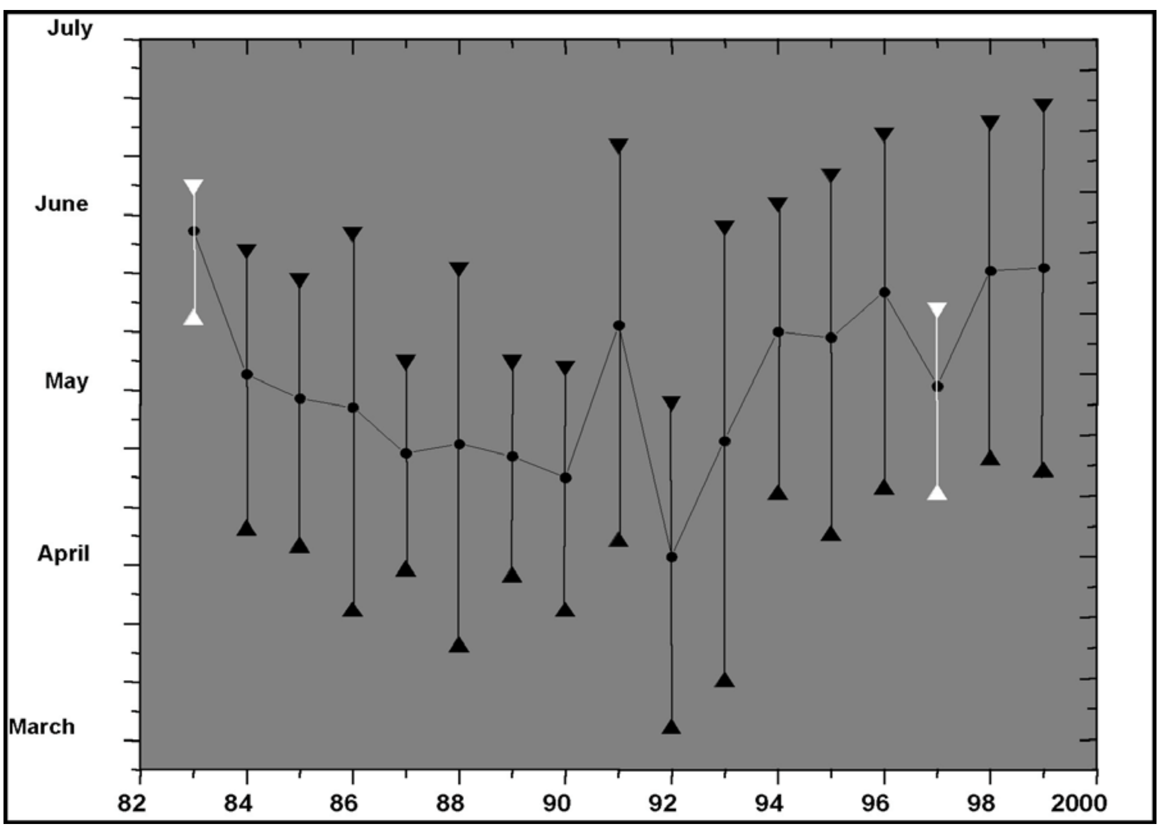


Figure 1. Annual estimated fall abundance index of adult delta smelt. Data source: California Department of Fish and Game.



July
June
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2000

Figure 2. Estimated timing and duration of the delta smelt spawning window from 1983 – 1999. The timing of the spawning window is represented by the trend line and the duration by the vertical extent of the lines. Figure courtesy of Bill Bennett (Bennett, in prep.).

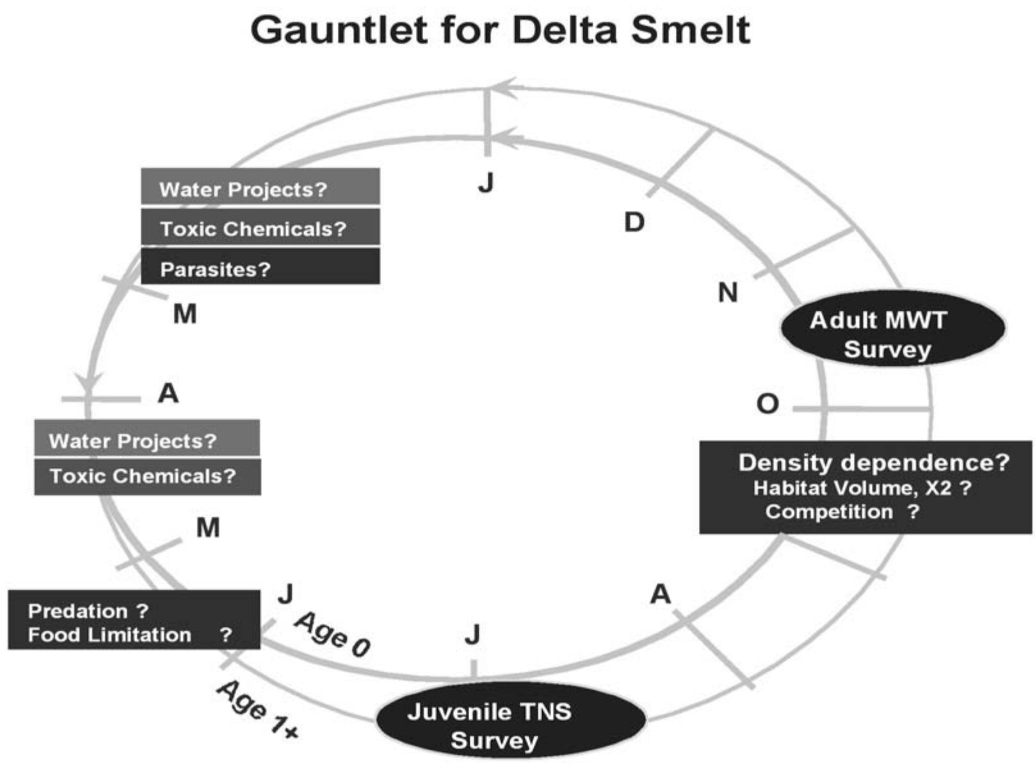

Figure 3. A conceptual model of the "gauntlet for delta smelt" relative to various stages in its life history. Letters are months, proceeding counter clockwise through the year. Factors boxes are anthropogenic and natural stressors that may affect population size. Surveys are points where the standing stock is estimated. Timelines for Age 0 and Age 1+ fish represent fish living about one year and longer than one year, respectively. From Bennett in prep. Figure courtesy of Bill Bennett (Bennett, in prep.).

Technical Note: Delta Smelt

The Indicator

Goal: The delta smelt indicator provides one means to evaluate CALFED's progress towards meeting the first goal of the Ecosystem Restoration Program's Strategic Plan:

> Achieve recovery of at-risk native species dependent on the Delta and Suisun Bay as the first step toward establishing large, self-sustaining populations of these species; support similar recovery of at-risk native species in the Bay-Delta estuary and its watershed; and minimize the need for future endangered species listings by reversing downward population trends of native species that are not listed.

There are specific abundance and distribution recovery criteria that provide quantitative measures of restoration progress. The abundance criteria are:

- Delta smelt abundance must meet or exceed 239 individuals from all zones combined in two out of five years
- The two-year running average must never fall below 84 individuals from all zones combined
- If any of these conditions are not met, the five-year recovery period will start again.

The distribution criteria are:

- Site criteria must be met in all zones (north central Delta, Sacramento River and Montezuma Slough, Suisun Bay) in two out of five years
- In at least two zones in one of the remaining three years
- In at least one zone for the remaining two years.

The Data: The following discussion of the data focuses first on the adult abundance index and then on the spawning window.

Adult Abundance Index

Data for the adult abundance index are collected by the California Department of Fish and Game staff as part of the Interagency Ecological Program (IEP). The data are from monthly field surveys conducted each year from September through December at set locations throughout the Sacramento-San Joaquin Delta, Suisun and San Pablo bays, Montezuma Slough, and the Napa River. An annual abundance index is calculated by summing all the weighted catches of delta smelt from all the sampling regions. The weighted catch of delta smelt is calculated for each region by multiplying the individual catches of delta smelt within a region by an estimate of the volume of water in the region. More specifics on the sampling methods and locations and the historical data are available at http://www.delta.dfg.ca.gov/data/mwt99/charts. It is not appropriate to compare values between individual years because there is no measure of the error associated with the individual values. However, the data are useful for examining longer-term trends in adult delta smelt abundance. A subset of these abundance data (field data collected in September and October at select sampling stations) is used to evaluate the status of the species relative to established recovery criteria listed above. Delta smelt recovery is evaluated over five years. The abundance and distribution recovery criteria were all met in the most recent recovery period spanning 1998-2002.

Spawning Window

The annual spawning window (timing and duration) is a calculated value based on data from age and growth studies conducted by researchers (Dr. Bill Bennett and Jim Hobbs) at the University of California at Davis, Bodega Marine Laboratory. The age of individual delta smelt is based on microscopic examination of bony material called otoliths present in each individual. The otolith accumulates rings of new bony material as the fish ages. A new ring of material is added each day the fish lives. Calculating the age of delta smelt captured throughout the year in various sampling programs allows researchers to estimate the date of birth for each fish. Performing these age estimates on many fish allows researchers to evaluate the number of cohorts (a cohort is a group of fish with approximately the same birth date) and the range of dates over which young fish were born. It is these types of data that are then used to calculate the annual spawning window.

Monitoring the timing and duration of the delta smelt spawning window provides an indication of the potential for early recruitment success. Early recruitment success is particularly important for delta smelt, since it is principally an annual species; thus, the larvae occurring each spring comprise the majority of the population carrying forward into the next generation. Success of the species requires each generation to survive a series of environmental challenges (both anthropogenic and natural) that, while present throughout the year, are most acute during the early life stages. Delta smelt are confronted throughout their life cycle with an environmental gauntlet (Figure 4, Bennett in prep.). The occurrence of optimal spawning conditions earlier in the year (i.e., April) is considered more advantageous to the delta smelt. Early spawning gives new recruits more time to grow and emigrate from areas in the Delta most directly affected by increases in SWP and CVP South Delta exports and in-Delta agricultural diversions, which typically occur in late May or June. Longer duration spawning windows (on the order of two months) are considered more optimal, because of the increased opportunities for recruitment of multiple cohorts (Bennett, in prep.). Overall, Bennett, *in prep*, hypothesizes that spawning windows occurring earlier in the year and of longer duration are more favorable to delta smelt because they allow the species to spread the risk of succumbing to the environmental gauntlet over a greater number of individuals with different ages.

Longer-Term Science Needs

The three most important needs for improving estimates of adult abundance are: 1) estimates of confidence limits for each annual value;2) an understanding of how the adult abundance index relates to the population size of the species; and 3) research to develop a quantitative understanding of the environmental factors (e.g., freshwater flow, water temperature) directly affecting the movement and distribution of young delta smelt. Further research could also focus on understanding the interactions between adult population size, the succeeding spawning window, and recruitment success.

Literature Cited

Bennett, in prep. A white paper summarizing the state of knowledge and research needs for delta smelt, *Hypomesus transpacificus.*