Review of North Delta Salmon Out-migration Study
January 23, 2008

1. Introduction

This document is a review of the North Delta Salmon Out-Migration Study (NDSOS) proposed to the California Department of Water Resources (DWR) by a group of PIs lead by Jon Burau of the USGS. To carry out this review, the CALFED Science program, acting at the request of DWR and the PIs, convened a panel[1] that was given a substantial written proposal describing the study. In addition to the written proposal, the PIs gave a series of presentations to a majority of the panel members at a public workshop held on January 10, 2008. The presentations provided many details about the proposed study that were not included in the written proposal. The panel was charged by CALFED to:

> ".... make recommendations concerning, and oversee incorporation of modifications to, the proposed study to ensure that, when funded, executed, and analyzed, the proposed investigation will provide the best-available science when characterizing the hydrodynamics and movement of out-migrating salmon smolts in the north Delta region in response to several alternate regional configurations."

This report is the panel's response to that charge. In the sections that follow, we start by describing those aspects of the proposal that the panel found would work well or were strong positives. We follow this with a critique of perceived shortcomings of the proposal and a set of recommendations for possible changes to the proposed work that would improve the proposed study. These recommendations were based on the information in the written proposal provided to the panel and on the presentations made at the public workshop.

2. Positive aspects of proposal

Firstly, the panel was impressed by the overall objective of carrying out coupled biological and physical experiments aimed at understanding the interplay between fish behavior and hydrodynamics as applied to a very strategic question about vulnerability of juvenile salmon to mortality as a function of natural and anthropogenic conditions in the Delta. The panel thought that the simple management model mixing salmon populations and flows was an excellent *conceptual* model[2], upon which much of the larger, detailed framework of the study could be built. As argued convincingly in the proposal, the behavior of salmon smolts near junctions, like that of the Sacramento River and the Delta Cross Channel (DCC), and the hydrodynamics of such junctions, may substantially influence route selection, and thus the overall success of outmigrating young salmon through the Delta into San Francisco Bay and ultimately to the Pacific Ocean. This information can potentially be used to guide current operations of the system so as to maximize smolt survival and to design diversion facilities so as to minimize entrainment. Thus, the topic of proposed study is most timely and is likely to be of high value to the State of California, easily justifying the substantial price tag this project carries.

Secondly, the PIs are to be commended in the way they have systematically worked over the past few years to develop needed data collection and modeling tools, analyze preliminary

---

[1] William Bennett (UC Davis), Richard Denton (consultant, Oakland, CA), Stephen Monismith (Stanford University), Ken Newman (USFWS), Dennis Ronsdorf (USGS), Kenny Rose (LSU), and Charles ('Si') Simenstad (University of Washington)

[2] Note discussion in §3.5 where the limitations of this model as a quantitative management tool are discussed.

data, and (perhaps most importantly) assemble the expertise needed and the capability to carry out such a large scale and complex study. A large scale study as that proposed is needed in order to address the fundamental questions of fish behavior-hydrodynamics interactions. Indeed, when properly analyzed and written up, the preliminary studies carried out over the past few years (e.g., the Clarksburg Bend experiment) will make a significant contribution to the field of eco-hydrology.

The proposed Skalski-CJS procedure for estimating route selection probabilities and reach specific survival probabilities using the acoustic tag recapture data will be an excellent start on the data analysis. The methodology appears to have been applied successfully to the data from the 2006-2007 North Delta pilot study, and should be a good template for initial analyses of the NDSOS study data. Relatedly, the *a priori* statistical analyses (i.e., power analyses) carried out to determine the number of fish that must be tagged to obtain desired levels of statistical confidence in the results (e.g., flow-dependent survival) is well thought out[3] , with the team's statistician having considered several key components of the survival modeling problem in particular, and highly valuable.

The proposed hydrodynamics work, and the associated team of PIs, is of very high quality. The observational plan, which is very thoroughly worked out, would make excellent use of modern tools of estuarine and riverine hydrodynamics research. The data collection would also advance the field through innovative use of autonomous survey vehicles and the novel application of HF radars (CODAR). The panel had difficulty finding anything to criticize in any of the hydrodynamics aspects of the proposed work, although we do make a few small suggestions below. Moreover, the USGS researchers involved are *the* experts on the hydrodynamics of the Delta, and should be expected to do a sterling job on this aspect of the project.

The modeling work proposed is also state of the art and represents a needed synthesis of practical, currently available engineering tools. The RMA 2D model is capable of modeling the larger spatial and temporal scales needed to represent particle transport and dispersion on the scale of the Delta, while the three dimensional code (SI3D) will be used to model flow details at critical locations like the DCC. Like the observational work, the modeling group represents a nice blend of experience at modeling the Delta (the RMA team) and experience with advanced three-dimensional modeling to elucidate flow physics (Rueda). Overall, the modelers are all skilled and careful practitioners of the art of numerical modeling and we expect that they will produce high quality, useful results that are needed to help interpret field observations and to translate those observations into information that can be used to help manage Delta hydrodynamics for environmental purposes.

As already discussed, the statistical analyses carried out to determine the number of fish that need to be released to ensure statistical confidence in the results are cutting edge and highly valuable (Perry).

In summary, the PIs have proposed a study that is a scientifically laudable and is state-of-the science in blending cutting edge hydrodynamics and fish observational technologies. The statistical tools that have been employed to design the study, and that will be used to analyze the data once a full set is collected, are a good blend of state-of- the-science methods while still being highly practicable and relevant to management issues. Most importantly, the project shows

[3] With the caveat of replication discussed in detail in §3.1a

a degree of integration of disparate elements that is needed to understand complex questions of physics-biology interactions, yet this integration is rarely seen in practice.

Finally, the panel wishes to thank the PIs for the well written proposal and the clear presentations that have enabled us to gain a fairly detailed idea of what is planned for this project and thus to make, what we believe, is a relatively well informed critique.

3. Recommendations

Below we list a series of recommendations based on some fundamental weaknesses in the overall concept and experimental design. These are not listed in any order of priority, although the first three related to the experimental design are clearly of very high importance because they determine the quality of the data that will then be used by the other aspects of the study.

3.1 Recommendation: Re-think the experimental design

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

One of the primary objectives of the proposed NDSOS study is to understand how DCC gate position affects route selection probabilities, in particular, the probability that a juvenile salmon out-migrating down the Sacramento River enters the central Delta, either through the DCC or Georgiana Slough. Four treatments related to DCC gate position are proposed: (I) DCC open day and night, (II) DCC closed day and night, (III) DCC open during the day and closed at night, and (IV) DCC partially open day and night. Four groups of approximately 1100 tagged fish will be released (by Old Sacramento and in Georgiana Slough), on November 9, December 7, January 11, and February 1, for each of treatments I, II, III, and IV.

Such a simultaneous release of multiple fish implies that the experimental unit is a group of fish, not individual fish, thus there is just one replicate per treatment. At least two replicates are required in order to estimate the standard error of the treatment effect, and subsequently determine the variation in the treatment effect and three replicates is usually considered the scientific minimum. Without multiple replicates, one cannot statistically determine whether or not observed differences in response variables (e.g., route selection probabilities) are real differences or just sampling variation. For example, suppose that the actual fraction of fish (that have survived from Old Sacramento to DCC) entering the central Delta under treatment I is 0.7, and the fraction that enter the central Delta under treatment II is 0.5. Thus a difference of 0.2 has been observed. If two other releases were made, the difference will likely be something other than 0.2. However, without replication there is no way of determining how much variation there is in this difference and statistical hypothesis tests cannot be carried out and confidence intervals for the average difference cannot be constructed. Note that, in practice, the actual fractions entering will be estimated with error, and this estimation error can be calculated with the Skalski-CJS model, but this error is not the same as the sampling variation between releases of fish.

To estimate the treatment effects in a classical statistical experiment design setting, the tagged fish (or groups of tagged fish) would be randomly assigned to one of the four treatments and each fish's route selection would be observed. For example, take a fish (or group of fish) and randomly select treatment I, II, III, or IV, set the DCC gate accordingly, release the fish, and see what happens. Repeat with a second fish (or group of fish) and so on. In actuality, such a design cannot be conducted for multiple reasons, including: (1) the DCC gate must be closed when Sacramento River flows exceed 25,000 cfs; (2) the operation of the gate on such a random basis would not be approved by authorities; and, (3) the historical operation of the gate has included closure during January and February. These factors severely complicate the experiment design because of potential confounding between flows and fish size. Flows tend to increase from November through January and fish are growing larger over this time interval; flows and fish size may affect the route selection probabilities.

To deal with these multiple issues of lack of replication and potential confounding of flow and fish size, we make the following design and analysis suggestions: (i) consider fewer treatments, perhaps just I and II; (ii) each treatment have at least two, and preferably three, "replicates" (e.g., close the gates during the first two weeks of November, open the gates during the last two weeks of November, close them during the first two weeks of December, open them during the last two weeks of December, and then vary gate position to the degree possible during January and February); (iii) within a treatment period, release individual fish or small groups of fish throughout the entire period; and, (iv) include flow at the DCC junction and fish size as covariates in a sub-model for route selection probabilities, and possibly in the sub-models for survival probabilities (discussed below). Gate position would, in effect, become a covariate, and would allow for the case when slower moving fish were released when the gate was in one position but that actually reach the DCC when the gate was in another position.

With this design, the experimental unit becomes the individual fish or small group of fish released at a single point in time, thus increasing the number of replicates. . The analysis procedure is more similar to a regression analysis than an analysis of variance for treatment effects.

We note that this proposed design is straddles the line between a completely randomized experiment and an observational study in that complete randomization of treatments (I or II) will not be done; e.g., treatment I cannot be applied with flows exceeding 25,000 cfs. We are also conscious of the potential problem of pseudo-replication that could be inherent to this our defining a single fish or small group of released fish as an experimental unit because of the lack of randomization to multiple treatments (DCC gate positions) within a treatment period. However, if flow does affect route selection probability (or survival) and if within a treatment period "substantial" variation in flow is observed, then more information will be gathered on the effect of flow for a given gate position. Conversely, if all fish within a treatment period are released simultaneously, then the flows experienced will likely be much the same for all fish and flow could be highly confounded with gate position.

Note that the two experiments, gates open and gates closed, bookend the range of gate positions originally proposed by the PIs. The PIs have previously determined that closing the DCC has a small effect on the flows in the vicinity of the Sutter and Steamboat Slough junctions, but this is expected to only have a very small effect on route selection and survival in this area. Future experiments with other DCC gate operations (night time closing only, gates half open, etc.) could be carried out locally with releases just downstream of Steamboat Slough, without the need to monitor route selection and survival over the whole North Delta area.

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

If the proposal was not contingent on its applicability to ESA listed at-risk salmon populations in the watershed, and was designed more as a basic test of the technical ability to track fish relative to the physics of their migratory pathways through the delta, the use of hatchery fish would not be such a major issue and the application of these technologies and analyses to salmon "smolts" (see above) would be entirely appropriate. However, both the stated premise and the impetus for the study is the applicability of the results to at-risk Chinook stocks. Thus, how well the released fish represent natural fish of the stocks of concern is of utmost importance.

The PIs acknowledge that a host of explicit and implicit assumptions apply to the proposed study and they state several assumptions in the proposal (p. 53 General assumptions associated with this approach). We believe the proposal violates to an unknown degree the very first, and perhaps most critical, assumption of a mark-recapture survival model "the tagged individuals are representative of the population of interest" (Proposal p. 49). The proposal needs to acknowledge that hatchery fish likely do violate this assumption. Hatchery fish tend to have a different physiological state compared to natural or actively migrating fish even of similar size because of a different disposition (e.g., migration timing, water depth, schooling, velocity and/temperature preference/avoidance) to migrate, and different abilities or behaviors to avoid predation. Significantly smaller fish, which the natural Chinook stocks at risk are during their outmigration, poses even greater likelihood of different physiological states and behavior. The panel certainly recognizes that surrogate fish that more fully meet the assumptions may not be readily available at the times needed by the study, and of the limitations of the tagging methodology, but use of surrogates raises the question of the applicability of results based on hatchery fish for small, sub-yearling Chinook salmon. The question also arises as to whether the "times needed by the study" represent the conditions that pose the greatest mortality to the Chinook stocks in question. This additionally poses the question of whether there ways to address this issue using other, more appropriate tagging methodologies and fish without essentially having to do an entire second, equally complex, study.

Furthermore, an implicit assumption is that "physical factors, such as river inputs, current speeds, turbidity, and solar radiation are first order drivers of the outmigration process", while "biotic factors, such as species, stock (e.g., fall-run versus spring-run), life history stage, degree of smoltification, parental origin (e.g., hatchery or wild), size of juveniles, location (e.g., distance from ocean), food availability, and non-stationary predator fields are second order processes that can be 'layered on,' or taken into account, after impacts of the first order processes are fully investigated." The obvious question is: "How can you investigate the importance of the important biotic factors if your entire initial baseline for understanding the patterns of juvenile salmon behavior, and the associated modeling, is based on inappropriate test animals?" For example, there is evidence that migration rates of juvenile yearling Chinook salmon may not be significantly different between day and night (Beeman and Maule 2006). If the results from the DCC pilot study indicate a strong diel pattern of migration with juvenile Chinook salmon holding near shore, is it possible that the results are due to the use of fish of hatchery origin which are known to be more prone to hold during the day? Similarly, does the outmigration period of late-fall run salmon smolts properly coincide with outmigration of winter-run Chinook salmon fry? As will be discussed later, the study team would greatly benefit from inclusion of, or advice from, scientists with expertise on salmon biology and behavior.

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.

The proposal lacks sufficient detail on the biological aspects of the experimental design. Examples of details that could be important are:

(1) What will be the history of the juvenile Chinook obtained from the Coleman National Fish Hatchery?
(2) What will be the fish target size?
(3) Will there be any stratification of fish size within and among releases? and,
(4) Will the releases occur coincident with or avoiding co-occurring downstream migrants?

We have two primary concerns about the size of fish proposed for tagging and how representative they will be of natural migrants. The first is related to the population migrating during the winter months of this study and the second concern is about the complex life history of the Chinook salmon runs of interest. First, if the investigators use the limit of a maximum tag to body weight of 5%, then, based on 2006 data, about 75% of the hatchery Chinook salmon population from Coleman National Fish Hatchery could be tagged. However, if a smaller 0.65 g tag is used, then 94% of the hatchery fish could be tagged. Tag weight is usually related to tradeoffs about battery size, pulse rate, and required tag life. The thought process and logic used by the PIs concerning these tradeoffs was unclear. Given the importance of these decisions, clear documentation of the decision-making process should be part of the study design. Furthermore, because the 3D (route selection) studies and survival studies could use tags with very different specifications, these potentially competing needs should be discussed and documented.

To re-emphasize our primary concern, the proposal appears to be designed to most specifically address "how abiotic factors and behavioral responses control the outmigration of juvenile salmon in the north, central and western Delta" with an emphasis on juvenile Chinook that have suffered the greatest declines (i.e., winter-run and spring-run Chinook). However, the proposed methodology is potentially only marginally applicable to some outmigrants of these endangered and threatened populations because of the restriction to much larger fish in order to accommodate the acoustic transmitters. Most of the acoustic tag applications with which we are familiar are constrained to juvenile salmon that are at best >90mm FL, and many comparable scientific fish tracking studies involving juvenile Chinook will not implant tags in fish <120 mm FL. Although the PIs propose to use 0.65g tags (5% of fish weight at 104 mm) in the proposal, a 1.0g tag (5% of fish weight at 120 mm) was proposed for use during the presentations at the workshop. This conflicting information should be explained.

Review of Brandes and McLain's (2001)[4] revealed that most Chinook salmon fish in the Delta study area were 100 to 150 mm during the winter months when this study is proposed, but may not represent components of the population that appear to be at greatest risk. However,

---

[4] Brandes PL and JS McLain. 2001. Juvenile Chinook salmon abundance, distribution, and survival in the Sacramento-San Joaquin Estuary. In: Brown RL, editor. Contributions to the Biology of Central Valley Salmonids. Fish Bulletin 179(2). Sacramento (CA): California Department of Fish and Game. p 39-136.

numerous smaller, more appropriate juvenile Chinook salmon were captured February to April of each year. The vast majority of fish, and perhaps those most vulnerable to the factors behind their decline, are subyearling, "ocean-type" fish <80mm FL, and most of the downstream migrating population during certain seasons of the year may be <60 mm FL ("fry"). A relatively small proportion of some spring-run Chinook in the Sacramento River watershed emigrate as yearlings ("stream-type"). Because the behavior of juvenile Chinook is size-dependent, it is possible that a tagging study based on fish >80-100mm FL would not capture the patterns and rates of the bulk of salmon individuals at risk.

We recognize that coded wire tags (CWT) may be the preferred technology for fish <80 mm FL at this time. The role of these CWT studies, and the use of PIT tags, should be better described to show how the proposed study will contribute to the overall understanding of the complex life history of ocean-type fish and how the results relate to population-level dynamics. A fundamental question is how well does the results based on a >100mm FL hatchery fish relate to a <60mm FL wild Chinook fry. These fish can differ significantly in their depth preferences, responses to light regimes, rheotactic responses, food selectivity, physiology, etc. The PIs understandingly have a strong bias toward measuring and modeling the physics of the system, which may have resulting in an unintentional over-simplification of the some of the biological details in favor of a technological approach of questionable applicability to the Chinook stocks of concern. What appears to be lacking is a clear explanation of how the investigators arrived at the restricted study period during November to January, how they selected the surrogate experimental fish, how they selected acoustic-tag technology, and how this study relates to the complex life history of Chinook salmon that use the Delta during other months. To put this in perspective, the PIs could provide a full description about how this study relates to other studies (e.g., Brandes and McLain 2001; CWT), beach seining, and trawling efforts.

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.

The panel felt that time series information about the vertical structure of flow and turbulence in the region near the junctions would be more useful to both the modeling effort and to understanding possible flow cues for salmon. Conversely, given that the conceptual picture of flow under the DCC gate when partially open shown in the proposal is likely incorrect and that it is equally unlikely for safety and structural reasons that DWR would operate the gate partially open position, the ADCP deployment in front of the gate would seem to be of little value. Instead, it would be better to deploy three ADCPs, configured for turbulence measurements as described by the PIs, across the Sacramento River immediately upstream and downstream of the DCC. To examine flows on the sides of the channel, it might be useful to deploy simpler tripods carrying Acoustic Doppler Velocimeters (ADVs) rather than ADCPs. The panel chair believes that any necessary instrumentation for this work that the USGS does not have may be borrowed from colleagues at UC Berkeley and Stanford University. [Note: While this recommendation is less important than many of the other recommendations, we have included it for completeness.]

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

During discussions with the investigators, there was a diverse list of covariates (e.g., turbidity, temperature, transit time) mentioned at various times. To ensure that the most information is gleaned from the data and the modeling, it is critical to describe: a list of covariates; a description of how they will be estimated; their temporal and spatial scales; what certainty should be associated with their values; and, how they will be used in analyses. Formal description of the covariates now will ensure that the future data collection enables the best possible estimation of covariate values for later use in analyses. For example, the term "hotspots" was used several times in the workshop without much detail about how hotspots would be identified. Another good example of an important covariate for which information is somewhat fuzzy is predation by striped bass. Multiple discussions occurred at the workshop about striped bass predation as a covariate. However, by the end of the workshop, it was not clear to the Panel exactly what was going to be done to try to estimate predation by striped bass as a covariate. Were 40 tags enough to say anything? Where and when would the tagged striped bass released? Is a pilot study, like the Clarksburg Bend study, possible for tagging striped bass?

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.

The statistical analysis focused on how many fish (integrated over time) made it to various detection locations, and the response variable of survival in the analysis was the fraction surviving the reach regardless of transit time or route. We note that the 2006-2007 north Delta pilot study was the first to use unassailable statistical procedures to estimate both route selection probabilities and reach-specific survival probabilities simultaneously (using the Skalski-CJS procedure). The proposed 2007-2008 NDSOS study can be viewed as attempts to not only estimate these probabilities, but also to explain these probabilities as a function of covariates (e.g., DCC gate position, flow and other hydrodynamic measurements at junctions, and predator abundance). For example, one could envision a standard logit-transformation being used to relate survival to covariates: logit(survival probability) = $a + b*x$, where x is some covariate. The Panel felt that there could be a gap between the statistical analysis of survival and the very detail, individual-oriented analyses involving the tagging data and particle tracking model (PTM) simulations. The investigators clearly have considered how to compute some of the many possible covariates using the various tagging data and PTMs, and the statistical analysis also has a clear link to covariates. However, it was not clear to the Panel how the various sources for covariates would be melded together and used in the statistical analysis.

Finally, using the fraction surviving as the response variable in the statistical analysis ignores the time aspects of mortality. While fraction surviving is a useful response variable and may be well-suited to the statistical analysis, a population dynamics viewpoint would look at mortality rate and transit time. The combination of mortality rate and transit time results in the fraction surviving. The Panel suggests that when analyses are performed on survival, the mortality (or equivalently survival) rate and residence times also be investigated.

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.

A primary objective of the proposed study is to estimate relative survival for out-migrating salmon among various travel routes through the Delta, and it is generally accepted that predation comprises a major component of that mortality. The PIs recognize the importance of predation, as was well-illustrated by the "house-boat incident" at Clarksburg Bend with larger predatory fish becoming "self-tagged" presumably after ingesting acoustically tagged smolts. Although the proposed study includes plans to acoustically tag and monitor a few striped bass, a higher emphasis on understanding the predatory field would likely provide information crucial to the overall success of the proposed study, including how to devise an effective and logistically feasible strategy for minimizing predator-cuing on the study fish during releases.

Predation is one of the more important covariates in the proposed study. However, the magnitude of this effect will likely vary among reaches and over time and thus is unlikely to remain constant among the various possible travel routes that could be taken by individual fish. The frequency of occurrence, abundance, and interplay of predatory fishes with the out-migrants (i.e., predation intensity), varies markedly at several spatiotemporal scales, from tidally to inter-annually, and from micro-habitat (sunken log, or house boat) to the entire system. Thus, the survival estimates derived from a particular release of smolts may relate only to the prevailing conditions specific to the release period. Important questions such as is survival always lower in Georgiana Slough relative to Steamboat Slough, and is this lower survival a function of striped bass abundance or due to a longer travel-time for smolts among reaches, will be difficult to address with any certainty. One could argue that striped bass abundance increases in the study area during spring (as these anadromous fish prepare for spawning) roughly coinciding with most of the fall-run and winter-run Chinook out-migrants, but are in relatively low abundance in the Delta during November-December when the proposed study is planned. How well then might this seasonal mismatch reflect the expected survival of the wild fish? Only two-thirds of the released salmon survived as far as the Sutter Slough entrance in the second Clarksburg Bend experiment. How much, for example, is predator abundance in the first reach downstream of the West Sacramento release point related to nutrient releases from a major urban wastewater treatment plant?

While a thorough study of the predator dynamics is beyond the scope of the proposed study, more consideration of how small changes in the design and modeling that make opportunistic use of these efforts could provide additional important information on predation as a covariate.

Fortunately, striped bass have been well-studied in eastern estuaries and various reservoirs throughout the U.S., and much is known about their predatory behavior and environmental responses. Thus the proposed study would benefit greatly from a general literature review, and especially from work such as by Hartman and Brandt (1995)[5] that combined hydroacoustics with bioenergetics modeling, and recent work by Ken Able (Able and Grothues, 2007)[6] that also used acoustic methods. There is also potential for cooperation and considerable

[5] Hartman, K.J. and S.B. Brandt. 1995. Predatory demand and impact of striped bass, bluefish, and weakfish in the Chesapeake Bay: applications of bioenergetic models. Canadian Journal of Fisheries and Aquatic Sciences 52: 1667-1687.

[6] Able, K.W. and T.M. Grothues. 2007. Diversity of estuarine movements of striped bass (Morone saxatilis): a synoptic examination of an estuarine system in southern New Jersey. U.S. Fishery Bulletin 105:426-435.

leveraging with the Interagency Ecological Program (IEP; also see 3f), given their traditional emphasis on studying striped bass in this system, the CALFED Science Program (see Kimmerer and Brown 2006)[7], as well as with the high-profile recreational fishery. Charter-boat captains and professional fishing guides are extremely knowledgeable and likely to share information on striped bass occurrence and behavior in the study area. To enlist such help, the PIs might consider coordinating (and perhaps obtaining additional funding) from the Striped Bass Stamp Fund (http://www.delta.dfg.ca.gov/stripedbass/stampfund.asp), as well as various other sport-fishing alliances, e.g., California Striped bass Association (http://www.striper-csba.com/).

We note in passing the possibility that the abundance of striped bass in particular river reaches can be estimated if some striped bass are acoustically tagged and that some acoustically tagged Chinook salmon are ingested by the tagged bass. Suppose M striped bass are acoustically tagged and suppose that n acoustically tagged salmon are ingested and that r of these n ingested salmon were ingested by acoustically tagged bass. A simple Petersen estimate of striped bass abundance is Mn/r. The usual assumptions about closed population, no errors in the values of n and r, etc, may not hold, e.g., whether or not a tagged salmon has been ingested by an unmarked striped bass will not be know with certainty, but variations on the Petersen estimate might be possible.

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

The investigators did a nice job of assembling mock versions of the various data collection technologies and data analysis tools that will be used in the study. We suggest they now take these mock tools, and whatever pilot study and other data is available (even hypothetical), and apply the mock tools in an integrated mock analysis. The Panel thinks a lot can be learned by performing a mock analysis on a common set of data, and seeing how seamless the outputs of one analysis become the inputs to another analysis. For example, a trial run-through of the estimation of covariates from the individual tagging data and the PTM results, and how they will fit into the statistical analysis would likely be helpful in ensuring the appropriate data were collected during the actual field study. Likewise, exactly how the Chinook salmon acoustic tag data will be integrated with the very detailed hydrodynamic measurements is a crucial part of the analysis that should be made more explicit.

3.4b Recommendation: Standardize, to the level that is practicable, the formulation and testing of the PTMs.

The proposed project expects to use results from two PTMs (2-D RMA, 3-D Si3D). The 2-D and 3-D PTMs are being developed and applied by different members of the research team. On top of this, there is a third PTM (DWR's 1-D PTM with DSM2) that has been used extensively in the system, and indeed has been used for management decisions on operations to protect Delta fish species. It is critical to be able to know that the results of the 2-D and 3-D PTMs do not differ simply because different people developed them. Further, it is important to

---

[7] Kimmerer and Brown. 2006. A summary of the June 22-23, 2005 predation workshop, including the expert panel final report. CALFED Science Program. http://science.calwater.ca.gov/pdf/workshops/SP_workshop_predation_report_final_052706.pdf

know how the results of these two new PTMs relate to the results of the 1-D PTM that has been used so much in other studies. At minimum, results from the 2-D and 3-D PTMs need to be comparable, and thus they should be developed in a coordinated manner across models and researchers within the proposed project. Somehow, there should be a link to the 1-D PTM, but it is not clear how to accomplish this. It would be unfair to ask this proposed project to also do a new versus old PTM comparison, as this is a study by itself. But the question will arise about do the new results compare to 1-D results.

Also, there should be rigorous evaluation of the realism of the new PTMs, given they can differ in how behavior will be represented and are being applied to juvenile fish who exhibit movements not completely controlled by the physics of transport. How will the 2-D and 3-D PTMs be compared to measured tracks? Some of the Panel members have had experience in doing this, and argue that it is quite complicated. Do you look at individual tracks from the data, the tracks from the data as an ensemble, or do compute statistical measures from the tracks? There are many questions about how to compare simulated and observed tracks and movement patterns. The proposed project overlays on this even more potential for ambiguous results by having multiple PTMs being developed and run by different people. Evaluation of the PTMs should be rigorous, statistically-based, uniformly applied to both PTMs, and transparent.

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

It is the panel's experience that often (and this was the case for the much of the proposal and the presentations) that the quality of a model result is often represented by a side by side or overlapping plot of model results and data, with the comment that, "the model looks pretty good". Such comparisons are to be discouraged in favor of the use of formal metrics of success like model skill as defined by Warner et al (2005)[8].

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

According to the proposal, the study is motivated by a desire to manage the Bay-Delta system to improve the survival of Sacramento River salmon outmigrants. However, in addition to the Panel's concerns about large hatchery fish as surrogates for ocean-type Chinook fry of concern and the timing of the their natural outmigration, the effects of operations on route selection and on reach survival is not yet understood, and covariates such as predation, turbidity, and other water quality parameters increase the complexity of the problem. The proposed experiments will only produce data for hatchery surrogates released at specific time of the year and at specific locations, and these fish will experience a limited range of Sacramento and San Joaquin flows, export pumping, and DCC gate positions. It is unrealistic to expect to be able to develop a robust and generally applicable management model from these data. The Panel recognizes that the PIs have already made some progress in developing the concepts of a user-friendly management tool to compute overall survival (see for example Figure 8.3 in the proposal). However, the simplified form of the draft North Delta Salmon Survival Model does not account,for complex variability in the influences on juvenile Chinook accessing the Delta.

---

[8] Warner, J.C., Geyer, W.R., and Lerczak, J.A., 2005, Numerical modeling of an estuary; a comprehensive skill assessment: Journal of Geophysical Research, v. 110, C05001, doi:10.1029/2004JC00269

For example, it does not include: the role of Liberty Island in providing temporary habitat for outmigrants; the contribution of San Joaquin River and eastside tributaries to the flow through the western Delta; or, the effect of Three Mile Slough on fish passage through the western Delta. The effect of the Delta export pumps on salmon survival is also more complex than the simple mean flow link with the pumps shown in Figure 8.3.

The Panel recommends that proposed study 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. Less emphasis and effort should be placed on developing a user-friendly management model at this time. The proposed set of experiments, carried out over a four-month period, will not provide sufficient statistical certainty (insufficient replication, insufficient treatments over a wide enough range of flow and barrier operations) to calibrate a management model within the proposed study time frame.

It is more important that good data be collected, thoroughly analyzed, and published in a timely manner. This will make a significant contribution toward management of the salmon stocks and enable biologists, engineers, and decision makers to develop operational criteria, and tools, to protect the species. We foresee that several additional years of similar release-recapture experimentation with acoustically tagged salmon will be required, however, to get sufficiently precise and accurate understanding of the between release and between year variation in survival probabilities in particular.

Current proposals to divert water from the Sacramento River at Hood, north of the Sutter and Steamboat Slough junctions, will significantly reduce flows approaching that junction and the DCC and Georgiana Slough junctions. This may significantly alter route selection and survival of salmon species in the North Delta. Similarly, reoperation of the DCC to protect Sacramento River salmon may affect the survival of Mokelumne River outmigrating salmon. However, one year of experimentation under a limited range of flow conditions is simply not enough to enable development of a credible management model to address these types of issues.

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

To maximize both the expertise and the capability to collaborate various study components, the PIs should consider the value of leveraging their effort with the IEP. Beyond coordinating with the USFWS to obtain study fish from the Colman National Fish Hatchery, and with Pat Brandes to serve as a mentor on Russell Perry’s CALFED Fellowship, little mention is given to a potential involvement of the IEP in the proposed study plan. Given that the ultimate goal of the proposed study is to understand hydrodynamic influences on the transport routes and survival of out-migrating ocean-type Chinook, IEP may serve a valuable role by helping to bridge the gap between the proposed experiments (which will use larger hatchery smolts during late fall), and wild Chinook fry that pass through the system during spring and fall.

Clearly, one appropriate linkage would be to coordinate more closely with the Delta Juvenile Fish Monitoring (DJFM). Since 1976, this survey has sampled about 30 stations using beach seines weekly during spring and intermittently during late-fall (http://www.delta.dfg.ca.gov/jfmp/beachseine.asp). These data, and others like them, could provide important information to allow fine-tuning of the study design and could provide a glimpse into how the study results relate to the broader issues at the population level. To illustrate, consider the Clarksburg Bend pilot study. The DJFM includes a station just upstream from Elk Slough (Station SR043W) on the west-bank of the river (outside bend) which was favored by the tagged smolts. A casual summary of the catch data for SR043W indicates that the catch of juvenile Chinook salmon declined markedly from 1976-1999, as did fish mean length (from 80 to 50mm). Other relevant questions might include slightly modifying or augmenting the sampling in light of the findings from the pilot study; do the much smaller (~50mm vs. 120mm in length) wild Chinook employ similar behaviors as the test fish, traveling by night and holding-up in the small backwater eddy immediately above the river bend during the day? Is the behavior consistent in spring, in fall? Similar questions could be explored by coordinating with the Chipps Island and Sacramento river trawls also conducted by DJFM, as well as with other IEP surveys to facilitate assessment of predator abundance and behavior (see §3.3 above).

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.

The proposed study is well thought out and is the type of study that is needed to address the pressing issues about how water actions and routing affect salmon survival. The current make-up of the research team is slanted heavily towards the physics and hydrodynamics in particular. While the Panel does not question the current membership of the research team, a complicated project like the proposed project will always have some imbalance in coverage of the areas of expertise that are needed. There will also be much time spent on the details and implementation of the study, especially because the releases which are all compressed into a short period of time. A standing advisory panel could help the investigators in several ways. An advisory panel could provide advice on expertise areas perhaps unrepresented in the research team, specifically expertise on salmon biology and behavior. Respected scientists like Colin Williams, John Williams, and Julian Dodson would be good candidates for an advisory panel. Regular meetings (perhaps every six months) with the advisory committee would encourage the investigators to organize their results and issues, and perhaps sooner than if left to their own preferred schedules (project meetings also serve this purpose). Finally, an advisory panel has the luxury of putting a new set of eyes on the project activities and stepping back from the day-to-day activities and providing an opportunity to view progress, vent issues, and offer solutions. Using the advisory panel as a sounding board is often an effective way to improve a complicated study like the proposed study.

There are also people who could contribute to the project in greater depth than could an advisory panel. This review panel is not trying to force others onto the research team, but remain convinced that it would be valuable to get some people involved at a level intermediate between a member of the advisory panel and being a member of the research team. For example, Dr. Skolski from the University of Washington, the PhD advisor to Russ Perry (one of the PIs) might be a good addition, as would Prof. Carl. Schwarz from Simon Fraser University in British Columbia.

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

As stated above, the Skalski-CJS statistical model is a good starting point to the modeling and data analysis. Further analyses and methodological development for these data include: (i) examining the effect of milling or back and forth movement past receivers on estimates of survival using the existing Skalski-CJS model and the last time of detection at the receiver by simulating data with a milling process; (ii) fitting sub-models for route selection and survival probabilities using covariates such as flow; and, (iii) trying out the travel-time linked model for survival developed by Carl Schwarz and others[9].

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.

The panel is extremely concerned that the results of a $6 million study not end up solely as a set of powerpoint presentations, IEP newsletter articles, and un-refereed technical reports. A recent National Academy of Science review[10] of the controversy over management activities related to salmon in the Klamath system highlighted the <u>unsuitability of grey literature as a basis for making management decisions</u>. The panel supports the CALFED science program position in funding its own projects that publications are a necessary outcome and build this requirement into their funding arrangements.

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

Invariably in reviews of IEP programs, this issue has come up with the inevitable reply that staff involved in the work does not have adequate time to complete their analyses of the data or to prepare publications of sufficient quality to pass peer review. Thus, the recommendation is also extended to those paying for the study that they pay for all of the study, including preparation of manuscripts.

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.

Despite some concerns over aspects of how the study might be carried out and its direct applicability to the Chinook stocks of concern, 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.

4. Summary and final recommendation

4.1 Overall view

It is important to recognize that the project is really two different studies addressing two different questions: route selection and overall survival. The proposed acoustic tagging experiments will provide information regarding both route selection at each junction and survival

---

[9] Muthukumarana, Schwarz, and Swartz, Canadian Journal of Statistics, to appear

[10] National Research Council (2004). Endangered and Threatened Fishes in the Klamath River Basin: Causes of Decline and Strategies for Recovery. National Academy Press, 424pp.

within each route or channel. The experimental method and level of detail required to quantify route selection is different than the approach needed to quantify overall survival, or survival within each reach. The proposed levels of effort for the two types of experiment should be reconsidered to optimize the use of experimental and tagged fish resources**.**

4.1a. Route selection

Route selection is a function of the total rate of flow approaching the junction, the junction geometry, the degree of secondary circulation immediately upstream of the junction, and other factors such as time of day (day, night, or crepuscular periods). Route selection also appears to be affected by operation of barriers downstream of the junction, as in the case of the small effect of closure of DCC on flow through Sutter and Steamboat Sloughs.

Route selection is a local effect in the vicinity of a junction and a reasonable distance upstream (to allow time for the distribution of fish across the cross-section to establish). The duration of the route selection process may be relatively short relative to the time period for the survival experiments. This may allow the choice of smaller tags and use of smaller fish for the route selection experiments and, therefore, better representation of the size and life stage of out-migrating winter-run salmon. Through the tagged fish experiments and numerical 2-D and 3-D modeling, the PIs should be able to make significant progress toward understanding the paths taken by out-migrating fish through the north and central Delta channels.

4.1b. Overall survival

Estimating survival or its equivalent, mortality, in the wild is traditionally a thorny problem. In the proposed study, survival of the tagged fish will primarily result from the probability of being eaten by larger fish over a given transit time. Typically, predator-prey interactions are viewed as a sequence of events involving the probabilities (rates) of prey encounter, detection, pursuit, strike, and capture. Of these, prey encounter rate appears most important for this study and will be influenced by the densities of large fish predators and the densities of smolts released each trial, the frequency and predictability of releases, and the routes and the time smolts spend in transit; i.e., the longer one is in a tiger's cage, the higher the chance of being eaten. Secondarily, the use of larger hatchery smolts may increase tag detection rates relative to natural migrants, but this effect may be compensated for by faster swimming speeds which scale with fish size, potentially leading to shorter travel times. Overall, it is important to recognize that predator density and travel-times of the tagged smolts are major components requiring further attention if the proposed study is to estimate overall, or reach-specific, survival rates. Given the overall nature and tractability of the problem combined with modest improvements in the general approach proposed by the PIs, there is potential for this study to significantly improve our understanding of juvenile salmon survival rates through the Delta.

4.2 Final recommendation

The panel recommends funding the proposed work subject to resolution of the significant issues defined above. Moreover, the panel feels strongly that for the work to be of real value to understanding survival as opposed to route selection alone, the proposed experiments will need to be carried on for multiple years, admittedly a large and expensive task. Nonetheless, when weighed against the costs involved in building and operating facilities like the Through Delta

Conveyance or the Peripheral Canal, the information that could be gained by continuing these studies seems worth the investment required.

5. Postscript

The panel uniformly agreed that structure of the review was somewhat extraordinary (i.e., reviewing a proposal that the funding agency had apparently already selected for funding via a sole-source selection process). While a truly competitive proposal vetted via a RFP has some additional desirable aspects (the best get funded), specific questions sometimes need focused proposals. Some of the Panel members felt this study was an example of situation that needed a focused proposal. Others felt that an open RFP would be the best option in future. All agreed that further discussion by CALFED agency managers in consultation with the CALFED lead scientist and the Independent Science Board of how the CALFED agencies research portfolio should be balanced between directed activities and projects selected by open solicitation is warranted. In any case, the PIs are to be commended for requesting a peer-review, preparing a detailed proposal, and making informative presentations at the workshop. The Panel offers these recommendations in the spirit of trying to improve an already very good project.