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TO:
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FROM:
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Dear Mr. Brown,

First, I would like to thank you for giving me the opportunity to participate in the Delta Action 8 workshop held on May 27, 2005. I would also like to thank those who provided presentations. The discussion during the workshop was both educational for me and revealing for the strengths and weaknesses of the ongoing studies. The workshop was a good opportunity to learn about the complex fisheries issues that occur in other regions of the West. Please find my comments below based primarily on review of the background materials and also on insights gained through discussion at the workshop itself. First I examined the "big picture" to address how well the Coded Wire Tag study answers important questions relating to Delta Action 8 and 9. Next, I made recommendations for ways to gather additional data that would provide better understanding of how water management actions affect survival of juvenile salmonids. Last, I made detailed comments on specific aspects of the CWT study used to address Delta Action 8.

<u>Answering the "big picture" questions</u>

Given the complexity of the Sacramento/San Joaquin river system, understanding the proportion of the population using different pathways (or routes) and survival rates through each route is crucial to gaining insights on the how water management actions affect survival rates of the population at large. Major routes that fish may use include Steamboat/Sutter Slough, the Delta Cross Channel, the mainstem Sacramento River, and Georgiana Slough (in addition to numerous secondary routes). The Delta Cross Channel and Georgiana Slough entrain fish into the Central and Southern Delta, where water exports are hypothesized to negatively affect survival rates of fish using this route. Water management actions include water exports, but also operation of the Delta Cross Channel. If water exports influence operation of the Delta Cross Channel (e.g., if the Cross Channel is opened at low river flows and high exports), then operation of the Delta Cross Channel should also be considered in the scope of the Delta Action 8 studies. From discussions at the workshop, I found that operation of the Delta Cross Channel substantially influences water discharge through other routes. When the Cross Channel is closed, it appears that discharge is higher in both Steamboat and Sutter sloughs and in Georgiana Slough. One hypothesis is that fish will be entrained into specific routes in proportion to the discharge of each route. Thus, when the Delta Cross Channel is closed (a function of exports and river discharge?), a higher proportion of discharge and fish may pass through Steamboat/Sutter Slough where survival is likely higher (Sommer et al. 2001), thereby boosting the overall survival of the population. Fish passing through Steamboat and Sutter Slough also avoid entrainment into the Central and Southern Delta through Georgiana Slough, reducing the proportion of the population using this low-survival route. This example shows that to estimate the effects of water exports on survival of the population, we need to know 1) the proportion of fish passing each route, 2) survival rates of fish using each route, and 3) the affects of water management actions (exports and operation of the Delta Cross Channel) on survival rates and the proportion of fish passing each route.

One major drawback of the Coded Wire Tag (CWT) survival study is that it can not address the complex processes that likely affect the overall survival rate of the population of winter run juvenile Chinook salmon. What became clear through discussions at the workshop was that survival rates juvenile salmon will likely depend heavily on the pathway (or route) of fish through the Delta.

The CWT survival study estimates only one component of the “big picture” – survival rates of fish using Georgiana slough relative to those using the mainstem Sacramento River below Ryde/Isleton. Missing from this picture are survival rates through other routes (e.g., Steamboat/Sutter Slough and the Delta Cross Channel) and the proportion of the population passing through each route. Even if survival rates of fish in the Central/Southern Delta are negatively related to exports, exports may have a small affect on survival of the population if a low proportion of fish pass into the Central/Southern Delta. For example, assume 10% of fish pass through Central/Southern Delta, 30% of fish survive through the Central/Southern Delta at high exports and 70% at low exports, and 80% of population survives through all other Delta pathways (regardless of export levels). At high exports survival of the population would be 75% [(0.1*0.3)+(0.9*0.8)] and survival at the low export level would be 79% [(0.1*0.7)+(0.9*0.8)]. Although a simplistic example, it highlights the importance of understanding how the population distributes among the available routes.

The CWT survival study can not estimate the proportion of the population using each route. Although the authors propose for 2005 to use additional release sites in an attempt to compare survival among release sites, thereby gaining insights on survival of fish using different pathways. Given the extremely low recapture rates and high standard errors, this approach at best will be an indirect and imprecise method to draw inferences about different routes used by fish.

Technologies and statistical models exist to directly estimate 1) the proportion of fish using each available route, 2) the survival rate of fish passing through each route, and ultimately 3) the survival rate of the population at large. Telemetry technology (both radio and acoustic) has advanced substantially in recent years allowing smaller fish to be tracked over a longer period of time. Telemetry data provides very detailed information on the location and time of detection of each fish. In addition, because “capture” probabilities are extremely high (usually over 85%)

using telemetry, standard errors surrounding survival estimates are typically low relative to other mark/recapture techniques (e.g., CWT). Recently, statistical survival models such as multi-strata models (Brownie et al. 1993) and the route-specific survival model (Skalski et al., 2002) have been developed specifically to estimate the proportion of the population using specific routes and route-specific survival rates. For example, the route-specific survival model was developed to estimate the proportion of fish using available passage routes at Columbia River dams, the survival rate of fish through each passage route, and the overall survival of the population passing the dam.

With strategic deployment of telemetry equipment, these recent survival models could be modified for use in the Sacramento/San Joaquin Delta to understand the effects of water management actions on movement and survival of the population of juvenile salmon. Conceptually, the study design would consist of releasing tagged fish some distance upstream of the first channel divergence in the mainstem Sacremento River (which presumably is Steamboat/Sutter Slough) and monitoring the entrance and exit to all major pathways (routes) through the Delta with telemetry equipment. Tagged fish would be allowed to distribute naturally as they migrate downriver and choose different migration pathways through the Delta. The survival models would estimate route-specific detection probabilities, survival probabilities, and the proportion of tagged fish using each route. Survival of the "population" of tagged fish is typically estimated as the average survival through all routes weighted by the proportion of fish passing through each route. Multiple releases of tagged fish within a given year would allow 1) estimation of empirical variation and 2) response of fish to planned treatments such as export levels or operation of the Delta Cross Channel. Although the upcoming telemetry study presented by Steve Lindley should provide useful "general" information to help guide future studies, it is important to note that the study is not specifically designed to address the effects of water management actions on the proportion of fish passing each route, the survival of fish passing each route, or the survival of the population passing all routes.

Both CWT and telemetric survival studies have benefits and drawbacks. The CWT study can not provide the level of detail that is needed to fully understand the complexity of processes affecting survival of juvenile salmon populations in the Sacramento/San Joaquin River Delta. However, the CWT study is relatively inexpensive. Although telemetry studies are capable of obtaining the level of detail required to address the issue, the cost of obtaining this information will likely be ten-fold or more that of the CWT study. One possible approach is to embark on a path of implementing a telemetry study (given available funding) of such a design as described above, while continuing the CWT study, realizing the low cost of the CWT study relative to the added information. Another approach in the near term could use telemetry techniques to obtain the migration behavior information for the proportion of the population using different routes and use this information in conjunction with the survival data from the CWT study. This approach may limit the cost of the telemetry study by reducing sample sizes that would be needed to estimate survival. The CWT study has a relatively large data set that could benefit from additional data to strengthen the relation between exports and relative survival, especially at extremes of export levels and/or water temperature. However, once a telemetry study begins producing sound survival, behavioral, and route-specific migration information in relation to water management actions, the information obtained from the CWT may become obsolete. This multi-prong approach will insure that useful information from more traditional techniques (CWT) continues to be gathered during a period when the outcomes of a new technique (telemetry) are uncertain.

Specific Comments and Recommendations for the CWT study

- Low Recapture Rates – Recapture rates at Chips Island are extremely low, which is an inherent drawback of the CWT study. Because recapture rates are low, little information is gained relative to the number of fish released. Estimates of survival using this technique are subject to many assumptions that are difficult (if not impossible) to test because of the lack of information resulting from low recapture rates. It seems there is little recourse for increasing capture rates using CWT technology. Different techniques (e.g., telemetry) gather much more information relative to the number of fish released because capture rates are very high.

- Releases – Currently, there is only a single release group per release site and year. This is a risky approach since 1) any estimate of survival will be based solely on a theoretical estimate of variance, and 2) unforeseen and unaccountable events (e.g., water temperatures during transport, transport times, tides, etc.) may affect survival of a given release. The theoretical variance estimate will typically underestimate the true variation in survival (Burnham et al., 1987). Ultimately, underestimates of variation could lead to spurious relationships between survival and exports, when in fact, there may be no true relationship. To better estimate variation in survival rates, multiple discrete releases of fish (with unique tag codes) should be made. This would allow a measure of release-to-release variation and "cushion" any release-specific events that might affect survival of a given release group. Ms. Brandeis noted that a release group consists of an entire raceway and therefore, it is not possible to split tag codes within a raceway into separate release groups. I believe this is a limitation that could be overcome at relativelylow cost and with some ingenuity.

- Release sites – Over the years, the number of release sites has increased to attempt to address uncertainties in recapture rates of the primary release sites (Ryde/Isleton and Georgiana Slough). Unfortunately, survival estimates obtained from these additional release sites will likely not have the statistical power to draw meaningful inferences when comparing survival estimates among release sites. A better approach would be to limit the number of release sites and then use the increased sample sizes to make multiple discrete releases at each release site.

- The "shock" effect – Workshop participants had strong and well-founded concerns over violation of the assumption that survival of the upstream and downstream release groups was similar downstream of the release point of the control group. Fish released directly from a hatchery at specific release points likely will have lower reach survival than fish migrating in-river through the same reach. For example, there is likely a period of adjustment to natural river conditions that affect a smolt's disposition to migrate. During this transition period, fish may be subject to higher mortality than fish already in-river. The "shock" effect described by Ken Newman would cancel out in the survival estimates if both release groups experience similar post-release mortality related to the "shock" of being released from a hatchery to the river. However, given that one release site is in the river and one release site is in the estuary, we would expect that the "shock" effect would be different for both groups. This would lead to biased estimates of relative survival. Biased survival estimates would not affect the slope of the relation between exports and survival *if* the "shock" effect remained constant over the range of exports. But if the "shock" effect of the two release groups varied as a function of exports, then the relation between exports and survival may also be biased. The only way to eliminate the "shock" effect is to capture naturally-migrating fish at each release site, handle fish in exactly the same manner at each release site, and tag and release fish separately at each release site.

- Different Types of Survival Estimates – I had a difficulty sorting through the variety of survival estimates that were calculated, which estimates were better than others, and which estimates should be used for relating to water exports. At least four different types of estimates were calculated. I recommend using only the soundest estimates possible to avoid confusion among which estimate to compare against exports. In general, the best estimates are those calculated by Ken Newman using mark/recapture models. However, these estimates depend on ocean recoveries, which take years to obtain. In the interim, relative recapture ratios would provide the next-best estimate, but should be only considered as preliminary estimates until ocean recoveries are complete.
    - "Survival Indices" – estimates are obtained through expanding the number of recoveries by the proportion of time sampled and the proportion of the channel sampled. I recommend against using these estimates because of likely failure in assumptions needed to expand the recaptures. The approach used assumes uniform distribution of fish over the sampling time and uniform distribution of fish across the channel cross-section. These assumptions are not fulfilled because 1) travel times will follow a skewed (to the right) distribution according to advection and diffusion processes, and 2) spatial distributions will be both patchy and concentrated in particular sections of the channel. Although Ms. Brandeis showed that survival indices were not very different from relative recapture ratios (described below), the highest survival indices were the most different from the recapture ratios. Because the two years with the highest survival rates (during low exports) are essentially driving the relation between exports and survival, which form of survival estimate (indices or recapture ratios) will affect the strength of the relation between exports and survival.
    - "Survival Indice Ratios" – estimates are obtained as the ratio of the upstream survival indices by the downstream survival indices. I recommend against using this measure because of failure of assumptions noted above.
    - Relative Recapture Ratios – estimates are obtained as the ratio of the upstream recapture rate to the downstream recapture rate. This is a better estimate than those using survival indices because the relative recapture ratio does not depend on assumptions used to expand the number of recaptures. This approach assumes that capture probabilities are similar between Ryde/Isleton and Georgiana Slough. I recommend against using these estimates since capture probabilities likely differ between these release sites.
    - Mark/Recapture survival estimates calculated by Ken Newman – estimates of relative survival to Chips Island is obtained from mark/recapture models that utilize recoveries from Chips Island and ocean fisheries. This approach will yield the best estimates of survival because it is able to estimate separate survival and capture probabilities at Chips Island. Using this approach, capture probabilities can vary without affecting survival estimates. The major assumption using this approach is that capture probabilities in the ocean fishery are the same for all release groups. This assumption is also inherent in all other estimates that utilize ocean recaptures.

- Colinearity of covariates with survival – Brian Manly found that survival rates were significantly related to both water temperatures and export levels, and that water temperatures and exports were related to each other. Unfortunately, this finding makes it impossible to know whether exports or water temperature affects survival. Further, two data points (the highest survival estimates) are driving the relationships with temperature and exports. The relationships of these covariates with survival disappear when the data points are removed. The data points driving the relationships occur during both low export levels and low water temperatures. The only way to sort out which factor is affecting survival is to intentionally plan for high export levels during a year when water temperatures are low. This planned experiment would fill in the largest data gap in data set.

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