Principal Investigator and Management Team
Responses to the North/Central Delta Regional Salmon Outmigration Study Plan Review
June 10, 2008

Principal Investigators
Jon Burau (USGS-CAWSC)
Aaron Blake (USGS-CAWSC)
Russell Perry (University of Washington)
Noah Adams (USGS-CRRL)
Chris Holbrook (USGS-CRRL)
Theresa Liedke (USGS-CRRL)
Dave Vogel (Natural Resources Scientists, Inc.)

Management Team
Victor Pacheco (DWR, Delta Conveyance Branch)
Jim Wilde (DWR, Delta Conveyance Branch)
Ajay Goyal (DWR, Delta Conveyance Branch)

* CAWSC – California Water Science Center
* CRRL – Columbia River Research Lab

Preliminary remarks
The PI's would like to thank CALFED for conducting the review of our "*North/Central Delta regional salmon outmigration study plan*". In particular, we would like to thank Steve Culberson who deftly handled the interactions between the panel members, the Management Team (MT) and the Principal Investigators (PI's) leading up to, and during the review. Certain clarifications and communications between the various groups were needed so that everyone was clear with regard to the charge of the panel, expectations of the PI's etc.; Steve Culberson handled these with great care and was able to maintain a high degree of transparency throughout the review process, while keeping everyone on the same page. The usefulness of the review was a direct result of his efforts.

The PI's took each and every one of the review comments seriously; the evidence of this should be clear in the thoroughness of the responses and in the broad range of changes made in the study design, particularly with regard to the way in which the gate operations will be investigated, the release strategy, the incorporation of wild and smaller fish in the study design and an increase in the number of tags used to study predatory fish.

As was indicated during the public comment period, the review process itself was an experiment – and by all accounts a successful one. The PI's along with the MT jointly requested this review and believed the review process would be most useful if it were conducted prior to study implementation rather than after, as has typically been done in the bay/delta research community. The process of writing a proposal is absolutely critical in clarifying one's thinking, especially in the case of this experiment, where multiple study elements from multiple disciplines have to work together well. It should be noted, however, the review needs to be conducted well in advance of the proposed experiment execution date so there is ample time to make adjustments to the study plan in response to the review. Moreover, both the review itself (preparing presentations, etc.) and careful consideration and response to the recommendations from the review Panel require a considerable time commitment. In our case, contracting delays thankfully kept us from conducting this study in the 2008 water year, leaving us ample time (basically ¾ of a year) to make the necessary adjustments to the study design in response to the review.

The PI's feel the Panel succeeded admirably in offering their "recommendations in the spirit of trying to improve an already very good project". The Panel did a great job in being constructive with their comments; the language in the review was clearly designed to be helpful and was professional throughout.

The PI's feel strongly the study was significantly improved by having "another set of eyes" look at the problem from a fresh perspective. The PI's thank the members of the panel for their considerate and insightful comments.

The remainder of this document addresses specific review comments, following the organization of the review document. The revised study plan incorporates changes resulting from the review and information gained by the PI's from the implementation of the most recent Vernalis Adaptive Management Plan (VAMP) study that now uses a similar approach and technologies.

3.1 Recommendation: Re-think the experimental design
PI Response: The PI's agree with the Panel with respect to study design and replication of treatments, and, as a consequence, have substantially altered the treatment and release strategy to incorporate the Panel's suggestions. Indeed, the Panel's comments with regard to the release strategy were particularly helpful.

Experimental constraints
The PI's greatly appreciate the Panels' clear understanding of the hydrologic and management constraints on the execution of this experiment. An "optimal" release strategy from a statistical analysis point of view, for example, is simply not possible given these constraints. Significant changes in the Sacramento River inputs are essentially out of our control because uncontrolled runoff can dominate the Sacramento River discharges during the fall/winter study period. And, since the reservoir levels are very low this year, the willingness of the management agencies to allow us to manipulate the Sacramento River flow rates at the lower discharges is also unlikely. Finally, because Sacramento River inputs are likely to be low throughout the summer due to the lack of stored water, salinity standards in the western delta will likely "control" exports during the study period and thus significant disruption of the flows through the Delta Cross Chanel (DCC) due to experimental operations will likely not be allowed by the management agencies. Taken together, we'll be facing significant constraints on the experimental manipulations of the Sacramento River flows and on DCC gate operations this fall.

On the up side, we will be conducting our study under conditions where management actions are likely to have the greatest positive impacts: the drought-like conditions we are likely to face next fall are the conditions under which salmon have historically done poorly (Newman and Rice 2002, Newman 2003). These conditions also create the greatest conflict between water supply and quality (e.g. salinity) objectives and the management actions designed to protect endangered and threatened species, such as delta smelt and winter run Chinook salmon.

Revised release strategy

The PI's have significantly revised the release strategy to address (1) the lack of replicates during similar hydraulic conditions in the original design (e.g. Sacramento River flows, DCC gate operations), (2) the possibility of greater resolution in the survival discharge relations within each channel and (3) our ability to investigate the effects of many of the other covariates on the observed differences in route selection and survival (see response to comment 3.2b).

The original proposal maintained the notion that we needed to keep hydraulic conditions steady for the entire time it takes outmigrants to traverse the system – from the city of Sacramento to Chipps Island. This, of course, was an incorrect notion, since in the proposed study we have significantly increased the spatial resolution of the sampling design by junction and by specific reach and thus the time a study fish spends in each junction and in each reach is relatively short (order minutes and days, respectively). The increased spatial resolution in this study therefore allows the possibility of considering gate manipulations while the study fish are en route. However, we still have the problem of dealing with telemetry data associated with study fish that are "caught" in the network during hydrodynamic transitions associated with changes in gate operations (order day), which we discuss below. Thanks to K. Rose for correcting the conceptual baggage associated with previous studies (this is a good example of the benefits of conducting an outside review).

3.1a Recommendation: Reduce experimental conditions to two in order to have replicate measurements

PI Response: In the case of the North/Central Delta Regional Salmon Outmigration Study **(**NCDRSS), the ideal experimental design would consist of a randomized block study design. This ideal design (1) replicates treatments over multiple time blocks to represent the full range of environmental conditions, (2) controls confounding factors among treatments (e.g., discharge, turbidity, temperature, study fish developing over time, etc.) by implementing treatments within a short block of time when environmental conditions are likely to be similar among treatments, and (3) allows for environmental variation to be partitioned among and within blocks, thereby yielding higher statistical power of detecting treatment differences. The single most important aspect of this design is the control and elimination of confounding factors by interspersing repeated treatments over time and random ordering of treatments within blocks. Unfortunately, as acknowledged by the Panel, this ideal study design can not be implemented due to strict regulation of the DCC gate operations and our significant lack of control over Sacramento River inputs. Nonetheless, we describe this ideal design as a basis of reference for designing a treatment and release schedule that incorporates as many features of this design as possible.

Although the Panel suggested studying only two treatments instead of four, we elected to implement three of the proposed treatments, with the fourth (DCC gates half-open) implemented as a pre-study pilot. The PI's and MT felt it was extremely important to study the efficacy of the current management strategies associated with the DCC (fully open and completely closed) using acoustic telemetry techniques and, given the recent crash in the number of returning salmon, to investigate the potential benefits associated with night-time closures as an interim strategy that could balance the need for water supplies (or increased San Joaquin River flows for delta smelt) while potentially providing significant protection for outmigrants.

Finally, we did not want to completely abandon the ½ open gate closed operation and have proposed a significantly reduced effort for this treatment – a pilot scale investigation that would also serve as a dry run for the full experiment. We propose to release ~200 tagged fish just downstream of Steamboat Slough in a highly contrived manner for this pilot. To maximize the information collected from these tags, we propose to release fish so that they will arrive at the DCC during periods in the tidal cycle when water is significantly flowing into the DCC. We perfected Lagrangian travel time estimates in the Sacramento River upstream of the DCC during previous DCC studies and will use these techniques to increase the possibility of tagged fish interacting with the DCC during this pilot. These data will be used as a "proof-of-concept" to guide future studies.

The major restriction in achieving the ideal study design is implementation of the "DCC closed" treatment. As discussed above, we have little experimental control over dictating when the DCC gates are closed. The "DCC closed" treatment will therefore be implemented when the gates are normally scheduled to be closed (typically late-December or January). Likewise, implementation of the remaining treatments ("DCC closed at night", "DCC open") are restricted to time periods when the gates are normally open (November, December). We took advantage of flexibility within this time frame to incorporate features of the ideal study design.

In general, we identified three levels of replication that could be incorporated into the study design: (1) treatment periods within blocks of time, (2) release groups within each treatment period, and (3) individual fish within each release group. Time blocks were defined to be approximately three weeks long resulting in 12-day treatment periods. Within each treatment period, two releases will be timed such that fish arrive throughout the treatment period, but with arrival-time peaks centered on days 2 and 5 of each treatment period. We also set a minimum release size of 200 fish (implanted with the Model "E" tags) released at Sacramento, which influenced the total number of possible replications at each level. These design criteria resulted in three time blocks, two treatment periods within each time block, and two releases within each treatment period for a total of two treatment periods per treatment, four releases per treatment, and twelve total releases (detailed in the Release Strategy Table: release.strategy.xls).

For the first two time blocks, we used a systematic design with the treatment order initially determined by random assignment resulting in the treatment ordering "DCC open", "DCC closed at night" within each time block (release.strategy.xls). We elected not to implement completely randomized blocks due to interactions between tidal patterns and release patterning because there are a limited number of possible random permutations (i.e., only four possible orderings of two treatments within two blocks). With this systematic design, each treatment will be repeated approximately three weeks after the first treatment, which will ensure that any variation in tidal patterns between the two replicates remains consistent between the treatments. With completely randomized blocks one treatment could be repeated in consecutive order with the start date of the other replicated treatment separated by as much as one month. Thus, variation in tidal patterns within each treatment could differ substantially among the treatments. Complete randomization within blocks is more appropriate when there are many blocks to ensure complete coverage of all possible conditions within each treatment.

Although the last time block consists solely of the DCC closed treatment and could lead to potential confounding of environmental variables with the treatments, we believe the design described herein comes as close as possible to the ideal design described above, given the constraints to the experimental design. In addition, this design considerably improves on the original proposal where each treatment was implemented once with only one release per treatment. For the "junction experiments", treatments are interspersed through time, with multiple releases for each treatment, which should result in some overlap of environmental conditions among treatments. For the "survival experiments", the largest effect of the gate treatments will be to alter discharge through various secondary routes through the Delta. From this perspective, 12 releases (instead of four in the original study plan) implemented over time should result in a range of environmental conditions for relating to survival and route selection.

We considered five other candidate designs, but none simultaneously met all of our design criteria. For example, we considered implementing halving the treatment periods to increase the number of blocks and decrease the time between alternate treatments. However, when switching between treatments, time is needed for hydraulic conditions to stabilize in response to the treatment change (discussed below). With 12-day-long treatment periods this transition time is a small proportion of the total treatment period, but increases sharply when doubling the number of treatment switches and halving the treatment periods. This rationale led to selection of the 12-day-long treatment period. Another design considered 18 total releases instead of 12, but we rejected this design because release sizes were too small to precisely estimate release-specific survival and routing parameters, especially as sample size is diluted through fish mortality and dispersion among numerous routes. We want to retain the ability to measure release-specific parameters so that both group-level and individual-level covariates can be modeled. This rationale led to the selection of 12 release groups which achieves some replication at each level, but still allows adequate sample size for release-specific parameter estimation (See response to comment 3.2b).

Dealing with hydrodynamic transitions associated with changes in gate operations

Our release and treatment schedule is designed to allow the majority of fish to migrate through the north delta and Mokelumne system (see figure 1 for regional definitions which are based on the tidal to residual current ratio shown in figure 2) under a given treatment so that we can examine the effects of each treatment on survival of fish within these regions. The influence of the net flows, and, by inference, DCC gate operations on the physical processes that govern outmigration, is drastically reduced as fish pass through the boundaries shown in figures 1 and 2, and thus the timing of releases with respect to the DCC gate manipulations is principally aimed at getting most of the study fish past these boundaries before the positions of the DCC are changed.

Considering hydrodynamic transitions are important because, for example, acoustically tagged fish that enter the Mokelumne system under full gate open operations experience significantly different hydrodynamic conditions than when the gates are closed. When the gates are open, the Mokelumne system is dominated by the net flows created by the water flowing through the DCC. Once the gates are closed, however, the Mokelumne system virtually instantaneously becomes dominated by the tides, because the river inputs from the upper Mokelumne River are typically small, except during short-lived uncontrolled run-off events. Thus, we expect that the DCC treatments could affect not only route selection, but also survival in these secondary routes.

With respect to estimating treatment effects on survival in these secondary routes, one concern is how to treat fish that enter a secondary channel under one treatment, but remain in that channel after switching to the next treatment (e.g. a change in gate position). These fish can be expected to have survival probabilities that lie somewhere between survival of fish that migrate solely under each treatment. Thus, their inclusion under a given treatment could reduce the apparent difference in survival between treatments. One approach is to exclude so-called "transition fish" from the survival analysis. But the difficulty lies in classifying fish that enter under one treatment but then die prior to exiting the secondary route (or survive, but are not detected at the exit). In this case, the time of death (or time of exit for undetected survivors) is unknown so it is impossible to determine whether these fish should be classified as a "transition fish" for exclusion from the analysis. As a consequence, any attempt at such exclusion could result in negatively biased survival estimates since detected "transition fish" would be excluded, but non-detected (possibly dead) "transition fish" would be included in the analysis. Rather, the appropriate way to proceed is to include all fish in the analysis, but minimize the number of fish "caught in the transition" by allowing sufficient time for fish to migrate through these secondary routes. This approach is reflected in the 9-day period following the last release within each treatment, which should be an adequate amount of time based on analysis of our pilot study data collected under low Sacramento River flow conditions in 2006/2007.. In summary, for the purposes of the survival model, we assume a change in gate operations has little impact on the net flows seaward of the North Delta and Mokelumne/San Joaquin River junction since these areas are dominated by tidal exchanges.

From a purely hydrodynamic perspective, DCC gate operations change the *distribution* of the net Sacramento River flows among the channels of the north delta (see appendix A in the original study plan) – this means a change in both (1) the flow splits at junctions and (2) the total discharge within each reach within the north delta. One of the benefits of compartmentalizing salmon outmigration into route selection and survival is that we only need to explicitly consider the influence of gate operations on route selection through their effects on the flow splits at junctions. Thus, the influence of the gates on total discharge in each channel will be captured in our proposed normalization of survival based on reach specific conditions, such as the net flows, net/tidal current ratios and the correlation between the tidal currents with ambient light (e.g. day/night). In other words, for the purposes of understanding the hydrodynamic influences on survival, we do not care if a change in discharge in a given channel is driven by changes in Sacramento River inflows or through changes induced by DCC gate operations. The influence of gate operations on overall salmon survival will be primarily captured in the route selection component of the study, but only if there are significant spatial differences in survival. If the survival is the same everywhere, route selection and therefore gate operations will have no impact on overall survival through the Delta. Yet, previous studies (Brandes and McLain 2001, Newman and Rice 2002) and the pilot study results (see appendix A in the original study plan) indicate there are significant reach-specific survival differences, and thus we expect DCC gate operations to have an impact on overall survival, though, again, primarily through its influence on route selection (except, perhaps, for the effect DCC gate operations have on survival in the Mokelumne system, as described above). By compartmentalizing route-selection and reach survival, both influences can be incorporated in a simple model – this approach mitigates the confounding influences of gate operations and changing Sacramento River flows. For example, a gate operation at Sacramento River flows near 25,000 cfs may have a different effect on overall survival than operations at Sacramento River flows near 10,000 cfs.

Dealing with simultaneous increases in fish size and Sacramento River discharge

In this section, the Panel noted the possibility of confounding between fish size and discharge due to both fish size and discharge increasing over time. Although the mean length of hatchery-origin run-of-the-river smolts increases by about 10 mm per month between November and January (Figure 3), variation in fish size results in substantial overlap of the monthly size frequency distributions. We therefore expect good representation of a range of fish sizes over the full range of discharge experienced during the study, save perhaps the extremes of the fish size distribution. We will incorporate fish size as an individual covariate in most of our analyses (See response to comment 3.2b for details).

We believe this particular case of confounding (fish size and discharge increasing over time) is unlikely to occur, but it is worth noting that many other factors will naturally co-vary through time, and these will possibly relate to our response variables. For example, discharge and turbidity are typically positively correlated and will co-vary through time, although turbidities are generally much higher during the "first flush" for a given discharge (Schoelhammer, 2002). Increases in turbidity could reduce predation rates on juvenile salmon by reducing the reactive distance of predators (Gregory and Levings 1998, Vogel and Beauchamp 1999), yet coincident increases in discharge could speed the migration of juvenile salmon, also reducing encounter and predation rates (Anderson et al. 2005). We recognize that these related covariates could make it difficult to disentangle the causal mechanisms affecting survival; however, it is important to note that potential confounding of this nature enters the study not as a consequence of the study design, but as an inherent feature of the system itself.

3.1b Recommendation: The violation of critical assumptions for the mark-recapture release model when experimental fish are confined to large, hatchery-origin juvenile latefall run Chinook salmon as surrogates for smaller wild winter-run outmigrants should be explicitly stated and the possible consequences clearly discussed.
(See 3.1c below)

3.1c Recommendation: The critical assumptions about the size of fish being tagged and the size of juvenile salmon in the study reaches of the Delta should be explicitly stated and the possible consequences of violations of these assumptions should be discussed in the proposal.

PI Response: The preceding recommendations (3.1b and 3.1c) addressed very similar concerns and to some extent included redundant remarks. To address these recommendations we have grouped the concerns into four categories and provide responses that individually address each category:

A. Rationale for acoustic telemetry
B. Rationale and justification for fish selection and release timing
C. Suitability of large hatchery fish as surrogates for small hatchery fish
D. Relation to other studies and understanding of population-level dynamics

A. Rationale for acoustic telemetry

We recognize that acoustic telemetry has limitations with respect to the study of all juvenile life stages and all stocks of interest, yet the rationale for using acoustic telemetry arose specifically due to the limitations of other tagging methodologies such as coded wire tags (CWT). Use of CWT in the Delta has been the backbone of long-term studies to estimate survival and has yielded important insights (Brandes and Mclain 2001, Newman and Rice 2002, Newman 2003), but a recent review of such a study (Delta Action 8) has highlighted the limitations of CWT to answer questions relevant to management of water resources and salmon populations (Brown and Kimmerer 2006). CWT suffers from low recapture rates, consequent imprecision of estimates, inability to estimate use of different migration routes through the Delta (partially a function of management actions), and dependence on many untenable assumptions related to the recapture process (Brown and Kimmerer 2006). The biological objectives of our study fall into two broad categories: 1) large-scale (on the order of kilometers) behavior, movement, and survival through specific migration routes of the Delta; and 2) fine-scale (sub-meter) behavior and distribution at junctions. Acoustic telemetry allows us to address both of these objectives with a single tool. Acoustic telemetry is restricted to large individuals and as such, we agree with the Panel that CWT is the best available technology for the study of small individuals such as fry. We believe that using multiple tagging technologies best suited to a given life stage will result in insights about all life stages that can not be gained from using a single technology such as CWT.

The acoustic telemetry tool (Hydroacoustic Technology, Inc., Seattle, WA) that we will be using was first applied by USGS in 1999 to obtain fine-scale behavior information as fish approach and pass hydroelectric dams on the Columbia River. Over the years this tool has been refined and is the only tool of its kind that can be used to obtain continuous fish movement data in both two and three dimensions. This makes acoustic telemetery well suited for collecting information at the DCC and other junctions in the Delta, and will provide high temporal (signal every 2 to 15 seconds) and spatial (sub-meter) resolution. The ability of this system to record and describe the movements of hundreds of tagged fish simultaneously has led to its extensive application in the Columbia and Snake rivers and allowed us to collect individual-based behavioral data on thousands of fish as they migrate to the ocean.

Within the last few years, we have expanded the demands on the acoustic technology to not only allow us to collect behavioral information but to also provide a rigorous means of estimating survival using mark-recapture models. In its simplest form, survival estimation requires multiple "contacts" (i.e., recapture or detection) with marked individuals. This can be fairly straightforward with conventional mark-recapture techniques (e.g., CWT combined with rotary screw traps, trawls, etc.) in closed, linear systems (i.e., rivers) when the number of potential pathways is small; but exceedingly difficult and logistically challenging in more complex systems, like the Delta. Fortunately, acoustic telemetry provides simultaneous, continuous monitoring at multiple sites. Unlike CWT or PIT tags, acoustic tags are active and can be detected and identified from great distances (usually hundreds of meters), resulting in high detection probabilities. Compared to conventional mark-recapture methods, acoustic telemetry studies require less labor, fewer assumptions, and provide more precise parameter estimates.

Because this tool was initially designed to gather fine scale movement data over a relatively short temporal scale, its greatest limitation for collecting survival information over a longer temporal scale is the relatively short battery life of the tag. The functional life of the tag can be extended by using a bigger battery, but this leads to a larger tag which limits the minimum size of the study fish. The optimal tag for a given study is one that is small enough to be implanted in fish that represent the "run-of-interest" and has a functional life that exceeds the duration of time that fish will be in the study area. The acoustic tag (HTI model 795-E; 1.5 g in air) that we plan to use will allow us to tag smolts that weigh 30 g or greater (about 138 mm fork length based on length-weight regression) with minimal effects on the behavior of study fish (Adams et al. 1998). This tag has a minimum life expectancy of 14 to 18 days, depending on tag configuration. A smaller tag (model 795-S; 0.65 g in air) is available that would allow us to tag fish as small as 13 g (113 mm fork length) but the minimum life expectancy is 11 days. Since we have limited knowledge of migration rates through the study area (Sacramento to Chipps Island), we will employ the larger tag for the bulk of our study fish in the 2008-2009 study to eliminate bias due to premature tag failure, which cannot be distinguished from mortality. We have plans to tag a subset (1350 tags) of smaller fish (113-138 mm) with the smaller tag (model 795-S) to evaluate size-dependent behavior and survival.

Like transmitter size, battery life is constantly improving with advancing technology. Indeed, during the 2008-2009 study, we will be testing a prototype tag (LPAT; HTI) weighing about 0.5 g with a minimum battery life of about 25 days. If successful, the inclusion of such a tag in future studies will allow study of smaller individuals over longer time frames. Regardless of the outcome of the tag testing, we select research tools based on their ability to address the questions of interest. We regularly explore the availability and compare the capabilities of similar tools (e.g., JSAT; in development by U. S. Army Corps of Engineers) in order to ensure that we are conducting the best possible science.

B. Rationale and justification for fish selection and release timing

Given that direct inferences from our study are limited to the population from which individuals are randomly sampled, the ideal study population represents a random sample of wild, actively-migrating (or dispersing) juvenile salmon from the Sacramento River during the period of migration of at-risk stocks. Unfortunately, this ideal study population can not be sampled for reasons such as fish size, fish abundance, and management restrictions on the study period. These factors largely drove the rationale behind fish selection and timing of the proposed study, and we discuss each below.

As discussed above, transmitter size and battery life limit the size of fish that can be studied with acoustic telemetry. In our study, this limitation restricts direct inferences largely to yearling, stream-type life histories and excludes from our study fry and ocean-type life histories. In addition, actively-migrating wild and hatchery-origin yearling juvenile salmon are in low abundance and can not be sampled *in situ* in adequate numbers needed for the proposed study. Due to the limited availability of actively-migrating river-run fish, we will use yearling late fall run smolts from Coleman National Fish Hatchery (NFH) in this study. Coleman NFH releases 1,200,000 of these smolts in November, December, and January of each year to mitigate for the effects of dams in the upper watershed and recreational and commercial fishing on adult spawning escapement. Based on previous length-weight data, we anticipate that the upper 50% of the hatchery size distribution will be within our target range for the Model E tag and 90% for the Model S tag (see previous section and response to comment 4.1a for details on tag models). Further, yearling Chinook salmon within this size range are not uncommon in trawls between November and January (Brandes and McClain 2001), although most fish of this size are of hatchery origin (i.e., marked; Figure 3).

Study timing was selected between November and January to (1) compare behavior among three hydraulic treatments during a period when experimental treatments are not restricted by mandated DCC gate operations and (2) minimize risk of additional mortality to already depleted stocks. As discussed above (response to comment 3 and 3.1a), the study period represents the period of juvenile migration when there is limited flexibility to experimentally operate the DCC gates. Although juvenile salmon abundance in the lower Sacramento River and Delta may be higher in late winter and spring (Williams 2006), the DCC gates remain closed February 1 through May 20 per order of the National Marine Fisheries Service (NMFS), U. S. Fish and Wildlife Service (USFWS) and California Department of Fish and Game (CDFG). We cannot identify mechanisms affecting entrainment into the DCC without implementing the proposed DCC gate treatments. Interestingly, in stark contrast to these review comments, representatives from several of the management agencies suggested we emphasize the period prior to the mandated 25,000 cfs gate closure in our release strategy, arguing that this is the most useful period from a management perspective because we can actually manipulate the gates during this period. Finally, the late winter/spring gate closure is mandated because this is the period of the greatest (although largely unquantified) perceived threat to the fish population. Thus, even if experimental gate operations were plausible, conducting the study between February and May would expose more juvenile salmon to the high mortality conditions of the interior Delta. The bottom line: the management agencies will not allow us to open the gates for experimental purposes during this period even if the Sacramento River flows are below 25,000 cfs (the 25,000 cfs condition is a public safety constraint designed to protect Mokelumne River levees from Sacramento River flood stages), which in itself is unlikely given the typical hydrology during this period.

Direct inferences from our study will not encompass all stocks and all life stages of juvenile salmon present in the Delta, but we will be able to make strong inferences to stocks of concern that have recently experienced drastic declines. Stock identification and run timing during juvenile emigration are not thoroughly understood (Hedgecock et al. 2001), but it is likely that our study fish will most closely match the size distribution of the late fall and winter run Chinook salmon that are emigrating through the Sacramento River during the study period (Williams 2006). Compared to other runs, winter and late fall run Chinook salmon in the Central Valley have historically experienced lower abundance and greater declines (Myers et al. 1998). Myers et al. (1998) concluded that the winter-run evolutionary significant unit (ESU) "is comprised of a single population with very limited spawning and rearing habitat that increases its risk of extinction due to local catastrophe or poor environmental conditions." Indeed, winter run Chinook salmon remain well below draft recovery goals (CDFG 2004). While the Central Valley fall run ESU (which includes late fall run Chinook) is "merely" classified as Species of Special Concern, Myers et al. (1998) concluded that the fish in this ESU were "not in danger of extinction but [are] likely to become so in the foreseeable future." In fact, adult spawning escapement in 2007 failed to meet escapement goals for the first time since 1992, and "jack" returns were at an all-time low (PFMC 2008)—a crash that has resulted in unprecedented recreational and commercial fishery closures. Natural production of the fall-run ESU is believed to be limited by several factors, including fluctuating river flows, flow reversals in the Delta, and losses at water diversions (Myers et al. 1998). Inferences from our study will directly address the extent to which these factors affect survival for an important stock of concern.

Although direct inferences are limited, results from our study may be applicable to other stocks, life stages, and time periods with adequate recognition of how differences in biological factors influence fish behavior in response to the environment and management actions. For example, it seems that active downstream migration occurs primarily during the night (Blake and Horn 2006) in the fall, but during the day (Wilder and Ingram 2006) in the spring. Thus, certain management strategies (e.g., night-time closure of DCC gates) that are effective in the fall may need to be adapted for the spring season based on knowledge of fish behavior. Fortunately, seasonal changes in behavior and spatial distributions at junctions can likely be quantified without repeating the proposed study during every season, and many appropriate methods (i.e., trawling, seining, hydroacoustic surveys, etc.) have already been applied to monitoring programs in the delta.

C. Suitability of large hatchery fish as surrogates for small wild fish

We acknowledge that this study population represents only the larger, hatchery-reared portion of the river-run population (i.e., "population of interest"), and that survival and behavior may depend on size and rearing history. Direct inference to the overall population that falls outside of the study population must be subject-matter based – that is, based on knowledge of biology and ecology. Although the magnitude of size-dependent and temporal differences may be difficult to predict, the *direction* of the differences may be more predictable with basic knowledge of mortality processes in the system (i.e., predation, starvation, entrainment at diversions, etc.).

Most studies have shown that survival favors larger body size during the smolt migration (Martin and Wertheimer 1989; Beckman et al. 1999; both as cited in Connor et al. 2004) and other life stages (Burrows 1969; Unwin 1997; Zabel and Achord 2004) of Chinook salmon. In many systems, mortality has largely been attributed to selective predation by fish during juvenile migration (Poe et al. 1991; Tabor et al. 1993; Connor et al. 2004), with larger individuals exhibiting higher survival. Smaller fish may be more susceptible to piscivorous predation (i.e., more vulnerable to capture by a wider size range of predators) because they have limited swimming capacity (Bainbridge 1958; Taylor and McPhail 1985; Swanson et al. 2004). Smaller smolts also tend to migrate more slowly than larger smolts (Giorgi et al. 1997; Beckman et al. 1998; Tiffan et al. 2000; Connor et al. 2004), potentially increasing exposure time to the predator field. In contrast, surface-oriented avian predators may select larger individuals (Collis et al. 2001), thus imposing selection in the opposite direction. However, because predation by fish (e.g., striped bass) is suspected as a major cause of mortality to juvenile salmon in the Delta, we suspect that survival of larger tagged fish may be higher than that of smaller untagged fish. That is, using larger fish alone may result in an overestimate of true survival of the river-run population.

Our discussion of size-dependent mortality must be framed in the context of actively migrating smolts, because it is well known that fry and smolts differ in their behavior, physiology and morphology. Juvenile sampling data are often marked by bimodal size distributions in the Central Valley (see Williams 2006). Smaller individuals are commonly considered "fry" (fork length < 70 mm) and larger fish as "smolt" (fork length > 70 mm). While there is no question that fry move through the system in great numbers (see Williams 2006), physiological (Beckman et al. 2007) and catch data in the estuary (MacFarlane and Norton 2002) support the hypothesis that these fry are simply dispersing—as opposed to migrating. Extrapolation of results to dispersing fry would require careful consideration (i.e., further investigation) of fry behavior at junctions and knowledge of the factors behind fry survival in the delta. The limitations, however, should not preclude the use of these data to formulate educated, testable hypotheses about the behavior of smaller fish, even fry.

If subyearling Chinook salmon in the Central Valley exhibit similar behavior as those in the Columbia and Snake rivers, they may be characterized by four "migrational" phases, as described by Connor et al. (2003). These phases are: (1) discontinuous downstream dispersal along the shorelines of the free-flowing river; (2) abrupt and mostly continuous dispersal offshore in the free-flowing river; (3) passive, discontinuous downstream dispersal offshore in the river; and (4) active and mostly continuous seaward migration as fish become smolts. A similar pattern of behavior may occur in ocean-type fry in the Central Valley. The very fact that fry are regularly captured in great numbers in rotary screw traps and trawls (see Williams 2006) indicates that even fry use the mid-channel habitats to disperse.

While small fish (fry and ocean-type smolts) appear to occur in higher abundance than the larger yearling stream-type fish that will be used by this study, differences in size-dependent mortality could result in disproportionate representation of these size classes in the adult spawning stock. For example, Connor et al. (2005) found that subyearling and yearling Fall Chinook in the Snake River each comprised about half of the returning hatchery adults, but the abundance of subyearling Chinook are suspected to dominate the outmigrating population. Likewise, Bugert et al. 1997 found that hatchery yearling Fall Chinook salmon in the Snake River returned to the hatchery at rates 10 times higher than subyearling Chinook salmon. Furthermore, the potential for life history plasticity has been shown within the Sacramento River winter run Chinook salmon (Beckman et al. 2007). Thus, the importance of large smolts as represented by our study should not be underscored by their relatively low abundance in the outmigrant population, but rather by their potentially large contribution to the returning adult population.

Hatchery smolts have been known to incur higher mortality than their wild counterparts in many systems (Raymond 1988; Collis et al. 2001; Fresh et al. 2003). Documented differences may be associated with behavioral or physiological mechanisms that are critical to successful predator avoidance (Dickson and MacCrimmon 1982; Olla and Davis 1989; Berejikian 1995) or seawater entry (Shrimpton et al. 1994; Fuss and Byrne 2002). Thus, by using hatchery fish alone, we may underestimate true survival of the wild river-run population. Nonetheless, we have proposed, in the revised study plan, to use a limited (order 100) wild ("run of the river") fish. This is the most we can expect, given these fish will be obtained from ongoing activities (screw traps) and the need for minimal handling prior to surgery and re-release.

It is difficult to predict how the interaction between size and rearing history (i.e., larger hatchery versus smaller wild) may influence survival. However, from a management perspective, differences may not be as detrimental as the Panel suggests. A primary objective of this study is to estimate the *relative difference* in smolt survival between the interior delta and the main stem Sacramento River. When considered in combination with the probability of entrainment into the interior delta, we will examine the "effect" of entering the interior delta on survival through the system. We postulate that the spatial distribution of migrants within a junction is the primary factor in route determination. If this is true, then the key question becomes one of spatial distribution: "Do smaller, wild fish tend to migrate within the margins or mid-channel; near the surface or river bed?" Unless rearing history and size have a significant effect on route determination, our estimates of the population-level effect of entering the delta on survival are unlikely to differ between our study fish and the river run population. Moreover, a recent study (Barnett-Johnson et al. 2007) suggested that hatchery fish comprise 90% of the adult Chinook population off the California coast. Therefore, the hatchery smolts used in this study may represent the majority of smolts that will ultimately contribute to future reproduction.

The most detailed comparisons of hatchery and wild behavior and distribution in the water column come from research at dams in the Columbia River basin. Many studies have revealed that hatchery and wild steelhead have similar travel rates, diel patterns of behavior, approach distributions at dams, and proportional use of various dam passage routes (Evans et al. 1995; Adams et al. 1996; Evans et al. 2001). Passage route determination at most dams is largely dependent on both horizontal and vertical distribution of migrants in the water column. Thus, we may expect that, among smolts, rearing history has little effect on route determination in the Delta.

Since the advent of telemetry studies, the suitability of using data gathered on larger fish to characterize the entire populations has been a concern. The miniaturization of transmitters never seems to keep pace with the desire to study smaller fish. It never seems to fail that as soon as we implant tags in a size category that has never before been studied, we immediately ask vendors to reduce tag size so that smaller fish can be studied in the following year. Using the smallest available technology to implant tags in as small of fish as possible has allowed researchers from around the world to collect data that would otherwise be unattainable. The alternative would be to forgo any information in favor of waiting for the technology to advance to a stage that allows 100% of the size range to be represented in the study. We argue that collecting some data on the greatest proportions of the population as possible is far better than waiting for the technology to catch up. Indeed, when telemetry studies were first conducted by USGS in 1994, the smallest available tag weighed 2.5 g. In the ensuing 15 years, tag size has been reduced to 0.35 g. Data collected during those 15 years has been critical in shaping management strategies that have contributed to the protection and recovery of threatened and endangered salmon populations in the Columbia River Basin. These runs would be in far worse shape if we had forgone the last 15 years of research in favor of waiting for a smaller transmitter.

D. Relation to other studies understanding population-level dynamics

This study relates directly to other Delta studies such as Brandes and McClain (Brandes and McClain) and related studies using beach seine and trawling data. One major purpose of beach seining and trawling data are to provide recoveries of coded-wire tagged (CWT) fish for use in mark-recapture studies (Brandes and McClain(2001), Newman (2002) and Newman and Rice (2003)). These studies have examined the effect of migration routing (Sacramento R. versus Interior Delta) on survival indices of juvenile salmon, but have used a coarse-scale tool in attempt to understand fine-scale processes. As a result, critical assumptions about the capture and routing process affect interpretation of their analyses (see Brown and Kimmerer 2006 for a detailed review of these studies). This study takes a similar approach (i.e., mark-recapture), but uses fine-scale tools to answer fine-scale questions and explicitly quantifies the critical assumptions made by these previous mark-recapture studies.

To relate our findings to these previous studies, we plan to calculate parameters directly analogous to those estimated in the CWT studies. For example, one series of CWT estimated the ratio of recoveries from CWT fish released at Courtland to fish released at Ryde to estimate relative survival between the two locations (Newman 2008). Another study measured recovery ratios of fish released into Georgiana Slough relative to CWT fish released at Ryde (Newman 2008). Since our study will estimate each of the component survival and routing probabilities through the Delta, we can construct parameters that directly estimate the same relative survival probabilities as these CWT studies. These measures will provide context for comparing our data to past studies, and for revealing the underlying components that cannot be estimated using CWT mark-recapture studies. Thus, while our study will provide new information, relating our results to previous CWT studies may also shed new light on previous findings.

Finally, we expect that our findings can be directly incorporated into models of salmon population dynamics. An understanding of population-level dynamics can be critical for identifying factors that limit population growth and size, particularly for species at risk of extinction. Even a basic understanding of population-level dynamics, however, can require complex modeling of system processes (Lebreton 2006). Such models are typically developed as meta-analyses, requiring data from many finely focused studies to effectively incorporate information over a range of spatiotemporal scales and life stages. Although the life history of Central Valley salmon is complex, we intend to monitor a specific stage – juvenile seaward migration. This period is largely a "black box" in the population-level view of Central Valley salmon, with the work of Newman and Rice (2002) and Newman (2003) representing the best analysis of the available data. Thus, results from the proposed study will help to understand the processes of route-selection and survival of migrating juvenile salmonids in the Delta. Our findings should contribute substantially to others developing population models of salmon that incorporate the complete life-cycle. For example, in their state-space population model, Newman and Lindley (2006) included a single survival parameter (ϕ_{2t}) for juvenile survival and acknowledged that explicit components such as export-related mortality are absorbed into this parameter. Our study will explicitly estimate the components that comprise juvenile survival in the Delta, and our findings could be directly included in these population models to either explicitly model these components, or to reduce uncertainty in parameter estimates used in these models.

3.1d Recommendation: Re-arrange hydrodynamics measurements to include better coverage of vertical structure and velocity measurements on the channel sides in shallows where small Chinook may more likely to be migrating.

PI Response: We agree with the Panel that it "would be more useful to both the modeling effort and to understanding possible flow cues for salmon" to collect time series information regarding the vertical structure outside of the DCC channel entrance and have modified our deployment strategy. This revision includes a series of upward-looking Acoustic Doppler Current Profilers (ADCPs) deployed along the river beginning upstream of the DCC and continuing on to the mouth of Georgiana Slough (see figure 4). With this deployment strategy we will obtain time series (at 10 minute intervals) of secondary circulation throughout the bend (albeit profiles at 6 discrete locations) over the entire study period (e.g. September 2008 through February 2009). Figure 4 also provides the locations of proposed transect locations for the Unmanned Survey Vessels (USV) fitted with downward-looking ADCPs. A number of the upward-looking deployments will be co-located with the proposed downward-looking ADCP transect locations (stations DC-1, DC-2, DC-3) so that the individual upward-looking ADCP-collected velocity profiles can be tied to transects of secondary circulation measured at irregular time intervals using the USVs.

Stations DC-3, in front of the DCC, and GS-1, in front of Georgiana Slough, will be used in several ways: (1) to measure secondary circulation on ebb tides and during higher flow periods (Freeport flows > 20,000 cfs) associated with the bend in the river at Walnut Grove, (2) to measure secondary circulation within the "virtual bends" (see below) created by the reverse flows that enter both the DCC and Georgiana Slough on flood tides, and finally, (3) to estimate the surface velocities in conjunction with 5 SL-ADCPs deployed in each of these junctions (see "revised plan" below).

The hydraulics of the DCC and Georgiana Slough junctions during flood tides are intriguing because the water changes direction in the absence of a solid river bank (see figure 5 and 6) – a virtual bend in the river. In the case of both the DCC and Georgiana Slough, the flow direction changes roughly 90 degrees in a very short distance (a radius of curvature on the order of the channel width) which creates dramatic changes in the along-channel and lateral momentum balance. These conditions, in turn, create very strong secondary circulation as the water flows from the Sacramento River into both Georgiana Slough and the DCC, as is shown in the numerical model results for Georgiana Slough in figure 7. To our knowledge, no one has documented the hydrodynamics of a "virtual bend" in the field. We have the opportunity to study two different virtual bend geometries in the context of this experiment (e.g. the DCC and Georgiana Slough). Thus, we propose to deploy ADCPs within the junction of the Sacramento River and Georgiana Slough at locations GS-1 (figure 8) and GS-2 (figure 4) to measure secondary circulation patterns during flood tides. Similarly, an ADCP will be deployed in the Sacramento River/DCC junction at station DC-3 (figure 9) to measure secondary circulation patterns during flood tides there. Finally, flood tide transects will be taken by the USVs at 45 degree angles to the prevailing channel orientation at stations GS-F3 and DC-F3 shown in figure 4 to document the hydrodynamic properties of these "virtual" bends.

We agree with the Panel's recommendation that the half-open gate condition is of lesser value than the other proposed gate operations, and, given that there are a variety of safety and operational constraints that make this more difficult, we have requested the management agencies permission to conduct this treatment as a pilot. This will allow us to redistribute the available acoustically-tagged salmon among the remaining treatments to address concerns raised in sections 3.1a regarding replicates, etc. Further, we recognize that the simple schematic of flow under a partially closed gate shown during the public presentations on 1/10/2008 was incorrect and indicated so during the presentations. This graphic was intended for illustrative purposes and has been corrected to reflect the likely vertical structure under half gate open conditions at this location.

The PI's greatly appreciate the Panel chair's offer of Acoustic Doppler Vehicles (ADVs), however, based on acoustic telemetry data collected in Georgiana Slough (Blake and Horn, 2006) and within Clarksburg Bend (appendix C in the original proposal) salmon outmigrants appear to be primarily in the upper part of the water column as they emigrate through the delta during the fall winter period. Thus, salmon outmigrants don't appear to be near the sides of the channel unless they are holding, which we have observed usually occurs at night (Blake and Horn, 2006). Because of this, the PI's feel the measurement of near-bank hydrodynamic processes using ADVs is beyond the scope of the present study because we are primarily interested in salmon movement and survival throughout the delta, and not in understanding rearing and holding behavior. Having said this, however, understanding those conditions, hydrodynamic or otherwise, that create environments that are conducive to resting and rearing are very likely extraordinarily important in this system—a system dominated by armored prismatic channels—because these environments are rare in the north Delta.

Using Sideward Looking-ADCPs to measure surface current fields
The Original Plan – Use CODAR to measure the surface velocity fields
The problem of understanding the movements of juvenile salmon within velocity fields that are inherently unsteady (due to the tides) and are spatially complex (within junctions and bends) is extremely challenging. The hydrodynamics team has been actively pursuing various technologies and methodologies for capturing the 3D evolution of velocity fields within bends and junctions for several years. The complexity in space begs for detailed spatial coverage, yet this takes time given that the best way to do this, at least for now, is by

transecting with downward-looking ADCPs. Yet, if these boat-mounted measurements take too long relative to local rate of change of the currents (> 1 hour), temporal changes in the velocity field will be spuriously aliased into fictitious spatial structures. Thus, in the initial study design we proposed to measure the velocity fields within junctions using high frequency radar (e.g. CODAR), which allows us to measure time series of complete surface velocity *fields* (solving the measurement simultaneity problem) supplemented with measurements of the internal velocity structure (e.g. secondary circulation, etc.) using the USVs. We reasoned that even though the CODAR systems only measure the very near surface velocity field, these measurements would be reasonable first order estimates of what juvenile salmon typically "see" because salmon outmigrants are typically in the upper part of the water column, in particular at night, when they aren't holding (Blake and Horn, 2006).

CODAR and the need for wind

The CODAR systems use small-scale surface waves to estimate the surface currents (Teague et al., 2006) just as ADCPs use particles suspended in the water column as scatterers of acoustic energy. Unfortunately, recent testing of the CODAR systems in the Walnut Grove study area has revealed that the required small-scale surface waves do not exist at low flows in the absence of wind (Cheng et al., 2008). This limitation did not appear in initial testing of the CODAR systems at the Threemile Slough testing location (Cheng et al., 2008) because it now appears that strong tidal currents interacting with unusually large bed forms creates sufficient large-scale turbulence to generate the small-scale surface waves (boils, etc.) under a broad range of conditions needed by the CODAR systems to measure the surface currents. In the Walnut Grove area, however, it appears that a minimum of a 2 m/s wind is needed to reliably generate the surface waves the CODAR systems need to calculate the velocity fields under low flow conditions there (Cheng et al., 2008). This, of course, is a problem since we plan to conduct our study during the winter, a time of year where prolonged (>weeks) periods of low winds and fog can occur in California's central valley between storms. Bottom line: during periods of low Sacramento River flows and low winds the CODAR systems appear incapable of measuring the surface currents.

The revised plan – Use Sideward-Looking ADCPs

Because the CODAR systems appear to be limited at low Sacramento River flows and periods where the wind speeds are ~2 m/s or greater, we are instead considering using 10 SL-ADCPs (figure 10) deployed in the junctions of the Sacramento River with the DCC (figure 11) and Georgiana Slough (figure 12). A pair of ADCPs, one in each junction (figure 4), will be deployed for a couple of reasons (as discussed above), including estimating the surface current field. This solution is not optimum for a variety of reasons, including:

(1) increased manpower to deploy and maintain 10 SL-ADCPs,
(2) increased vulnerability due to multiple instruments that need to operate simultaneously and the equipment being submerged where it is vulnerable to burial due to sedimentation and being struck by debris (large trees and the like),
(3) the acoustic beams will be at depth during high water periods (figure 13)(e.g. not at the surface)
(4) we will be putting a significant amount of acoustic energy into both junctions that will raise the noise floor in the area and thus will (a) likely reduce the detection range of hydrophones deployed in the junctions to detect the acoustic tags (fortunately

there is significant frequency separation between the tags, which ping at roughly 300 khz, and both the SL-ADCP [600 khz] and the UL-ADCPs [1,200 khz]) and, (b) increase the difficulty of deploying the hydrophones and the SL-ADCPs to insure no direct interference occurs,

(5) the need to interpolate between lateral transects to generate a complete velocity field (e.g. the CODAR systems generate surface current fields directly).

The upside of this approach is the USGS-CAWSC is very familiar with this technology – we've worked with SL-ADCPs since they were developed (roughly 10 years ago) and operate roughly 30 SL-ADCPs on a day-to-day basis, 365 days a year, as part of our flow monitoring network. We have also tested the use of 600 khz ADCP in the context of an acoustic telemetry array in Georgiana Slough in 2003 (Blake and Horn, 2006) and found that there was little conflict between the technologies so long as the acoustic beam of the SL-ADCP was not directly aimed at the acoustic telemetry hydrophones.

Interpolation of velocity fields

One of the downsides of using a network of SL-ADCPs is the need to interpolate between lateral profiles to achieve a complete velocity field. We have been experimenting with various interpolation schemes in the context of a numerical modeling framework to address this issue before we purchase equipment to conduct the experiment using this approach. We began by sampling "virtual" SL-ADCP transects of 3D numerical model results (figure 14) and then applied simple inverse distance and Kriging approaches to interpolate velocity fields in the Sacramento River/Georgiana Slough junction. Since we have full 3D velocity fields computed by the model that are mass and momentum conserving we compared the interpolated fields, based on various proposed SL-ADCP locations and alignments, to the complete fields generated from the numerical model. Figure 15 shows a comparison of interpolated velocity fields at four points in the tide based on simple inverse distance interpolation of the transects shown in figure 15 (black) and the complete velocity fields from the 3D model (green). The comparison between streaklines generated from the interpolated field and complete velocity field from the model are "reasonably" close. This is due in part to the "well behaved" nature of fluid flows and the relatively detailed spatial coverage provided by the SL-ADCP transects. We expect to improve on the concurrence between the complete velocity fields and the interpolated fields by (1) optimizing the position and orientation of the SL-ADCPs and (2) using more sophisticated interpolation techniques (Tsubaki and Fujita, 2008) based on the higher resolution calculations of Rueda (5 m horizontal resolution instead of 10m), and (3) as suggested in section 3.4c, employ quantitative metrics to judge the adequacy of the interpolated results.

3.2a Recommendation: The covariates, and how they will be estimated, should be described in more detail.

PI Response: The PI's appreciate the opportunity to describe, in more detail, the long list of covariates that we plan to either measure directly as part of this study, or obtain from ongoing monitoring programs.

Abiotic covariates:

Water related variables include: (1) water level (2) velocity, (3) discharge, (4) turbidity, (5) water temperature, and (6) electrical conductivity. These data are typically measured at 15 minute intervals throughout the Delta as part of the agency monitoring programs. In particular, water levels, velocity and discharge is measured by the USGS-CAWSC at approximately 30 sites scattered throughout the Delta, many of these sampling locations are co-located with the proposed acoustic telemetry receivers. Turbidity, water temperature and electrical conductivity data are collected throughout the Delta, however, this study will likely focus on data collected at the Sacramento River at Freeport, Rio Vista, Emmaton, Jersey Point and Chipps Island. Obviously, DCC gate position is an important covariate, and not so obviously, correlations between variables such as the correlation between tidal current phase and ambient light. Measurements of river temperature at time of release, hatchery water temperature and other release related information will also be collected. Finally, relations between the acoustic telemetry data collected in this investigation and Delta-scale forcings such as river inputs (Sacramento, San Joaquin, Mokelumne, etc.), export rates at a variety of facilities (SWP, CVP, CCWD, north bay aqueduct pumping plants), total inflows, total outflow, and any important ratios of these variables, such as the export/input ratio will be investigated.

Metrological variables include: (1) ambient light, (2) wind speed (3) wind direction, and (4) atmospheric pressure. We plan to deploy a metrological station in the DCC for the duration of the study which will collect 15 minute interval time series of these above listed parameters. We will likely pull data from other meteorological monitoring stations in the Delta as needed.

Biotic covariates:

These covariates include: fork length (mm), weight (g), ATPase (measured on fish samples from hatchery), fish condition indices (scale loss, bruising, weight/length ratio, etc.), water temperature at hatchery, water temperature at release. For each release, samples of fish at the hatchery will be measured for ATPase, a physiological indicator of smoltification. Moreover, at many of the double hydrophone sites we will be able to compare tagged fish velocity estimates (channel distance between stations divided by the difference in the arrival times) to the measured water velocities, etc.

In so far as the references in this section to predation "hotspots" and predation in general please refer to the PI response to recommendation 3.3.

3.2b Recommendation: Statistical analyses should be modified as much as possible to accommodate the individual-oriented nature of the possible covariates, and the separate components of the response variable of survival (mortality rate, transit time) should also be investigated.

PI Response: In the proposal we outlined the basic structure of the mark-recapture model and the method of parameter estimation via maximum likelihood, but we did not describe how covariates would be included in an analytical framework. The Panel made numerous suggestions about including covariates (e.g., discharge, gate position, travel time, etc.). We agree with many of these suggestions. Here we describe how different types of covariates will be incorporated into an analysis framework, but do not focus on specific covariates per se (although examples are given).

Our approach to understanding the effect of covariates will center on maintaining the capability to analyze the data using a number of alternative approaches. Our experimental design will consist of multiple releases of fish, but maintain adequate release sample sizes to investigate release-to-release variation in demographic parameters. In addition, by making numerous releases, we have expanded the range of environmental conditions likely to be experienced by individuals. For example, if discharge varies among releases, then mean discharge as a group-level covariate may effectively quantify how survival of groups of fish varies as a function of mean discharge. Likewise, within-release variation among individuals in their exposure to discharge may further affect the survival of individuals. We believe our study design will allow us to examine both group-level and individual covariates, which will result in a more robust analysis by not being restricted to a particular mode of analysis.

In general, our analysis framework will consist of (1) fitting a general (i.e., "full", "saturated", or "umbrella") model, (2) assessing goodness of fit and testing for overdispersion, (3) developing a set of *a priori* hypotheses about the effects of covariates on model parameters, (4) structuring these hypotheses as constrained versions of the most general model using a generalized linear models framework (McCullagh and Nelder 1989), and (5) selecting among the set of models using standard model selection procedures (e.g., Analysis of Deviance, likelihood ratio tests, and AIC criteria) to determine which model(s) yields the highest likelihood of having given rise to the observed data. This approach is standard in the mark-recapture literature and has provided a powerful framework within which to estimate demographic parameters as well as test biological hypotheses driving variation in these parameters (Lebreton et al. 1992, Williams et al. 2002).

The most general model will include release-, reach-, and site-specific parameters. Our survival model will estimate three sets of parameters: survival (S_{ik}), detection (p_{ik}), and transition (Ψ_k^{rs}) probabilities. Here, the transition probabilities refer to route entrainment probabilities at a junction, but we borrow the more generic term of "transition" from the multistate mark-recapture literature (Brownie et al. 1993, Schwarz et al. 1993, Lebreton and Pradel 2002). Specifically, S_{ik} is the probability of surviving through reach k for release group i, p_{ik} is the probability of being detected at site k for release group i, and Ψ_k^{rs} is the probability of being entrained into reach s from reach r at junction k. All three sets of parameters can be modeled as functions of covariates. The most general model described above will contain the largest number of parameters, and all other models can be considered reduced-parameter versions of the most general model. Reduced models may consist of parameters expressed as functions of covariates, or may simply consist of equality among parameters (e.g., detection probabilities that are site-specific but equal over all releases).

The covariates in mark-recapture analysis can be classified as either group-level or individual covariates. Both types of covariates may either be continuous or discrete, and either time-invariant (i.e., fixed) or time-variant. A discrete covariate may further be broken down into an ordered discrete variable (e.g., size class) or a categorical variable (e.g., "DCC open" versus "DCC closed"). Of these covariate classes, time-dependent individual covariates are of particular interest, but this type of covariate presents the most difficulty in the statistical analysis due to missing covariate values when fish are not detected. Other types of covariates are more easily modeled, and we describe each below.

Group-level covariates here are defined to be values of a covariate common to a group of fish. For example, water temperature at time of release is a group-level covariate because it is common to an entire release group. An example of a time varying group-level covariate is mean discharge during the migration period of each release group through each reach. To model group-level covariates, response variables (S_{ik}, p_{ik}, Ψ_k^{rs}) will be expressed as a linear function of group-level covariates through a link function:

$$f^{-1}\left(\theta_{ik}\right) = \rho_k + \sum_l \beta_l x_{ikl}$$

Here, using the general notation of Hoffman and Skalski (1993), θ_{ik} is one of the three types of response variables for release group i in reach k (or site k in the case of p_{ik}), ρ_k is the main effect of the kth reach, β_l is the slope parameter for the lth group-level covariate, x_{ikl} is the value of the lth covariate for the ith release group in the kth reach, and f^{1} is a link function relating the response to the predictors. The most common link function is the logit, but others include the hazard function and the identity function (Lebreton et. al 1992, Skalski and Smith 1993, Williams 2002). Transition probabilities are constrained to sum to one at a given junction, and link functions satisfying this constraint include the multinomial logit and polychotomous logistic link functions (Pollock 2002, Fujiwara and Caswell 2002).

Time-invariant individual covariates are values of a covariate specified for an individual that remain constant over the duration of the study. For instance, sex is a time-invariant individual covariate. In our study, fish size (fork length or weight) can be considered an individual covariate that remains constant over time (at least during the short duration of our study). Due to the Panel's concerns regarding the extent to which inferences from large tagged fish can be applied to smaller non-tagged fish (Comments 3.1b and 3.1c), we will use fish size as an individual covariate to investigate the possibility of size-dependent survival and transition probabilities. The general approach is to model each individual as a single sample from a multinomial distribution where each individual has its own unique set of parameter values (Skalski et al. 1993, Smith et al. 1994, Williams et al. 2002). The likelihood of each detection history is then written in terms of the individual-specific parameters. It is important to note that this likelihood is over parameterized and parameters for each individual can not be estimated unless expressed as a function of time-invariant individual covariates (Skalski et al. 1993, Smith et al. 1994, Williams et al. 2002):

$$f^{-1}\left(\theta_{ijk}\right) = \rho_k + \pi_i + (\pi\rho)_{ik} + \sum_l \beta_{kl} x_{jkl}$$

Where θ_{ijk} is the response parameter of the jth individual in the ith release group for reach k (for survival) or site k (for detection) , ρ_k is the main effect of the kth reach, π_i is the main effect of the ith release group, $(\pi\rho)_{ik}$ is the interaction term between the kth reach and ith release group, β_{kl} is the slope parameter for individual covariate l in reach k, and x_{jkl} is the value of the lth covariate for the jth individual migrating through the kth reach. As above, f^{1} is a specified function linking the response variable to the predictors.

Much interest centers on understanding the effect of time-varying individual covariates on survival through the Delta. Unfortunately, time-varying individual covariates are particularly difficult to model because the value of the covariate is unknown for undetected individuals (whether due to death or non-detection). Travel times from one site to the next, or river discharge at the time of fish detection are examples of time-varying individual covariates. A variety of ad-hoc approaches have been developed for dealing with missing data, such as imputation of missing data and complete case analysis (where individuals with missing data are excluded; Catchpole 2008). However, some of these approaches can result in biased parameter estimates, especially if the missing covariate value is related to the observation process (Skalski et al. 1993, Abraham and Russell 2004, Catchpole et al. 2008). As recently as 2002, Pollock noted that current software was incapable of modeling time-dependent individual covariates and that he could not find literature that solved the difficulties of time-varying individual covariates in mark-recapture analysis. Also, Diggle et al. (1994) (as discussed in Catchpole et al. [2008]) knew of no well-developed methods for dealing with informative missing data in longitudinal studies. Although an acute problem, some alternatives exist and recent advances have been made allowing the examination of time-varying independent covariates. We will remain open to all of these approaches, since at this time none appear to offer clear advantages.

Although time-varying individual covariates represent significant challenge, we see at least three approaches that could prove successful. First, Lowther (2002) and Catchpole et al. (2008) offered a method of dealing with missing data by factoring the likelihood into a series of conditional likelihoods to make full use of information from individuals with missing covariate data. We see this as a particularly promising approach, as it keeps the analysis within the framework of maximum likelihood estimation. Second, multistate models form a canonical mark-recapture model for individual categorical covariates that change over time (Pollock 2002, Lebreton 2002, White et al. 2006). Multistate models were originally developed to estimate movement probabilities among geographical locations (Brownie et al. 1993, Schwarz et al. 1993), such as in our study where fish may transition from the mainstem Sacramento River into a number of secondary migration routes. However, multistate models are applicable to any discrete state variable with stochastic transitions among states (e.g., breeder and non-breeder, or transition among weight classes). Third, Bayesian modeling frameworks have recently been developed to deal with missing data in a mark-recapture setting with time-varying individual covariates.

For some time-dependent individual covariates, we will incorporate the multistate framework in our analysis. For example, the Panel suggested using a dummy variable regression approach for assigning treatment (e.g., "Gates open" = 1, "Gates closed" = 0) to individual fish. This represents a time-dependent individual covariate since the covariate is updated based on the time of fish arrival at the junction. Undetected fish will have an unknown covariate value, introducing the difficulties described above. Under a multistate framework, however, the treatment may be considered as variable where the transition probability is the probability of a fish arriving at a junction under a given treatment. Here, our transition parameters will estimate (1) the probability of a fish from release *i* arriving under treatment *m*, and (2) conditional on arriving under treatment *m*, the probability of being entrained into one of *s* channels (e.g., DCC, Georgiana Slough, or the Sacramento

River). This approach will allow more flexibility in conducting releases since fish from any given release may arrive at a junction under multiple treatments.

The Panel also suggested that we investigate the effect of back and forth movement on survival: we see the multistate framework as a potential approach to examine this issue. Although not fully developed at this time, we can envision a model with state-dependent survival where a state transition matrix allows for probabilities of moving from a downstream site to an upstream site. However, the number of possible transitions is unbounded and some constraints may need to be built into the model to control the number of parameters and maintain estimable parameters.

Since Pollock's 2002 review of the use of covariates in mark-recapture studies, much progress has been made on Bayesian approaches to modeling the effect of time-dependent individual covariates on survival (Muthukumarana 2007, Bonner and Schwarz 2004, Bonner and Schwarz 2006, Schofield 2007, Gimenez et al. 2007). Indeed, this is the approach used by Muthukumarana et al. (2007) in the paper mentioned by the Panel. In addition, Bonner and Schwarz (2004, 2006) utilized a Bayesian framework to develop a model that incorporated time-dependent individual covariates. Their approach modeled the time-evolution of the individual covariate (body weight) to impute the missing data values for non-observed meadow voles.

At this stage of our study, none of the aforementioned approaches offer clear advantages over another and all have strengths and weaknesses. However, we have outlined a framework and potential analytical methods that will allow us to examine important questions from a range of different angles. Regardless of the specific approach, we will use the method that best fits with our study and the specific nature of the data to understand how important covariates influence survival, detection, and transition probabilities of juvenile Chinook salmon migrating through the Delta.

3.3 Recommendation: The PIs should consider placing a higher priority on understanding the various factors influencing predation intensity on out-migrating salmon as part of the currently proposed study plan.

PI Response: The PI's agree with this recommendation. One component of the overall study will be to capture and surgically implant acoustic transmitters in predatory fish. This component of the study was not addressed in any detail in the study proposal nor in the public presentations to the Panel. In this section, we describe, in detail, our plans to study predatory fish. Our plan is to capture predatory fish, fit them with acoustic tags, then release and monitor them (1) using the acoustic receiver array deployed primarily to monitor acoustic-tagged smolts and (2) through mobile telemetry within the north Delta study area during the entire study period. Although this component of the overall study is not intended to provide a comprehensive evaluation of the predator-prey relationships, we believe tagging and monitoring predatory fish will provide invaluable data for interpreting estimates of acoustic-tagged smolt survival. For example, these data will minimize the potential for false positive detections at the acoustic telemetry receivers and will improve our understanding of predator-prey dynamics (which is basically nil) during the study period (November, 2008 – February, 2009).

Obtaining unbiased survival estimates from the acoustic telemetry receivers requires that false positive detections be removed from the data set. For example, if an acoustic-tagged salmon is consumed by a predator that subsequently swims past and is detected by an acoustic receiver, this detection could be incorrectly identified as a live fish, introducing bias in the route selection and survival estimates. Based on recent data analyses, these circumstances likely occurred during the 2006-2007 pilot study and during the 2007 Vernalis Adaptive Management Program (VAMP) acoustic telemetry study. This issue is one of the greatest challenges facing acoustic telemetry studies in the Delta – our assumption has been that these detections are rare and could be overcome through using greater sample sizes. However, we do not know how often these detections occur and the predation study described here will help address this uncertainty. Additionally, if data collected by the acoustic receiver network are assumed to be characteristic of juvenile salmon behavior, but in actuality represent predatory fish, subsequent computer models based on these data will be in error. The behavioral characteristics of highly migratory predators such as striped bass (which are abundant throughout the region during the study period) are unknown because predatory fish have never been studied in this way before. Therefore, to avoid biasing route selection and survival estimates, we need the ability to discriminate between acoustically tagged juvenile salmon from "self-tagged" predatory fish. Tagging and subsequently monitoring the movements of predatory fish using the existing telemetry network will provide data that can be compared with the movements of acoustic-tagged juvenile salmon.

Furthermore, a fundamental question associated with the survival estimates obtained from this investigation is the stationarity of the predator field and, by association, the stationarity of the survival estimates. If the predators are highly mobile and congregate in different regions in the Delta at different times of the year, then the survival estimates will vary depending on the spatial and temporal variability of the predator fields. We propose to examine the factors that may affect predation rates during the study period (e.g., seasonality, river flow, turbidity, water temperature, the proximity to channel forms [e.g., scour holes] and natural and artificial in-channel structures [e.g., woody debris and docks]), through mobile telemetry efforts. Additionally, as pointed out by the Panel, an added advantage of tagging predatory fish is the ability to empirically confirm predation events that occur when acoustic-tagged predators are detected with a consumed acoustic-tagged salmon.

The original plan was to conduct a relatively small-scale predator study by capturing, tagging, and releasing up to 40 predators and implanting them with acoustic tags. Because of the importance of acquiring better information on predation within the study area, we will attempt to tag and release up to 120 predators, a substantial increase in investment in understanding predatory fish behavior, as was recommended by the Panel.

Two species of predators known to be abundant within the study region will be the focus of this investigation: striped bass (*Morone saxatilis*) and black bass (*Micropterus salmoides*). If other predators, such as Sacramento pikeminnow (*Ptychocheilus grandis*), are abundant in localized areas, these fish will also be tagged. The intent will be to tag the fish in approximately equal numbers between species but will depend on our ability to capture fish. To the extent possible, most fish will be captured, tagged, and released prior to the installation of the acoustic receivers. Unlike the smolt transmitters, which last about three weeks, the larger predator transmitters last several months and, therefore, will provide data on predator movements within the receiver network over the entire study period (November, 2008 – February, 2009).

Tagged predator fish will be released near the original site of capture. Capture sites will focus on areas known or suspected to possess predatory fish and will include some areas where mobile telemetry (discussed below) will be performed. Specific sites are not known at this time, but will likely focus on habitats known to harbor predators (e.g., scour holes and artificial structures) and will not include the large main-stem channels such as the Sacramento River downstream of Cache Slough or the main-stem San Joaquin River. The goal will be to tag predatory fish distributed throughout the north delta region where detections by the network of acoustic receivers is expected to be high, such as near the dense network of hydrophones in the Walnut Grove area. The predatory fish component of this study takes advantage of the large network of 40+ acoustic receivers that will be primarily deployed to study salmon smolts, thus minimizing the additional costs associated with this element.

The PI's have found, through recent studies in the Delta, that mobile telemetry is useful in identifying locations of high predation, anomalies in acoustic tag detections and in deducing fish behavior. One of the principal objectives of this study is to quantify fish survival within specific reaches in the delta (e.g. between telemetry receivers), but not specifically where and how mortality occurs. Mobile telemetry helps fill in the gaps between receivers by locating defecated transmitters. Acoustic tags eaten by predatory fish are defecated intact and remain fully functional until the battery dies. During the 2007 VAMP acoustic telemetry study, for example, 116 motionless transmitters were located at a small site in the lower San Joaquin River near Stockton using mobile telemetry (the causal reasons for the high fish mortality are under investigation by State and federal agencies).

The technique is particularly useful in narrow delta channels where tags are relatively easily detected; however, the effectiveness of mobile telemetry will depend on the specific transmitter repetition rates (which have yet to be determined for this study). Mobile telemetry surveys will be conducted approximately two weeks after each of three proposed tagged fish releases in the narrower north Delta channels where the technique will be most efficient. The area in the vicinity of the Sacramento Regional Wastewater Treatment Plant (SRWTP) outfall on the Sacramento River near the town of Freeport will be included in the surveys. Georgiana Slough will be surveyed in detail because, based on prior telemetry studies, predation in this area appears to be high. The reaches of Sutter, Steamboat, and Miner Slough are largely unstudied for salmon emigration. These reaches are highly relevant to the regional Delta study because operations of the Delta Cross Channel gates affect the amount of flow and fish entrained into these smaller side channels. These reaches will be surveyed during each of the three fish releases.

Data will be subsequently used to assist in interpreting fixed-station receiver data, potentially correct for false positive detections, and provide for an improved understanding of differences in predator versus smolt behavior through the study area. Notably, the 2008 VAMP study plans to monitor 30 acoustic-tagged predators during the release of 1,000 acoustic-tagged smolts this spring; we will apply the knowledge from that study to enhance the NCDRSS this fall and winter.

3.4a Recommendation: Perform a mock analysis to ensure the various components of the project will fit together.

We agree with the Panel regarding the utility of mock analysis, in particular, as a means of making sure that the cascade of information, beginning with the data and extending to models and between models, is done correctly without any glaring gaps in the informational needs of any of the analysis tools. To a large extent we have completed a number of mock analyses, (although we didn't present these results to the Panel) for the very reasons the panelists outline in their comments and plan to continue to make sure all of the tools are able to exchange information. In particular, we plan to conduct more detailed mock analyses using numerical "listening" stations within the Resource Management Associates 2-dimension (RMA-2D) modeling framework to inform and refine our release strategies in the field.

3.4b Recommendation: Standardize, to the level that is practicable, the formulation and testing of the PTMs (Particle Tracking Models).

PI Response: The purpose of hydrodynamic modeling is to provide a framework for interpreting the observed salmon detection histories/tracks, and to provide velocity fields to be used for individual-based modeling of juvenile salmon outmigration. Because of the large range of scales relevant to both the data analysis and the individual based modeling, two separate hydrodynamic models will be utilized; SI3D will be used to model water velocities in three dimension at relatively fine spatial and temporal scales over a 60 mile reach of the Sacramento River from the city of Sacramento to Ryde, while the RMA-2D model will be used to model water velocities at coarser temporal and spatial scales throughout the entire Delta. A variety of particle tracking exercises will be undertaken using the output data from both of these models, and as a result, care will be given to ensure that particle tracking models are formulated and implemented consistently between SI3D and RMA, and that the procedures used to validate their implementation produce meaningful metrics that can be compared across scales, and generalized to the extent that any similar model for an overlapping domain element can be similarly evaluated (e.g., DSM2). Full documentation of the particle tracking routines and the outcomes of a rigorous set of tests are specific deliverables of the numerical modeling contracts. In particular, RMA is working with Dr. Ed Gross of Bay Modeling, Inc, to develop a series of standardized particle tracking tests. As part of this work, explicit comparison between scalar transport and particle tracking results will be conducted and documented. The results of particle tracking results were presented at the latest meeting of CWMEF by John DeGeorge of RMA on 2/26/2008.

For clarity, it is important to state that two types of modeling exercises will be undertaken that could be referred to as "particle tracking" and it is necessary to differentiate between the methods used to implement, calibrate, and validate each type of model. First, true Lagrangian particle tracking algorithms will be used to simulate the movement of neutrally buoyant water particles released at any *x,y,z,t* position within a model's simulated spatial/temporal domain. These algorithms, and their associated particle release and accounting methods, will be referred to as Lagrangian Particle Tracking (LPT) models. Secondly, algorithms will be implemented to simulate the movement of an individual juvenile Chinook salmon released at any *x,y,z,t* position within a models simulated spatial/temporal domain, these algorithms, and their associated parameterization, release, and accounting methods will be referred to as an Individual Based Models (IBM) for juvenile salmon.

The LPTs using SI3D and RMA model generated velocity fields were developed separately and independently. The SI3D LPT is implemented within the USGS post processing software, GR (http://ca.water.usgs.gov/program/sfbay/gr/), based on a true Lagrangian transport solution, which is similar in formulation to that used by Dunsbergen and Stelling (1993), while the RMA LPT is under development (a presentation of the status of this effort was given during the public presentations to the Panel). Standardized tests will be run for each model to look for discrepancies between model results (e.g. different travel time from Sacramento to Ryde), and, results that are physically incorrect (e.g., mass not conserved, etc.).

First, very large numbers of particles will be released continuously for long time periods in the Sacramento River cross-section near Sacramento, using a release strategy that distributes the particles uniformly within the river cross section. After a sufficient number of particles have been released, the distribution of particles entering each downstream junction in the test area will be compared to the distribution of flow entering each junction, and these comparisons will be stored as a function of time for each particle tracking model (PTM). This exercise will be carried out for overlapping temporal and spatial regions and time-series of the comparison between particle distribution and flow distribution for each junction using each PTM. Time series from each model will be developed using aggregate statistical metrics which will then be compared at similar locations with the model domain. This exercise will serve as both a validation of the individual PTM models ability to conserve mass over large scales, and, aggregate statistics from the process can serve as standardized metrics to use in comparing these and other PTM model's within overlapping domains. For example, the total integrated squared error of each PTM model (integrated over time, integrated across all junctions) for the test domain would provide a single number that could be used to compare the various PTM formulations.

In order to obtain outcome-oriented comparison metrics that apply directly to the North Delta outmigration study goals, a variety of Lagrangian release tests will be performed using each model and the results will be compared. For example, comparisons between the distribution of Lagrangian travel times for particles transiting common reaches for common time periods. Comparisons between travel time distributions can be reduced to a set of single-number metrics, such as; (1) the probability that each model's travel time distributions are drawn from different populations, (2) first and second distribution moments, (3) distribution skew and shape parameters, and (4) integrated difference metrics. Higher order comparisons between PTM models will be obtained by releasing large numbers of particles in the upper portion of the water column, and quantifying the temporally aggregated 2-D cross-sectional distribution of these particles in downstream bends and junctions, using the techniques similar to those illustrated in Horn and Blake, 2003. Again, comparisons between aggregated cross-sectional distributions can be reduced to sets of single number metrics, including the distribution of 1st and 2nd moments, and integrated error statistics. The advantage of using Lagrangian-based metrics is they provide direct assessments of the models ability to reproduce hydrodynamic process, and, most importantly, behavior-physical processes interactions that are relevant to the problem of interpreting and predicting juvenile fish movements. In addition, all of the tests described for the PTM models can be easily used to benchmark any number of complimentary/competing PTMs that have overlapping spatial and temporal domains, and standard test conditions and data sets could be established for formal evaluation of all relevant PTMs for a given Delta region.

Tests performed on the IBM models will fall into two categories: (1) tests used to compare IBM models to field data during model development and calibration, and (2) tests used to compare the performance of IBM formulations using both the Si3D and RMA formulations to field data and to each other (e.g. the validation step). Because the parent IBM will be developed using SI3D output files, development and calibration tests will be confined to Matlab and Java programming environments. Generally, comparisons between each SI3D IBM version and tag data will be made at the junction and the reach scale, using appropriate outcome-oriented metrics within stochastic and Monte Carlo statistical frameworks. At all scales, the numeric tests used will be designed to answer the same four validation questions: (1) how well does the IBM reproduce the observed spatial distributions of fish within the river cross section at key locations in the 3D arrays, (2) how well does the IBM reproduce the observed X-Y plane 2D spatial distributions of fish in the 3D arrays, (3) how well does the IBM reproduce the observed route selection histories for each measured junction, and, 4) how well does the IBM reproduce the observed travel time patterns. Questions 1 and 2 will be addressed by testing the IBM at fine scales against 3D tag tracking data collected in Clarksburg Bend, 2006-2007 and Walnut Grove 2008-2009, while Questions 3 and 4 will be tested by evaluating the IBM performance in the North Delta region against the acoustic telemetry receiver data. Tests against the receiver data will be confined to the North Delta because the SI3D domain will extend from the city of Sacramento to Ryde while the distribution tests will be confined to areas within the Clarksburg Bend 2006-2007 tracking arrays and the Walnut Grove 2008-2009 tracking arrays.

IBM model formulation and calibration will be performed in a cyclic process with three repeating steps: 1) develop behavior rules to implement within the IBM framework through detailed examination of all available juvenile salmon outmigration data (Walnut Grove 2001/2 and 2003/4, Clarksburg Bend 2006/7, North Delta 2008/9) and, 2) calibrate behavior rules, and test calibrated formulation against real data to answer the 4 validation questions, and 3) compare calibrated model tracks to real tracks at a variety of scales and refine behavioral rules. Formal comparisons between the IBM model(s) and actual fish tracks will take place during step 2 to answer the four questions outlined above, while the comparisons in step 3 will be focused on higher-order comparisons (e.g., pattern matching, behavioral classification matching, etc), and will be for analytical and exploratory purposes to drive model refinement.

The PI's have already begun this cyclic process and have developed an initial IBM framework, and including a set of initial behavioral rules as described in step 1, so that the calibration and evaluation step can begin as new data becomes available. The IBM is constructed using a stochastic perspective; every parameter that is a driver in the biological portion of the IBM will be drawn from probability distributions, some parameters will be fixed at the creation of a given fish surrogate and remain fixed for the surrogate's "life", while others will be set at the beginning of each surrogate's decision cycle. This approach is designed to reproduce real-world variability at a variety of population and spatial scales: intra-population, intra-life history, intra-cohort, and in-river turbulent scales. Whenever appropriate, behavioral rules will be partially based on size, smoltification, and life history variables that will be randomly set for each fish from parameter distributions that match the study fish. All other parameter distributions will be based on multi shape-parameter probability distributions (e.g., the gamma distribution), with each distribution's shape parameters fit during the calibration stage. Thus, the calibration process in stage 2 of the model development cycle will use non-linear optimization and machine learning techniques to determine the shape-parameters for each of the behavior-rule parameter distributions. Initial implementations of this process will use genetic algorithms to drive the calibration process by releasing large numbers of simulated fish at multiple locations within the domain, and evaluating these releases using fitness functions that integrate aggregate metrics for Lagrangian tests similar to those described for PTM testing. At the outset of the model development cycle the entire set of released tag codes will be randomly divided into an A, B, and C groups, with the A group used for automated model calibration, the B group used for the evaluation of calibrations during development, and the C group used for post-development validation of the SI3D and RMA IBMs.

The tests used to validate the performance of the IBM models using the C group tag data will be conceptually similar to the tests described for the comparison between PTM models. The first IBM model developed within SI3D/GR will be implemented in RMA in a formulation that is consistent with that model's numerics. The process of comparing the performance of the two implemented IBMs (SI3D and RMA) is the direct analog to the process described for PTMs, and will be performed using similar metrics; comparing predicted and measured fish apportionment for each junction over time across each model, comparing predicted and measured fish travel time metrics for test segments over time for each model, and comparing predicted and measured fish cross-sectional distributions (within the 3D arrays) over time for each model. For all of these tests, sets of single-number metrics will be calculated for the RMA IBM predictions, the SI3D IBM predictions, and the measured tag data. Thus, dimensional single-number metrics will be generated that can be used to compare the performance between each PTM model and actual fish data. Analysis of these tests and metrics will be written up in a calibration and validation report for each model, and the datasets and input-output files used to run the test conditions will be archived and submitted with the report.

3.4c Recommendation: Apply formal methods of evaluating model quality and success

We agree with the Panel: formal metrics of model performance need to be used in data model comparisons. In fact, one of the PI's (Burau) discussed many of the model-data comparison approaches discussed in Warner et al., 2005 with the lead author before he left the Bay/Delta research community to pursue work with the U.S.G.S. Coastal and Marine Geology Program at Woods Hole. Also, although not presented, RMA has a very nice calibration document that is available at http://baydeltaoffice.water.ca.gov/ndelta/frankstract/documents/(8)RMA-Calibration%20Report.pdf , which includes a number of formal model performance metrics.

3.5 Recommendation: The PIs (and funding agencies) should have realistic expectations as to outcome of current study.

PI response: The PI's and MT have an unusually collaborative relationship that attempts to achieve a balance between the management issues and scientific constraints. We meet frequently to discuss problems, concerns and priorities, which is fostered, in part, by the "directed action" nature of the funding. One of the disadvantages of the RFP process, at least in the way it has been executed in CALFED, is the management issues (e.g. the managers) are somewhat disconnected from the science (e.g. scientists) from the time the contract is executed to the time the final products are delivered. Not so in this effort; the management team is an integral part of the science team and visa-versa. As such, the MT and PI's believe we are approaching this problem with "eyes wide open" and, because of this, do have reasonable expectations, although these expectations may not have been clearly articulated to the Panel. We know, for example, that any management model developed as part of this initial effort will be based on data collected under a restricted set of circumstances. However, at least this model will be based on data, with all of the appropriate caveats given. The primary reason we presented the management tool to the Panel, and to our MT colleagues, was to make sure we are all very clear on what the end goal is. The GUI presented actually took very little time to produce using the Labview software. This project is not about publishing a bunch of papers, although this is certainly an essential part of the process, this study is about finding ways to better manage the biological and water resources in this system, and focusing on tools that are useful to managers. Moreover, in a study as complicated as this, it could be very easy to lose track of the ultimate objective. Thus, our intent is to develop a management tool, to the extent we can, with the data that will be available when the field work is complete. The management model developed as part of this study plan will be a starting point effort whose applicability will be somewhat limited for the reasons the Panel suggests (but notably better than anything else on hand). We expect the development of salmon outmigration models to follow a similar path to the development of hydrodynamic models that began in the early 1990's. Initially, the early hydrodynamic models could only marginally predict water level variations - accurate simulations of the transport of water quality parameters, such as salinity, were not very good (at least by today's standards). Now, every model worth discussing can very accurately predict water levels, most can accurately predict discharges and some can predict salinity variations. We believe that if a consistent effort is applied to the problem of salmon outmigration, like it was with the development of the numerical hydrodynamic models, we can expect similar improvements in predictive capability in the salmon outmigration models as more data are collected and refinements are made. We expect that through the process of building this initial model we will gain insights into its inadequacies, which will then allow us to identify information gaps so that future investigations can be appropriately focused. From a purely scientific perspective, models that perfectly represent reality are not very useful because they don't tell us what we need to learn. In short, the MT and PI's concur completely and emphatically with the Panel "the proposed study [should] focus on the goal of developing the experimental data needed to fully understand the important factors affecting the survival of salmon outmigrants as they pass through the Delta. " This is our focus – this is evident in the capabilities of the PI's on this research team, the considerable quantity of high-tech equipment, and a thorough consideration of the study plan.

3.6 Recommendation: The PIs should incorporate an effective plan of cooperation and coordination with the ongoing monitoring programs of the IEP.

Although not apparent to the Panel, this project has been, and is, collaborating with IEP scientists (e.g. Pat Brandes, Paul Cadrett, USFWS) including coordinating the CWT releases associated with ongoing "Delta Action 8" experiments and with the trawling efforts conducted above the city of Sacramento that assess the outmigration of run-of-the-river fish. We've also been collaborating with ongoing CALFED investigations, including Pete Klimley and Steve Lindley et al.'s *Survival and Migratory Pattern of Central Valley Juvenile Salmonids* study, which is using acoustic (VEMCO) tags to monitor salmon outmigration from the upper watershed to the Golden Gate. We have plans to officially brief the IEP management team regarding this study in May, although many members of the management team have already attended one or more of the various CALFED sponsored briefings on this study. With the concurrence of the IEP management team, we will also likely brief the IEP coordinators this spring/summer. The lead PI (Burau) has been a long time member of the IEP and has kept the IEP "in the loop" throughout the testing of the equipment, during the pilot study investigations and during the development of the study plan.

3.7 Recommendation: An advisory panel should be formed to provide ongoing feedback and review to the study as it proceeds. In particular, the Panel thinks that the injection of more salmon biology and biological advice would help the implementation of the study and the subsequent interpretation of the results.

PI Response: The proposal and the presentation to the Panel failed to demonstrate the level of "expertise" that is represented on the research team. While the team is open to advice from other qualified scientists, the Panel should be informed of the level of expertise that is currently on the research team. The scientists (Noah Adams, Chris Holbrook, and Russell Perry) have 35 years of collective experience in the design, implementation, and analysis of juvenile salmon passage, survival, and behavior studies. These studies have ranged in scope from as few as 200 tagged fish to as many as 40,000 tagged fish released in a single outmigration period. They have utilized active telemetry technology since its infancy in 1994, when they lead one of the earliest studies on juvenile salmon behavior (Adams et al. 1996). Since that time they have been instrumental in pushing the technology forward to gather previously unattainable information on relatively small fish (< 110 mm fork length). These scientists make up a majority of the handful of researchers that have successfully applied miniature acoustic telemetry technology to obtain three-dimensional behavioral data on juvenile salmonids. Collectively, they have authored over 20 peer-reviewed manuscripts that are published in mainstream journals, completed more than 50 reports of scientific findings to funding agencies, and have made more than 100 presentations at international and national symposiums, workshops, and technical advisory meetings. They are considered experts in the field of telemetry and have provided technical assistance to dozens of federal and state agencies, private consulting firms, Tribal organizations, as well as to scientists from five countries. These investigators have developed and implemented over 40 studies on juvenile passage, survival and behavior with associated budgets in excess of $42,000,000. For more detailed information, the researcher's Curriculum Vitae are available upon request. Nonetheless, we expect to present preliminary findings to the management agencies, including local salmon experts, a process we have engaged in throughout the development of this study.

3.8 Recommendation: The PIs should continue analysis of the pilot study

PI response: DWR has contracted with USBR and USGS to continue this analysis.

3.9a Recommendation: The proposed work must have submission of peer-reviewed publications as an outcome. These "deliverables" should be spelled out in whatever contract documents are developed between the PIs and the funding agency, with full payment contingent on provision of the deliverables in a timely manner.

MT Response: The DWR contract with USGS includes several reports and journal ready publications as deliverables. After the data is collected and analyzed, if warranted, work for peer-reviewed journal articles may be appended to this contract or under an RFP as suggested by the Panel. As this study is one of several in the region using similar equipment and methods, the RFP approach may be the most appropriate to ensure that a comprehensive review of the data and technology is properly addressed. We believe the combination of the documents funded through the current contract and funding of peer reviewed documents through a RFP will provide valuable information/"best available science" for both interim and long-term planning activities in the Delta.

3.9b Recommendation (to funding agencies): There must be adequate support over sufficient time to develop quality publications from the proposed work.

MT Response: Please see the response to comment 3.9a above. DWR has contracted for the analysis work and the report writing for two years beyond the study period. A need for additional time and funding can be assessed once the data is collected and analyzed.

3.10 Recommendation (to CALFED): Following completion of the study (including draft publications), the CALFED Science program in collaboration with the IEP agencies should issue an RFP soliciting proposals for further analysis of the data.

MT Response: DWR supports the Panel recommendation to issue an RFP for further analysis of the data and will also make the data readily available for those wanting to pursue independent analysis or as part of other studies in the region using similar equipment and methods. DWR wants the data and any resulting analysis openly available and this would be an acceptable way to see that it is studied in a thorough yet meaningful way.

4. Summary and final recommendation

4.1 Overall view

The Panel suggests that the proposed levels of effort for the two types of experiment should be reconsidered to optimize the use of experimental and tagged fish resources.

PI response: We reconsidered the levels of effort and offer the following changes, as described below.

4.1a. Route selection

PI response: We have decided, in part based on the Panel recommendations, to use roughly 1,350 of the smaller "S-tags" for the junction experiments specifically to "better represent the size and life stage of outmigrating winter-run salmon." These smaller tags will also allow us to compare survival of the smaller fish in the landward portions of the acoustic telemetry network. We plan to conduct a series of tag life experiments with all models of tags used in the experiment so that we don't bias the survival estimates in the seaward reaches of the delta.

4.1b. Overall survival
PI response: We agree once again with the Panel, in particular with regard to the importance of predation by fish in the overall survival of salmon outmigrants and have added an additional ~100 tags to the proposed 40 tags to study predatory fish behavior. Please see response to comment 3.3 for additional details on our expanded predatory monitoring.

4.2 Final recommendation
PI response: Thank you. Multiple years of this type of data would indeed be useful, however, at this point, the PI's feel that we need to conduct these large-scale acoustic telemetry experiments in an adaptive management framework. We need to fully assess the level of effort associated with this technology by doing it at least once and then determine the usefulness of the data before we embark on a multi-year program. Moreover, conducting annual large scale field investigations is one of the primary reasons there is a lack of published results within the Bay/Delta research community. Thus, the PI's expect to take at least a year off from the field to figure out what our data are telling us and to publish the results before we conduct another large-scale investigation.

MT Response: DWR agrees with the panel that continuing these studies for several years may be worth the investment. However, as the panel noted there are many uncertainties with the proposed approach and to embark on multiple years without some review and adaptation as described above does not seem prudent. As an example, the acoustic study used during VAMP last year has been significantly altered from the initial study plan based on information obtained during the first year of study and the pilot study conducted by the PIs.

5. Postscript

MT response: The Panel noted that further discussion is needed in balancing between directed activities and projects selected by an open solicitation process. The North/Central Delta Regional Salmon Out-migration Study is an unprecedented study in the Delta and we agree this is an example requiring a focused proposal. In addition, DWR has every confidence in the capability of USGS as they have the necessary experience gained from the pilot study as well as similar work performed in the Columbia River. This study includes involvement from USFWS, Natural Resource Scientists, and DWR. In addition, we have and will continue to coordinate with other agencies, scientists, and stakeholders, including the Interagency Ecological Program.

PI Response: The question of whether this study should have been best executed as an RFP or a directed action is a tough one; both approaches have strengths and weaknesses. In the end, the intensity of the field work and the state of the art nature of equipment to be used in this study tipped the scales in favor of using a directed action for this study. Firstly, because of the number of cutting-edge technologies that needed to be tested in this system an incremental, test-the-equipment-as-you-go approach was used, which would have been problematic using the RFP process. We didn't even propose this experiment until: (1) the equipment was fully tested and (2) we had the experience using this equipment in the Delta. Previous DCC investigations were conducted with the equipment and methodologies we had on hand rather than with the equipment and methodologies that we needed. In the final analysis, the directed action approach allowed us to take the time to fully develop and test the equipment before we even proposed a full scale study. If these new tools had not met the experimental needs, the full study would not have been proposed.

Finally, there are very few groups in the Bay/Delta that have the field resources necessary to pull off a study of this magnitude. In fact, this study will sorely stretch the combined field capabilities of the USGS-CAWSC, USGS-CRRL and UFWS field crews. We know of no academic institutions, singly or in combination, that have the resources (boats, trained operators, field technicians, etc.) necessary to pull off the field aspects of this effort. Furthermore, the idea of having students running around in the Delta for four months in the winter (during nasty weather and high water) with little experience seems a bit problematic, if not outright dangerous. In the end, we concur with the Panel when they wrote "*the panel thinks the study data will provide a potential goldmine for further analysis by scientists and engineers. The panel feels strongly that the best way to proceed would be to use a peer-review competition, like the competition that CALFED has used to fund its own science projects, to select a team or teams to continue working with the data*." The focus of this study (and indeed the selection of the study team members) is to collect foundational data sets that can be used by anybody interested in understanding the mechanisms that control salmon survival and the movements of predatory fish in the delta.

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