Estimating Population Level Effects for South Delta Fish Facilities

November 7, 2003

Background

The issue of estimating population level effects came up at the last South Delta Fish Facilities (SDFF) Forum on November 3. There was agreement at the meeting and there has been widespread general agreement (see recent EWA Science Panel meeting notes) that estimates of population level effects would be desirable. However, there are concerns about how such estimates could be made and about the uncertainties associated with them.

In fact, such estimates are already being made by established methods. Some new approaches have recently been proposed. This document describes how these methods could be adapted to estimate population level effects of state and federal exports. If such estimates could be developed, then changes in those estimates, attributable to SDFF, could also be investigated.

What does "population level effects" mean? Ideally, it would mean estimating the population of adults of a species, say, winter run salmon, under one set of conditions and comparing that population to the population estimated to occur under another set of conditions. Some method of estimating adult population under the conditions of interest would be required. A mathematical model of the winter run life cycle could be used for such estimates, provided that the model incorporated the conditions of interest. This model would have to be capable of dealing with factors that are important, uncertain, and difficult to predict. Ocean conditions would be such a factor for winter run. For delta smelt, the factor may be density dependence.

No such models exist yet, and it may be some time before they are developed. Once developed, they may be controversial because of the way they deal with uncertain effects (density dependence for delta smelt for example). For this reason, some might conclude that estimating population level effects cannot be done, at least not for now and probably not for a long time (years).

This paper argues otherwise and presents another approach to estimating population level effects that is, perhaps, not as elegant or satisfying as the ideal method described above, but one that could be used now and is likely to produce results useful to the SDFF Forum and others.

This approach can best be described by example. Consider a fish with four life stages, eggs, larvae, juveniles, and adults. Assume that important, poorly understood factors affect the survival from one life stage to another, making prediction of adult population difficult if not impossible. Assume that four actions could be taken, two affecting juvenile abundance and two affecting adult abundance. Also assume that estimates could be developed for the effects of these actions on the abundance of their associated life stage. If the estimates were made based on percentage changes in abundance, there would be some comparability among all four actions' effects.

Granted, because of the important, poorly understood factors, we could not be sure that the effects of an action would be propagated unaltered to the adult life stage. For example, it is possible that an action causing a 20% increase in juvenile abundance might only result in a 2% increase in adult abundance because of poor ocean conditions or density dependence. It is also possible that an action causing a 20 percent decrease in abundance of juveniles would occur when subsequent adult abundance increased by 50 percent because of uncontrollable factors.

Nevertheless, comparisons among actions could still be useful. If the population effects of the four actions were +1%, +2%, +17%, and +34% on their associated life stages and if the 1% and 2% actions were expensive relative to the 17% and 34% actions, we would choose the latter two actions.

Another useful comparison might be made. If the population effects of the four actions were all less than 3% and the effects of the important, poorly understood factors were in the range of 50% to 75%, we might conclude that none of the four actions was essential except perhaps when the species was in trouble.

So, these estimates of population effects, which might better be termed "percentage changes in life stage abundance," can be developed and can provide useful information, even if the subsequent adult population cannot be accurately predicted.

The remainder of the paper describes how estimates of population effects, expressed as percentage or fractional changes in life stage abundance, can be estimated.

Salmon direct mortality

Direct mortality is mortality occurring within the export facilities. It consists of prescreen predation, screening (or louver) losses, and handling and trucking mortality. Pre-screen predation is predation in Clifton Court Forebay at the Banks Pumping Plant and predation at the trash booms at the Tracy Pumping Plant.

Post-release mortality also occurs as predators gather at the release points. This mortality is not included in the estimates of direct mortality but probably should be.

Direct mortality is estimated from salvage (or, more precisely, expanded salvage). Knowing the daily salvage and the screening efficiency for different species and sizes of fish and approach velocities, the number of fish approaching the screens can be "back calculated" from salvage. For example, if 10 fish are salvaged and screening efficiency is 70%, the number approaching the screens would be estimated as 10/70% or 14.3 fish.

Similarly, the number approaching the export facilities can be "back calculated" from estimates of the number approaching the screens and predation rate. If predation loss rate is 75% in Clifton Court Forebay, for the example above, 14.3/75% or 19 fish would be the estimate for the number of fish entering the facilities.

Handling and trucking losses apply to salvaged fish and can be estimated from salvage. Multiplying handling and trucking loss rates by salvage produces an estimate of the number of fish dying during trucking and handling. In the example above, if the loss rate for handling and trucking is 60%, the number of salvaged fish killed during handling and trucking is 10*60% or six fish. Four fish would have survived.

Subtracting the number surviving, 4, from the number entering the facilities, 19, yields a direct mortality estimate of 15 fish per day.

Direct mortality estimates are routinely made for salmonids and striped bass, but data are not available to estimate direct mortality for delta smelt. However, because few if any smelt entering the export facilities now survive, the number entrained is the direct mortality. If the number entrained could be estimated, direct mortality for delta smelt could be estimated. This possibility is discussed below.

Population level effects of direct mortality for salmon are already being estimated. For winter run, a running total of direct mortality is estimated. This total is divided by each year's estimate of the number of winter run smolts entering the Delta. In fact, the expected take for this listed species is estimated as 2% of the smolts entering the Delta. The 2% figure is a population effect estimate or, more precisely, an estimate of the percentage change in life stage (smolt) abundance.

Estimates are not available for the number of late fall and spring run salmon smolts entering the Delta. However, large groups of hatchery grown, coded wire tagged late fall run smolts are released each year as surrogates for wild late fall and spring run. From the number of released fish salvaged at the pumping plants, the percentage changes in life stage abundance can be estimated.

Indirect mortality for salmon

If SDFF result in changes in export rates, indirect mortality should be considered.

Indirect mortality is mortality thought to be associated with federal and state exports but occurring outside of the export facilities. It should more properly be termed, "export-related indirect mortality" to distinguish it from other, water project-related mortality that might occur in the Delta.

Indirect mortality cannot be directly estimated on a real time basis. However, over the years, numerous releases of large groups (20,000-150,000) of coded wire tagged fall run smolts have been made in and upstream of the Delta. Specific releases of late fall smolts have been made as part of the AFRP Action 8, December-January experiments. Releases of San Joaquin River smolts have been made as part of the Vernalis Adaptive Management Plan (VAMP) and in similar, earlier experiments.

These released fish are recaptured at Chipps Island and other downstream locations. From the number released and the number recaptured, estimates can be made of the average survival of fish in each group during passage through the Delta. These release-recapture experiments have occurred under different Delta conditions, including different export rates and different operation of the Delta Cross Channel gates (i.e., open or closed). Statistical correlations have been developed for fall run (Newman and Rice and, later, Newman, for USFWS) and for late fall and spring run and San Joaquin fall run (Brandes, USFWS).

The correlation equations all relate survival rate (i.e., percentage or fraction surviving) through the Delta to export rate and other factors such as Cross Channel gate closures and river flow rate. Estimates of survival derived from these correlation equations are not real time estimates of survival. Rather, they are estimates of expected values in the statistical sense. They are estimates of what the survival is expected to be based on what it was in the past under similar conditions. Because these estimates are a statistics, they have confidence limits and could even be expressed as an exceedance curve, much the same way that estimates of water supply availability are. Therefore, the uncertainty inherent in these survival estimates can be estimated along with the expected value.

Manly has raised questions about the validity of these correlations (see notes of the June, 2003 Delta Smelt Workshop). These questions arise because of the underlying assumptions made by Newman and the paucity of data for the analyses by Brandes. So, it is possible that there are no significant relationships between extra-facility mortality and export rate.

Keeping Manly's questions in mind, the correlation equations can be used to estimate percentage change in life stage (smolt) abundance of indirect mortality. Assume that an export curtailment has occurred. The correlation equations can be used to produce two estimates of smolt survival through the Delta, S1, without the curtailment, and S2, with the curtailment.

Assume that N smolts enter the Delta. Then, the number surviving to Chipps Island without the curtailment can be estimated as N*S1. The number surviving with the curtailment could be estimated as N*S2. Then, the the percentage change in life stage abundance at Chipps Island would be 100% times the difference in number surviving (with and without the curtailment) divided by the number surviving without the curtailment or (100%)*(N*S2 – N*S1)/(N*S1)) or (100%)*(S2-S1)/S1. Note that N, the number entering the Delta cancels out of the calculation, and the percentage change in life stage abundance can be estimated using only estimates of survival, available from the correlation equations.

Note also that this estimate of percentage change in life stage abundance includes the effect of direct mortality because of the way the sampling was done.

If the action (export curtailment or Cross Channel gate closure) only affects a portion of the outmigrating smolts, this must be accounted for in the estimate of percentage change in life stage abundance. Estimates of the fraction of outmigrants affected would be required or at least some reasonable bounds on that fraction. It is possible that even using such bounds, useful information can be obtained.

As stated above, the uncertainty in these estimates can be evaluated and, of course, the results must be considered in light of Manly's cautions about the questionable nature of the correlations.

Delta smelt

Kimmerer has developed a method of estimating the percentage changes in life stage abundance of delta smelt due to entrainment at the export facilities. This method uses data from the various surveys of delta smelt abundance (summer townet, 20mm, and winter-spring Kodiak).

For each survey, data from a station or stations near the export pumps are used to estimate the density of smelt in water being exported. Dividing the number of smelt caught at those stations by the volume of water passing through the sampling nets produces an estimate of smelt density (smelt/acre-foot) in exported water. Multiplying this density by the export rate (acre-feet/day) produces an estimate of the number of delta smelt entrained (smelt/day) at the time of that survey.

Using data from all the stations in that survey, it is possible to produce an estimate of the total population of smelt. Kimmerer did this by dividing total catch at all stations by total volume passing through the net at all stations to estimate Delta-wide delta smelt density. He multiplied this density by the volume of water in the Delta in the total area sampled to produce an estimate of the population. There are other, more sophisticated ways to perform this step to get better estimates of population, but better estimates may not be necessary for most uses of this information. It is likely that comparability among surveys would be more important than precision in the population estimates.

Then, for each survey, the daily entrainment rate (smelt entrained/day) can be divided by the population. This yields an estimate of the percentage change in life stage abundance attributable to entrainment at the time of that survey.

This method was repeated for all surveys and the resulting data points (one per survey) were plotted against the day of the year. Connecting the data points (that is, interpolating between surveys) produces a curve of daily percentage changes in life stage abundance attributable to entrainment.

From this graph an estimate of the total percentage change in life stage abundance attributable to entrainment can be made for any period, including the entire year, by calculating the area under the curve for the period of interest. Doing so is equivalent to summing the daily percentage changes in life stage abundance over the days in the period of interest.

This method assumes that all entrained smelt either die or are exported; none are salvaged and returned to the Delta. If some did survive in the future, that survival would have to be accounted for in the estimates of percentage change in life stage abundance.

This method estimates entrainment mortality from survey data rather than from salvage. Therefore, this method reduces the problem arising from the difference (apparently often large) in the sampling efficiency of the salvage facilities as compared to the surveys.

This method also eliminates the problem that could arise from the possibility that smelt salvaged late in the juvenile season may be ones that entered Clifton Court Forebay earlier and reared there. Such salvage events might be an indication that entrainment should have been better controlled earlier rather than at the time of the salvage.

X2 Species

If SDFF results in changes in export rate, this could affect Delta outflow. Changes in Delta outflow could affect the abundance of those estuarine species whose abundance is associated with export rate or X2.

A number of estuarine species' annual abundance is correlated with X2 or Delta outflow. Each species has a "critical period" of several months over which X2 or Delta outflow is averaged to obtain the correlation. Any action that changes the average for a species' critical period, could also be associated with a change in abundance of that species.

The correlation equations could be used to estimate the percentage change in abundance by dividing the change in abundance by the abundance without the change and multiplying the quotient by 100% (that is, 100%*(A2-A1)/A1). As with indirect mortality, this estimate would be an expected value in the statistical sense and measures of uncertainty could also be developed.

Two of the "X2 species," splittail and American shad, are now generally believed to have relationships with Delta inflow rather than X2 or Delta outflow. Their apparent relationships with X2 or Delta outflow only result from the strong relationship between Delta inflow and X2 or Delta outflow. Changes in export rate could affect X2 and Delta outflow but not Delta inflow. This would have to be considered in making estimates of percentage changes in abundance attributable to changes in export rate.