Delta Outflows and Related Stressors Workshop

February 10 and 11, 2014

PWA Supporting Documentation

CRITICAL REVIEWS OF FALL X2

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UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA Partially Consolidated With: 1:09-cv-480 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	**DECLARATION OF DR. KENNETH P. BURNHAM IN SUPPORT OF PLAINTIFF'S MOTION FOR INJUNCTIVE RELIEF**
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	Date: July 26-29, 2011 Time: 8:30 a.m. Ctrm: 3 Judge: Hon. Oliver W. Wanger
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	

I, DR. KENNETH P BURNHAM, declare:

1. My declaration is set forth in the following manner

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I. PROFESSIONAL EXPERIENCE

2. I have previously filed two declarations in the *Consolidated Salmonid Cases*. See Docket # 439, 504, No. 1:09-cv-1053-OWW-DLB (E.D. Cal). As brief background, I am a retired Senior Scientist with the United States Geological Survey, Biological Resources Discipline, Colorado Cooperative Fish and Wildlife Research Unit. See Summary Professional Vitae, attached hereto as **Exhibit A**. I held that position from 2004 to 2008, and worked in various positions within the same Unit since 1988. I have a Ph.D. in Statistics from Oregon State University, a Master's of Science in Statistics from Oregon State University, and a Bachelor's of Science in Biology from Portland State University. I have taught graduate-level courses such as "The Design of Fish and Wildlife Studies" and "Sampling Biological Populations" for nearly forty years, and I was most recently a graduate professor in the Department of Fish, Wildlife, and Conservation Biology and affiliate faculty in the Department of Statistics at Colorado State University from 1988 to 2008.

3. I am the author of over 190 publications and reports, including Burnham, K.P. and D. R. Anderson, *Model Selection and Multimodel Inference* (2nd ed.), Springer-Verlag (2002). Among these articles are Burnham et al., *Design and analysis of fish survival experiments based on release-recapture data*, American Fisheries Society, Monograph 5 (1987); Burnham, K. P., D. R. Anderson and G. C. White, *Meta-analysis of vital rates of the northern spotted owl*, Studies in Avian Biology 17:92-101 (1996); and Osmundson, D. B., and K. P. Burnham, *Status and trends of the endangered Colorado squawfish in the upper Colorado River*, Transactions of the American Fisheries Society, 127:957-970 (1998). *See* Ken Burnham: A Life in Science attached hereto as **Exhibit B**.

4. In May of this year I was informed that I have been selected to receive the Wildlife Society's Aldo Leopold Memorial Award for 2011. The award is made "for distinguished service to wildlife conservation," and it is the highest honor bestowed by The Wildlife Society. Only one Aldo Leopold medal is given each year, and the principle criterion is that "the nominee should have a well-established and distinguished career that has been of undoubted significance to the

cause of wildlife conservation."[1] My background and experience enable me to review and evaluate the scientific analysis contained in the 2008 biological opinion on the delta smelt ("BiOp").

II. INTRODUCTION

5. I have been asked to review the scientific evidence regarding the purported influence of the location of X2 (the distance up the axis of the estuary to the daily averaged near-bottom 2-psu isohaline) on delta smelt abundance. In my review, I have primarily considered the discussion of X2 contained in the BiOp, and the underlying studies that the BiOp principally relies upon for its conclusions on X2. I have also reviewed the latest scientific data and publications on X2 that are currently available. My review has included, but not been limited to, Feyrer (2007),[2] the draft manuscript that is referred to in the BiOp as "Feyrer (2008),"[3] Feyrer (2010),[4] Kimmerer (2009),[5] and Maunder and Deriso (2011).[6]

6. Based on my review, I have concluded that the existing data on X2 and smelt abundance, which is relatively substantial and robust, and the current scientific analyses of X2, provide no support for the hypothesis that manipulation of the location of X2 will will provide any benefit to the delta smelt. The analysis presented in the BiOp, as well as the articles by Mr. Feyrer on which the BiOp's analysis appears to be solely reliant, are fundamentally flawed for three basic reasons, which I will summarize here and explain in more detail below.

7. First, there is no basis for using X2 as a surrogate for "habitat." The habitat of a species is considerably more complicated than habitat volume alone, and necessarily

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[1] *See* http://joomla.wildlife.org/index.php?option=com_content&task=view&id=48&Itemid=204.

[2] Frederick Feyrer, et al., *Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA*, Can. J. Fish. Aquat. Sci. 64:723-734 (2007) (AR 018266-018277).

[3] Frederick Feyrer, et al., *Modeling the Effects of Water Management Actions on Suitable Habitat and Abundance of a Critically Imperiled Estuarine Fish (Delta Smelt Hypomesus transpacificus)* (2008) (AR 018278-018306).

[4] Frederick Feyrer, et al., *Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish*, Estuaries and Coasts 34:120-128 (2010).

[5] Wim Kimmerer, et al., *Is the Response of Estuarine Nekton to Freshwater Flow in the San Francisco Estuary Explained by Variation in Habitat Volume?*, Estuaries and Coasts 32:375-389 (2009).

[6] Maunder, M.N. and R.B. Deriso. 2011. A state-space multi-stage lifecycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt. (In press.) Canadian Journal of Fisheries.

encompasses a number of biotic and abiotic factors. While it was not an illegitimate exercise for Feyrer (2007) to compare three abiotic variables (specific conductance (salinity), secchi depth (turbidity), and temperature) with smelt presence and absence, that exercise provided nothing useful in analyzing how to address smelt habitat. It was illegitimate, however, for the BiOp to correlate those variables (which Mr. Feyrer referred to collectively as "EQ") with X2, and then to use X2 as a measurement of "habitat." This practice of chaining together a series of analyses via surrogates (presence/absence to EQ, EQ to habitat, habitat to X2) without properly accounting for the considerable uncertainty at each stage is unscientific and results in a final relationship (X2 = habitat) that is not soundly supported.

8. Second, the BiOp's reliance on the analyses in Feyrer (2007) and the draft of Feyrer (2008) linking X2 and smelt presence and absence is flawed. First, Mr. Feyrer excluded 27 out of the 100 core FMWT sampling stations, including "stations on the periphery of the sampling grid where delta smelt were rarely encountered." Excluding those stations on the basis that smelt were rarely encountered there is arbitrary and erroneous. Those stations are essential to determine whether the habitat variables identified by Mr. Feyrer actually drive smelt presence/absence. For example, if favorable "habitat" conditions were present at those stations, but smelt were seldom found there it would indicate that the EQ factors identified by Mr. Feyrer do not drive smelt presence/absence to a strong degree, and that some other factors might be more important—the additional stations may have negated the significance of the model results that Mr. Feyrer found. Those stations are also essential to determine whether providing more of Mr. Feyrer's "habitat" will actually increase smelt presence/absence. If there is already existing suitable "habitat" that few smelt are using, a scientist should ask will it really benefit the species to increase the total range of that "habitat"? Such a significant omission is a clear scientific error that no reasonable scientist would purposefully execute. Second, because Mr. Feyrer's habitat analysis substantially underestimated the true extent of smelt habitat, the conclusions that he reached regarding rates of decline with changes in X2 are deeply misleading. All of these errors mean that Mr. Feyrer's "habitat index," which is the basis for Figure B-17 in the BiOp, is not

informative about changes in the true amount of smelt habitat. The BiOp's reliance on this analysis for habitat is misplaced.

9. Finally, the only justification in the BiOp for actually manipulating the location of X2 in the fall is the hypothesis that moving X2 will ultimately lead to an increase in smelt abundance. In his published papers Mr. Feyrer never directly tested this theory to see whether there was a relationship between X2 and smelt abundance in the existing data. Mr. Feyrer attempted to model this relationship in his draft Feyrer (2008) manuscript that appears in the record. Unfortunately, that draft work became a crucial part of the BiOp's analysis in the form of Figure E-22. (BiOp at 268.) But that analysis has subsequently been deleted in Feyrer (2010)—the final peer-reviewed published version of Mr. Feyrer's article—and the 2010 article contains no analysis of the effect of X2 on smelt abundance. Therefore, for the X2 action, it appears that the BiOp relied on a draft analysis that did not survive peer review.

10. More recent published studies have performed the analysis, and have found that there is no relationship between X2 and smelt abundance. For example, Kimmerer (2009) found that "abundance of delta smelt did not vary with [spring] X2" despite also finding—like Feyrer (2008) and Feyrer (2010)—a correlation between X2 and a narrowly defined metric of habitat volume.[7] Most importantly, Maunder and Deriso (2011) showed, using a comprehensive life cycle model that examines a large number of biotic and abiotic factors, that neither fall nor spring X2 has an effect on smelt abundance.

11. Given the general lack of statistical support for an X2 action in the Feyrer papers as well as more recent, and superior, statistical analyses showing no relationship between X2 and smelt abundance, I see no basis for FWS to conduct what is essentially an "experiment" with fall X2. The BiOp calls for a 10-year review of the action, and yet the reality is that the "experiment" would require, in my opinion, 30 or more years to provide any meaningful data, and even then the risk of finding no clear signal is very high due to the large number of confounding variables. The past few decades of data, which have included a wide range of X2 values, have generated no

[7] Dr. Kimmerer made use of a very limited definition of abiotic habitat, considering only salinity and water depth.

meaningful statistical relationship between X2 and abundance, and I have not seen any evidence suggesting that the next few decades will do so.

12. In the remainder of my declaration I will briefly summarize the BiOp's analysis of X2, and explain the central role that Mr. Feyrer's research plays in the X2 action. Then I will explain the significant flaws in Mr. Feyrer's analyses, and why more recent studies establish that the X2 action is baseless.

III. BACKGROUND

13. The X2 action is premised on the theory that "CVP/SWP operations control the position of X2 and therefore are a primary driver of delta smelt habitat suitability." (BiOp at 234.) In order to determine the effect of the X2 action, FWS undertook a three-step statistical analysis, relying on "[1] the effects of proposed CVP/SWP operations on fall X2, [2] how that affects the surface area of suitable abiotic habitat for delta smelt, and finally [3] how that affects delta smelt abundance given current delta smelt population dynamics." (*Id*.) It was this "series of linked statistical analyses" that the National Research Council recently found "lacked rigor" because "[t]he relationships are correlative with substantial variance being left unexplained at each step."[8]

14. To understand what FWS did and why it is flawed, it is important to follow FWS's analysis through each of its steps. In the first step, FWS used the CALSIM model to determine the shift in X2 caused by Project operations.[9]

15. The second step of the evaluation "used the modeled X2 to estimate the total surface area of suitable abiotic habitat available for delta smelt." (BiOp at 235). This step of the analysis was entirely dependent on the draft article Feyrer (2008), which used measurements of the presence/absence of smelt at sampling stations to generate "a measure of surface area (ha) of suitable abiotic habitat," and then used projected X2 values to predict changes in the extent of that

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[8] National Research Council of the National Academies, *A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay Delta*, March 19, 2010 at 41.

[9] I have been provided with a copy of the Court's summary judgment order and have observed that the Court has already recognized the serious methodological errors in FWS's CALSIM modeling.

habitat, as depicted in Figure E-20 of the BiOp. (BiOp at 266.) This same modeling effort provided the results for Figure B-17, which purports to be the BiOp's justification for the 74km/81km requirements in the X2 RPA. As I will discuss below, this step contains a number of serious statistical errors that render its analysis invalid.

16. Finally, the BiOp undertook the key step of analyzing the effect of X2 on delta smelt abundance. (BiOp at 236.) Once again, this analysis was entirely dependent upon the draft article Feyrer (2008), which contained several pages attempting to model the effect of management options on X2 and smelt abundance. (AR 018285-018291). Dr. Deriso has discussed the errors in these analyses at length in his declarations, and I will not repeat those comments here. However, it is worth noting that Mr. Feyrer's draft analysis was ultimately deleted in its entirety from the final manuscript that was published in 2010. Mr. Feyrer's new article does not include any direct analysis of the effect of X2 on smelt abundance, and thus for this crucial step of the BiOp analysis, FWS relied on a statistical model that was deleted apparently during the process of peer-review.

17. As this step-by-step analysis makes clear, the BiOp's analysis of X2 and the justification for the X2 action are based on two key statistical relationships, both of which derive from Mr. Feyrer's work: the relationship between X2 and the presence/absence of smelt (which the BiOp used to determine "suitable abiotic habitat"), and the relationship between X2 and abundance (which the BiOp used to justify X2 action itself). In the sections below I will discuss why Mr. Feyrer's conflation of X2 with the amount of smelt "suitable habitat" was invalid, and why the absence of a relationship between X2 and abundance means that the "habitat index" developed by Mr. Feyrer is useless.

IV. X2 IS AN IMPROPER SURROGATE FOR SMELT "HABITAT SUITABILITY"

18. The X2 action is premised on a scientifically improper conflation of the location of X2 and the extent of "suitable" smelt habitat. The basis for this erroneous correlation was Mr. Feyrer's work in Feyrer (2007) and Feyrer (2008). (BiOp at 234 ("Supporting background material on the effect of fall X2 on the amount of suitable abiotic habitat and delta smelt abundance is available in Feyrer et al. (2007, 2008).")) In Feyrer (2007), Mr. Feyrer undertook a

modest exercise: he examined how three habitat variables (specific conductance, Secchi depth, and temperature) correlated with delta smelt presence/absence in the FMWT. In other words, he looked at whether each individual sampling trip in the Fall Midwater Trawl caught smelt or not, and then tried to see if the presence or absence of smelt corresponded with concurrent measurements of those three abiotic variables. He found a weak predictive correlation (about 26% as R-squared) between the three variables and the presence/absence of smelt. (AR 018271.)

19. As a conceptual matter, there was nothing improper about this approach (I will discuss the methodological errors committed by Mr. Feyrer below), but it is almost entirely uninformative. As Mr. Feyrer admitted in the article, these three abiotic variables do not define the smelt's abiotic habitat, let alone its full habitat, which includes a number of biotic and abiotic variables. (Feyrer (2007) ("[W]e acknowledge that our analysis did not include all potential water quality, physical, or biological factors that affect fish occurrence and habitat." (AR 018274.) For delta smelt, variation in habitat quality can occur with variability in availability of food, shelter from predators, substrates for spawning, and a large number of physical variables, including salinity, turbidity, and temperature. Habitat is not measurable simply as a two-dimensional area, but as a matrix of all of these variables. For example, smelt will not survive in "suitable" abiotic habitat if there is no food for them. And given the weak correlation between the three EQ variables and presence/absence (26%), it appears likely that other variables—variables that Mr. Feyrer did not explore—are actually driving patterns of smelt presence/absence. As Mr. Feyrer noted in Feyrer (2007), the best way to understand a system with such a large number of variables is a life cycle model that would allow for a quantitative assessment of the effect of biotic and abiotic variables alike. (Feyrer (2007) "Current efforts in parameratizing life cycle models for delta smelt . . . are likely to better quantify the relative importance of water quality on their population dynamics." (AR 018274)).

20. In the discussion section of Feyrer (2007), he considered the role that the three EQ factors could play in management of the Delta. Unable to regulate EQ directly, Mr. Feyrer suggested manipulating the location of X2 as a method of managing salinity levels in the Delta. It is important to appreciate the accumulation of uncertainty that has taken place: Mr. Feyrer

began with EQ, which was already a weak predictor of smelt presence/absence. He then suggested a management option—changing the location of X2—that would affect only one of the three EQ factors, salinity. So here, at the genesis of the X2 action, the proposal is to control a self-described "surrogate" of salinity for what was already a poor predictor of smelt presence/absence. As I stated above, this is not scientifically improper; but it is not useful.

21. What Mr. Feyrer did next, however, was scientifically improper. In Feyrer (2008),[10] which served as the sole basis of the "Area of Suitable Habitat" section of the BiOp (BiOp at 235-36), Mr. Feyrer and his colleagues used their three EQ variables to define the extent of smelt abiotic habitat, and then used their habitat modeling to translate the model-generated probabilities of presence/absence "into a measure of surface area (ha) of suitable habitat." (AR 018283.) They then used X2 to predict the extent of "suitable abiotic habitat" in a precise number of hectares. These analyses became Figures E-20 and B-17 in the BiOp (BiOp at 266, 374).

22. In the next section I will discuss in greater detail the serious statistical and methodological errors in this approach, but such a fine-grained analysis is barely necessary. Predictive uncertainty in chains of modeling analyses is, roughly speaking, multiplicative rather than additive—the total error is more than the sum of its parts. This is elementary statistics. Here, Mr. Feyrer chained together multiple models (presence/absence to EQ, EQ to habitat, habitat to X2) each of which contained substantial uncertainty at each step, and each of which was based on assumptions (*e.g.*, the 26% relationship between the EQ factors and presence/absence was a matter of cause and effect rather than of mere correlation; the EQ factors can stand for abiotic habitat, etc.) that built even more uncertainty into the model. By integrating the results of each model into the subsequent model without compensating or accounting for the uncertainty, Mr. Feyrer masked the rapidly compounding error. This violates the most fundamental principles of statistical theory, which is that a statistical inference should include information on the uncertainty of that inference. *See, e.g.*, Cox (2006) ("Much of [statistical] theory is concerned with indicating the uncertainty involved in the conclusions of statistical

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[10] Again, recall that this draft manuscript was never published.

analysis.")[11] The end result, a model that appears to predict the exact number of hectares of suitable abiotic smelt habitat based solely on the location of X2, is so riddled with uncertainty as to risk being meaningless.

23. This was the same point made by the NRC, which found that "the examination of uncertainty in the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses . . . with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step."[12] My criticism here is not of models in general, or even of models containing uncertainty (as all models do), but rather of clumsy, ad hoc modeling efforts that fail to use the accepted statistical methods to rigorously examine and account for the known uncertainties in the data. The X2 analysis in the BiOp and in Feyrer (2008) (which the BiOp relies on even though the 2008 manuscript was never published), falls into this latter category, and is scientifically unacceptable.

V. THE FEYRER HABITAT ANALYSES ARBITRARILY EXCLUDE ESSENTIAL DATA POINTS

24. Mr. Feyrer's habitat analysis in Feyrer (2008) and Feyrer (2010) is built around an inexplicable methodological error: he excluded from his "habitat index" a large number of the FMWT sampling sites. These sites contained data that was essential to proving or disproving his hypothesis regarding the effect of the EQ factors, and ultimately X2, on the presence/absence of delta smelt. Without this data, Mr. Feyrer's analysis was essentially meaningless.

25. In Feyrer (2010), Mr. Feyrer excluded 27 of the core 100 FMWT stations—a quarter of the total. In Feyrer (2008), which the BiOp used to justify the X2 action, he excluded fully one-third of the stations, using only 62 total. (AR 018284.) Why? In both cases, the explanation was the same: Mr. Feyrer "exclud[ed] stations on the periphery of the sampling grid where delta smelt were rarely encountered or where the sampling record was inconsistent." (AR 018284; Feyrer (2010).) This is perplexing. It is understandable to exclude sampling sites where

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[11] Cox, D. R. 2006. *Principles of Statistical Inference*. Cambridge University Press, Cambridge, UK.

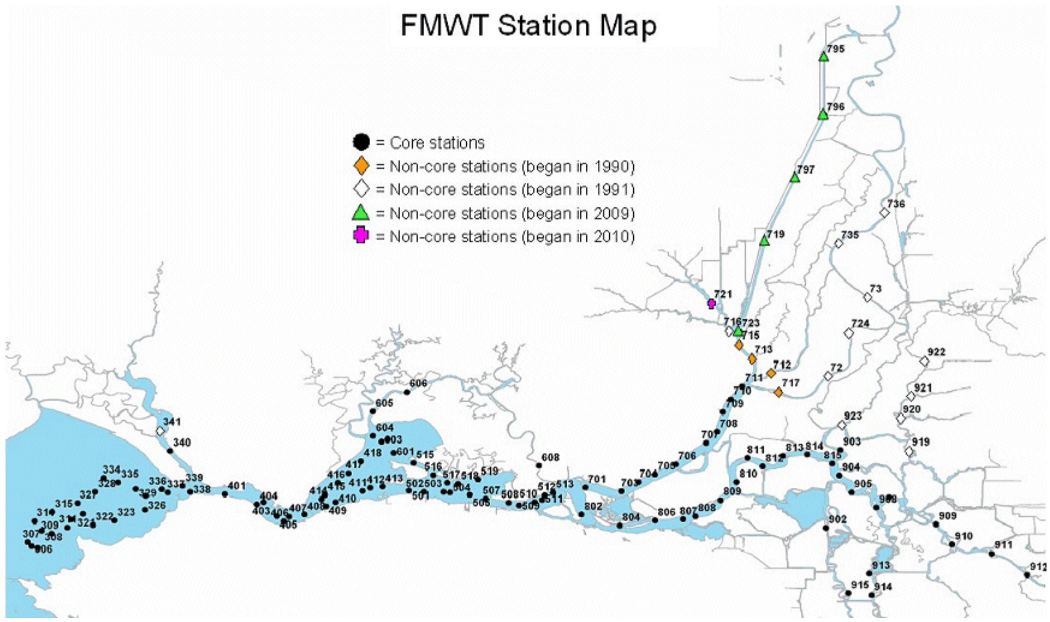
[12] NRC Report at 41.

the sampling record is inconsistent, but when one is trying to create an index of “suitable abiotic habitat” for smelt there is no justification for excluding a site where “delta smelt were rarely encountered.” If smelt are “rarely encountered” there, then they are sometimes encountered there, which means that it is sometimes habitat. Indeed, these stations “on the periphery of the sampling grid” are the most useful way to know if one’s sampling points have truly captured the extent of smelt habitat. If one locates fish at a site on the periphery, there is a good chance that there may be more farther out and thus the sampling sites do not provide the full extent of habitat.

26. Moreover, these sites are necessary to answer the exact questions that Mr. Feyrer needed to answer to justify his conclusions. First, do the three EQ factors actually drive smelt presence/absence? If the abiotic habitat conditions at a site are “favorable” and yet delta smelt are rarely found there, it may be the case that the EQ factors are not actually driving smelt presence/absence. If that were the case, including those stations might validly negate the signal that Mr. Feyrer claims to have received from the data—in other words, the EQ factors might explain less than the 26% of the variance in presence/absence that Feyrer (2007) claimed they explain. By cutting these sampling sites out, Mr. Feyrer likely arbitrarily inflated the influence of the EQ factors. Second, from a management perspective, it would be useful to know if there are sites with “suitable” abiotic characteristics that delta smelt are not using. This data would help to determine whether increasing the amount of Mr. Feyrer’s “suitable abiotic habitat area” would actually increase the area used by the delta smelt. Omitting this data was a basic scientific error.

27. This error had another significant consequence. In order for Mr. Feyrer’s model of “suitable” habitat to have any sound utility in predicting the “area of suitable abiotic habitat” for the delta smelt, the data on which the model is based must reasonably match up with the actual true area of smelt habitat. However, as discussed above, Mr. Feyrer’s model demonstrably does not include large segments of the smelt’s habitat, and thus falls far short of the comprehensiveness required for his model to be useful. In addition to the core FMWT sites Mr. Feyrer excluded from his analysis, he also neglected to consider that there are large areas of

known smelt habitat in Cache Slough and the Sacramento Ship Channel. These sites have recently been added to the FMWT, and significant numbers of smelt have been surveyed there.[13]



28. In Feyrer (2008), on which the BiOp's habitat analysis is based, Mr. Feyrer used the surface areas associated with his hand-picked sub-group two-thirds of the core sampling sites to conclude that there were a sum total of 18,781 ha of suitable abiotic habitat available to the smelt. (AR 018284.) The precision implied by Mr. Feyrer's analysis, in which he identified "suitable abiotic habitat" for smelt down to the individual hectare, is unreasonable, given the fact that Mr. Feyrer had excluded FMWT sampling sites where smelt had been present and had ignored habitat areas outside of the sampling grid where smelt were known to live. In Feyrer (2010), Mr. Feyrer once again ignored and excluded these habitat areas, contending, without support, that "delta smelt has a 'core distribution' in the sampling grid," and thus the "habitat index" suitably accounted for its total habitat. The potential for error in assuming that the limited selection of sampling sites covers the smelt's "core distribution" is very large, especially in a

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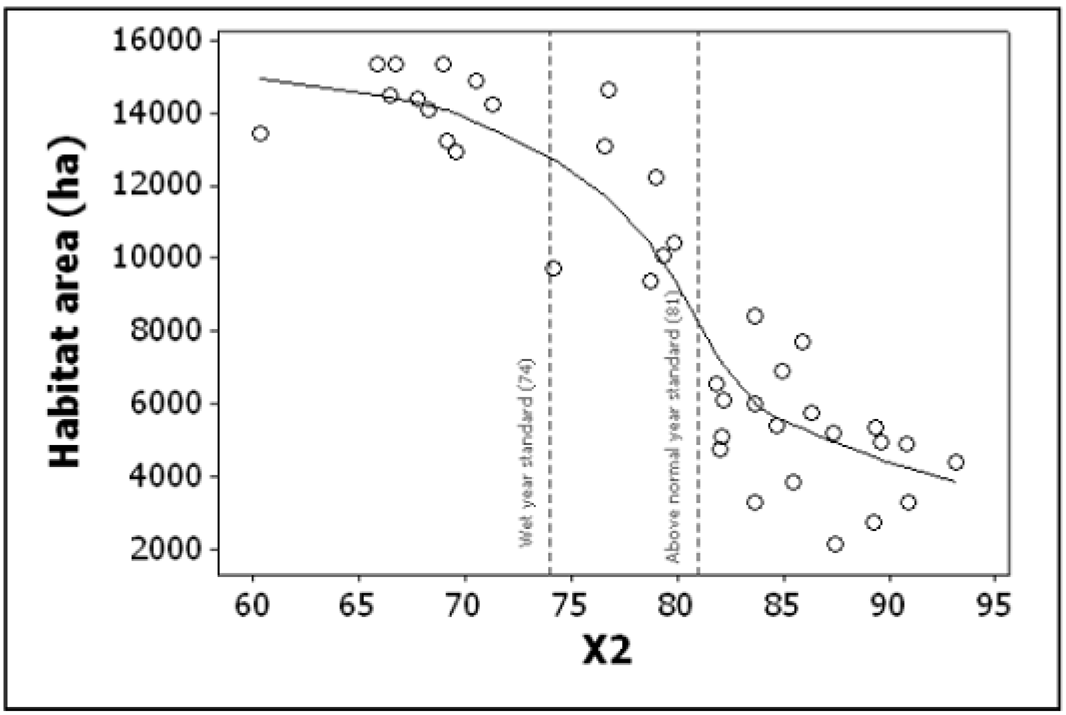
[13] *See* CDFG Fall Midwater Trawl Survey data at http://www.dfg.ca.gov/delta/data/sls/CPUE_map.asp.

model like Mr. Feyrer's that is dependent for its validity on providing a reasonable estimation of smelt abiotic habitat.

29. The fact that there are large areas of known smelt habitat that are excluded from Mr. Feyrer's "area of suitable abiotic habitat" makes it difficult, if not impossible, to draw any conclusions from Mr. Feyrer's analysis. For example, in Figure B-17 of the BiOp (from which the BiOp derived the 74 and 81 km restrictions in the X2 action), the analysis implicitly assumes that if all of the "area of suitable abiotic habitat" that Mr. Feyrer selected is used up, there will truly be zero habitat available to the smelt. If this assumption is incorrect, the model breaks down.

Figure B-17. Relationship between X2 and habitat area for delta smelt during fall, with standard shown for wet and above normal years.



30. And in this case, Mr. Feyrer's assumption is obviously false. Even if every one of the 18,781 hectares that Mr. Feyrer considered "suitable abiotic habitat" were to become entirely unsuitable for smelt, there would still be an unknown (and potentially large) quantity of suitable abiotic habitat still available: namely the core FMWT sampling areas that Mr. Feyrer arbitrarily excluded, and areas such as the Ship Channel, where suitable smelt habitat is known to exist but which have not historically been part of the core sample for the FMWT. Feyrer's model can only

tell about the rate and extent of change in the small subset of area that he selected, a subset that does not correspond with the actual extent of smelt abiotic habitat. Without a reasonably reliable measurement of the true smelt habitat area, Figure B-17 does not provide the context to determine what effect changes in X2 would have. Any effect of X2 on the "suitable abiotic habitat area" derived from the graph will be arbitrary.

31. Mr. Feyrer backed away from the obviously erroneous approach of calculating a definite habitat area in the final published version of Feyrer (2010). In that paper, Mr. Feyrer no longer predicts changes in the absolute size of the available area of "suitable abiotic habitat," but instead creates a "habitat index." However, this does not actually solve his problem. In Feyrer (2010), Mr. Feyrer confidently asserts that the "habitat index has declined by 78% over the course of monitoring," but he forgets once again that his habitat index similarly lacks a "true zero." To understand this, consider a hypothetical in which Mr. Feyrer defined his "habitat index" on the basis of the characteristics of just one square hectare at the 74 km X2 line, despite knowing that there was smelt habitat outside of that one hectare. It would be true that if X2 moved one kilometer eastward the habitat index would decrease by 100%—from one square hectare of "suitable" smelt habitat to zero smelt habitat—however, this would not be a useful metric for determining the effect of that X2 movement on the total true smelt abiotic habitat because we know that there are actually smelt that live outside of that one square hectare. 0% on such a "habitat index" does not equal, or even reasonably represent, 0 smelt habitat. Mr. Feyrer's "habitat index" is only slightly less arbitrary: even if the area of habitat on which the "habitat index" is based were to shrink to 0, it would not mean that there had been a 100% reduction in the area of true smelt abiotic habitat. It is well established that there are other areas of habitat, potentially large and highly suitable ones, that are not incorporated into his index. Therefore, Mr. Feyrer's claim of a "78% drop" in the habitat index is highly misleading as to the effect on the smelt's actual habitat.

VI. X2 HAS NO MEASURABLE EFFECT ON SMELT ABUNDANCE

32. Even if one were to accept all of the assumptions and uncertainty in Mr. Feyrer's analyses, the only empirical measure that would show if moving X2 seaward will have a

beneficial effect on the delta smelt would be if changes in X2 actually had a direct effect on subsequent delta smelt abundance. In the draft manuscript cited as Feyrer (2008) in the BiOp, Mr. Feyrer attempted such an analysis, and the result was incorporated into the BiOp as Figure E-22, which purported to show a statistically significant relationship between X2 and subsequent smelt abundance. (BiOp at 268.) Dr. Deriso has discussed the flaws with Feyrer (2008)'s modeling at length, and I will not repeat his explanation.

33. I will note, however, in addition to Dr. Deriso's criticisms, that it appears highly irregular that Feyrer (2008) used only post-1986 FMWT abundance data (corresponding with the introduction of the *Corbula* species of clam) for its analysis of the effect of X2 on abundance, but then used the full 1967-to-present abundance data for its analysis of smelt presence/absence. Mr. Feyrer only found a statistically significant effect of X2 on abundance in the 1987-2004 set, not in the larger 1967-2004 data set. Mr. Feyrer stated that he believed that it was appropriate to segregate out the 1987-2004 abundance data because of the changes in food supply caused by the introduction of the *Corbula*. However, the introduction of the *Corbula* almost certainly had some effect on the smelt presence/absence data from 1967 to the present, and yet Mr. Feyrer used the entire data set in his presence/absence analysis. It is methodologically improper to link these analyses together—to say that X2 determines habitat area and also that X2 determines abundance—while using fundamentally different data sets. This unexplained and unjustified use of non-comparable data sets creates the appearance of attempting to structure a result..

34. However, what is most significant at this point in time is that the X2/abundance analysis found in Feyrer (2008) (in review at the time of the BiOp), was not incorporated into the final, peer-reviewed version of the published paper. Lacking a direct analysis of the effect of X2 on abundance, Feyrer (2010) was forced to conclude, rather weakly, that the "78%" decline in the habitat index "has been coincident with the long-term decline in abundance." (emphasis added.) Coincidence is not causation.

35. In my review of Feyrer (2010) I was struck by his apparent unwillingness to test the effect of X2 on abundance, which is the necessary final step in the analysis. Why test the correlation between X2 and the habitat index, and then test the correlation between the habitat

index and the smelt abundance index, but not test the correlation between X2 and smelt abundance directly? It is simple to do. In another recent paper, Kimmerer (2009), Dr. Kimmerer performed a very similar (though more thorough) analysis of the habitat volume of a number of Delta species, including the delta smelt. Like Feyrer (2010), Dr. Kimmerer found an association between spring X2 and his defined habitat volume for the delta smelt. However, Dr. Kimmerer took the analysis one step further and directly considered the relationship between X2 and abundance using a very basic analysis. His results were clear: "[A]bundance of delta smelt did not vary with X2 . . . Despite the evident increase in the amount of habitat, delta smelt abundance appears to be regulated by other factors so far unidentified, or it may be at a low enough abundance to preclude density dependence, which may be necessary for abundance to track habitat quantity."

36. Given that Mr. Feyrer was aware of the finding in Kimmerer (2009) that Spring X2 does not affect smelt abundance despite its affect on habitat volume, and that Mr. Feyrer was aware of the management significance of fall X2, it is my opinion that any scientist would have taken the basic step of analyzing the effect of Fall X2 on smelt abundance.

37. Fortunately other scientists have undertaken that task. Feyrer (2007) noted that "[c]urrent efforts in parameratizing life cycle models for delta smelt . . . are likely to better quantify the relative importance of water quality on their population dynamics." (AR 018274.) In a forthcoming peer-reviewed article, Maunder and Deriso (2011) present the first fully developed quantitative life cycle model for the delta smelt. It incorporates a large number of biotic and abiotic habitat variables, and carefully accounts for potential sources of error using rigorous statistical methods. Their results, which weigh the available data on X2 with a much larger number of variables than the three abiotic EQ factors, shows no influence of X2 on abundance whatsoever. Drs. Maunder and Deriso found, instead, strong support for the influence of food supply, a biotic factor that Feyrer (2007) conceded was "[p]erhaps the greatest opportunity for improving our analyses of EQ distributions and trends."

38. In my opinion, the quantitative life-cycle analysis performed by Drs. Maunder and Deriso is the best and most comprehensive analysis of the data on delta smelt so far, and is the

best method for determining the effect of stressors on the species. I agree with the NRC report's conclusion that complicated systems with interlocking variables "can most effectively be understood through integrated analyses conducted in a modeling framework that represents the complete life cycle."[14] The model presented by Drs. Maunder and Deriso considers a wide range of factors, uses the best data on the species, and employs standard statistical methods to account for uncertainty rigorously and transparently. None of these things are true of Mr. Feyrer's modeling work. It is unreasonable in my opinion to rely on Mr. Feyrer's work for the imposition of a Fall X2 action.

VII. CONCLUSION

39. Based on my review of the available data analyses, the analyses of smelt abiotic habitat in Feyrer (2007), Feyrer (2008) and Feyrer (2010) are fundamentally flawed, and cannot properly be used to estimate the effect of changes in X2 management on smelt habitat volume, which was their intended purpose. However, even if Mr. Feyrer's analyses could be used to predict changes in the amount of available abiotic habitat for smelt, there is no statistical evidence that changes in X2 have any effect on smelt abundance. More recent studies, such as Kimmerer (2009) and Maunder and Deriso (2011) show that X2 is not relevant to smelt abundance, and that other factors, such as food supply, are most likely driving changes in the smelt's population level.

40. On this point, the NRC, which did not have the benefit of Maunder and Deriso (2011)'s more recent analysis, concluded that "[t]he weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand." I agree, and believe that more recent analyses render the action unjustified.

41. The X2 RPA commits FWS to a poorly designed experiment that would require at least 20 to 30 years of operation before it could produce meaningful data, if at all. Given the current complete lack of statistical support for an effect of X2 on smelt abundance, FWS has not explained how it would be useful to expend such extraordinary resources on an "experiment" that

[14] NRC Report at 25.

will, based on the existing statistical evidence, neither benefit the smelt nor confirm Mr. Feyrer's X2 hypothesis.

I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this Declaration was executed on June 16, 2011 at Fort Collins, Colorado.

Kenneth P. Burnham

DR. KENNETH P. BURNHAM

CERTIFICATE OF SERVICE

I hereby certify that on June 16, 2011, I electronically filed the foregoing with the Court by using the Court's CM/ECF system.

Participants in the case who are registered CM/ECF users will be served by the Court's CM/ECF system.

I further certify that the court-appointed experts are not registered CM/ECF users. I have emailed the foregoing **DECLARATION OF KENNETH P. BURNHAM IN SUPPORT OF PLAINTIFF'S MOTION FOR INJUNCTIVE RELIEF** to the following:

SERVICE LIST

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I declare under penalty of perjury under the laws of the State of California the foregoing is true and correct and that this declaration was executed on June 16, 2011, at San Francisco, California.

/s/ Lynda Robisch
Lynda Robisch
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Exhibit A

KENNETH P. BURNHAM

Retired from being Statistician, and Senior Scientist
USGS, Biological Resources Discipline
Colorado Cooperative Fish and Wildlife Research Unit
201 Wagar Bldg.
Colorado State University
Fort Collins Colorado 80523

EDUCATION

Undergraduate: B.S., Portland State University, Biology, 1960-1966
Graduate: M.S., Oregon State University, Statistics, 1966-1969
Ph.D., Oregon State University, Statistics, 1969-1972

PREVIOUS POSITIONS

Laboratory Technician, Department of Microbiology, University of Oregon Medical School, 1963-1965 (Portland, Oregon)
Mathematical Statistician, Institute of Northern Forestry, U.S. Forest Service, 1972-1973 (Fairbanks, Alaska)
Statistician, Migratory Bird and Habitat Research Lab, U.S. Fish and Wildlife Service, 1973-1975 (Laurel, Maryland)
Biometrician, Western Energy and Land Use Team, U.S. Fish and Wildlife Service, 1975-1983 (Fort Collins, Colorado).
Area Statistician, USDA-Agricultural Research Service, South Atlantic Area, August 1983-September 1988 (Raleigh, North Carolina)

20 Years in Colorado Cooperative Fish and Wildlife Research Unit:
Assistant Unit Leader, Colorado Cooperative Fish and Wildlife Research Unit, (Fort Collins, CO) since September, 1988. The Units were under the U.S. Fish and Wildlife Service from their inception in 1935 until late 1993. November 13, 1993 the Units were transferred to the newly created National Biological Survey agency within USDI. Later, the name was changed to National Biological Service. Then on October 13, 1996 all of NBS was eliminated as a freestanding agency by being merged with the US Geological Survey as a fourth division within USGS: then Biological Research Division (BRD); now called Biological Resources Discipline. Promoted to ***Senior Scientist*** on August 8, 2004.

Present Position at CSU)

ACADEMIC APPOINTMENTS

Adjunct Faculty, as Assistant Professor of Statistics, University of Alaska (Fairbanks) (1972-1973 academic year).
Affiliate Faculty, Department of Fisheries and Wildlife, Colorado State University (1978-1982 academic years).
Associate Professor (USDA), Statistics Department, North Carolina State University (1983-1988 academic years)
Faculty, Department of Fishery and Wildlife Biology, Colorado State University (September 1988-December 2008)

Affiliate Faculty, Department of Statistics**,** Colorado State University (September 1988-December 2008)

Note: See my Vitae information "*Academic*" for information on courses taught.

AWARDS AND FELLOWSHIPS RECEIVED

Note: See my Vitae information "*Awards, honors and special activities*".

PROFESSIONAL SOCIETIES

American Statistical Association (since 1967)
The International Biometric Society (since 1968)
Institute of Mathematical Statistics (since 1973)
International Statistical Institute, elected member (since 2007)
The Wildlife Society (since 1978)
Ecological Society of America (1990-2001)

On the Editorial Board of the Ecological Society of America (Oct. 1, 1989-December 31, 1992)
Associate Editor of Biometrics (May 1997-January 2000)
Elected to Regional Committee of the Western North America Region (WNAR) of the International Biometric Society (IBS) (2004-2006)
President-elect of WNAR (2006)
Present of WNAR (2007)
Past-President of WNAR (2008)

RESEARCH INTERESTS

Design of studies for sampling biological populations, especially for estimation of population abundance and population dynamics parameters.

Statistical inference methods for ecological, wildlife, and fisheries studies, and data-based modeling of biological processes, including model selection and assessing model selection uncertainty. Some specifics:

- Dynamics of exploited populations, especially the question of additivity of exploitation and natural mortality.
- The effect of heterogeneity in population dynamics (models), population sampling (i.e., size-biased sampling in ecology), and data analysis.
- Theory and application of release-recapture methodologies.
- Estimation of parameters from bird banding studies.
- Theory and application of distance sampling (line and point transects) of wildlife and plant populations.
- Closed-model capture-recapture theory.
- Open-model capture-recapture theory.
- Statistical design of environmental biotic studies.
- Model selection in population parameter estimation, especially using AIC in capture-recapture.
- Applied population sampling in natural resources based on finite population sampling theory.
- Theory and application of information theoretic (i.e., AIC) model selection in general

See also:
Publications
Awards, Honors and Special Activities
Academic

KENNETH P. BURNHAM

PUBLICATIONS

Burnham, K. P. and W. S. Overton, 1969. A simulation study of livetrapping and estimation of population size. Technical Report 14, Dept. of Statistics, Oregon State University (69 pages plus Appendix tables and figures).

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AWARDS, HONORS AND SPECIAL ACTIVITIES

State of Oregon partial tuition scholarship, Portland State University, September 1962- June 1966.

Undergraduate Award, The Portland State College Club of the Society of the Sigma XI in recognition of outstanding scholarship and exceptional promise in science, June, 1966.

Department of Health, Education and Welfare NDEA Title IV Fellowship for graduate studies at Oregon State University, September 1966-August 1969.

Department of Health, Education and Welfare, National Institutes of Health, Public Health Service Research Predoctoral Fellowship, Oregon State University, September 1969- August, 1971.

Excellence Award for "Robust estimation of population size from live trapping data," a paper presented at the 50th Annual Meeting of the Pacific Division, American Association for the Advancement of Science, Pullman, Washington, August 18-23, 1969.

The Li Award, Department of Statistics, Oregon State University, October 1970.

Adjunct Faculty Appointment, Assistant Professor of Statistics, University of Alaska, 1972-1973.

Federal training course, "The Supervisor's Job, Part 1," December 16-20, 1974.

Federal contract procurement procedures training, December 15-17, 1975, February 28-March 2, 1977, and July 27-28, 1981.

Attended the workshops regarding aerial line transect surveys of porpoise populations in the Eastern Tropical Pacific, National Marine Fisheries Service, August 30-September 1, 1977, December 8-9, 1977, October 5-6, 1978, and June 25-26, 1979. *See* NOAA-TM-NMFSSWFS-23 (Holt and Powers 1982), "Abundance Estimation of Dolphin Stocks in the Eastern Tropical Pacific Yellowfin Tuna Fishery Determined from Aerial and Ship Surveys to 1979."

Affiliate Faculty Appointment, Department of Fisheries and Wildlife, Colorado State University, 1978-1981.

Co-instructor of workshop "Inference procedures from capture studies to estimate population size in closed animal populations and other population estimation techniques," Denver Wildlife Research Center, February 27-March 2, 1979.

Quality Performance Award, U. S. Fish and Wildlife Service, December 4, 1979.

Attended "Workshop on Design of Sightings Surveys," International Whaling Commission, Seattle, Washington, September 11-16, 1980.

Participated in a one-week aerial line transect study of the humpback whale population on the Silver bank (just north of the Dominican Republic), February 1981.

Wildlife Publication Award for Wildlife Monograph No. 72, "Estimation of Density from Line Transect Sampling of Biological Populations," The Wildlife Society, 1981

Participated in Electrical Power Research Institute (EPRI) review of the EPRI-funded project "Sampling Design for Aquatic Ecological Monitoring," Seattle, Washington, June 13-15, 1983.

Associate Professor (USDA), Department of Statistics, North Carolina State University, and associate membership in the Graduate Faculty, NCSU, Fall 1983.

Special Achievement Award for "Field Methods and Statistical Analysis for Monitoring Small Salmonid Streams," U. S. Fish and Wildlife Service, November 1983.

Participated in the 1983-1984 pre-SOPS Panel C meetings, Southwest Fisheries Science Center, National Marine Fisheries Service, San Diego, California, December 5-9, 1983 and March 1-2, 1984.

Wildlife Publication Award for "Capture-recapture and Removal Methods of Sampling Closed Populations," The Wildlife Society, 1984.

Ecology Advisory Committee, North Carolina State University, 1984-1988.

Member of the Scientific Review Panel (also called the Study Design Group) on Monitoring Dolphin Populations in the Eastern Tropical Pacific (ETP), La Jolla, California, Nov. 1-2, 1984.

Member of the panel reviewing the final products from the EPRI project "Sampling Design for Aquatic Ecological Monitoring," Seattle, Washington, Nov. 27-28, 1984.

Ecology Executive Committee, North Carolina State University, 1986-1989.

Consultant to the National Marine Mammal Laboratory, Seattle, Washington, Sept. 29-30, 1986.

Regional Advisory Board of the Eastern North American Region (ENAR) of the Biometric Society, 1987-1990.

Received NSF travel grant under the NSF International Cooperative Research Program, 1988-1991.

Co-instructor of the "Workshop on design and analysis methods for fish survival experiments based on release-recapture," Fort Collins, Colorado, July 6-8, 1988. The textbook for this workshop published by Burnham, Anderson, White, Brownie and Pollock (1987)

Associate Professor, Department of Statistics, North Carolina State University, 1988-1989.

Affiliate faculty, Departments of Fisheries and Wildlife Science, and Department of Statistics, Colorado State University, Sept. 1988.

Participated in Smolt Survival Workshop sponsored by Bonneville Power Administration, University Washington, February 1-3, 1989.

Attended workshop, "Practical Biological Modeling" at the Spring ENAR meetings in Lexington, Kentucky, March 19, 1989.

Member of the Quality Review Board on the Minerals Management Service contract (to Envirosphere Company) "Oregon and Washington Marine Mammal and Seabird Surveys," Bellevue, Washington, April 20-21, 1989.

Editorial Board of Ecology, 1989-1992.

WNAR Nominating Committee, 1990.

Study Design Team regarding Snake River Birds of Prey Area, BLM, 1991-1994.

Presented seminar "A unified theory for release-resampling studies of animal populations," Institute of Statistics, National Tsing Hua University, Hsinchu, Taiwan, June 4-6, 1990.

Study Design Group on monitoring dolphin populations in the Eastern Tropical Pacific (ETP), Southwest Fisheries Science Center, National Marine Fisheries Service, La Jolla, California, July 10-11, 1990.

ASA Fellow, August 7, 1990.

Special Achievement Award for analytical work performed related to the Northern Spotted Owl, U.S. Fish and Wildlife Service, August 21, 1990.

Member of Scientific Organizing Committee for the third EURING conference "The Use of Marked Individuals in the Study of Bird Population Dynamics: Models, methods and Software," Montpellier, France April 7-11, 1992.

Attended Study Integration Workshop regarding Snake River Birds of Prey, Bureau of Land Management, September 18-20, 1990.

WNAR Nominating Committee, 1991.

Committee on Fellows and Awards, ASA Section for Statistics and the Environment, 1991-1992.

Member of the Quality Review Board on the Minerals Management Service contract (to EBASCO), "Oregon and Washington Marine Mammal and Seabird Surveys," in Bellevue, Washington, August 28-29, 1991.

Co-instructor of workshop on the analysis of marked animal resampling data, Fort Collins, Colorado, Sept. 23-27, 1991 and January, 13-17, 1992.

Review Panel member, Status of Porpoise Stocks (SOPS), Southwest Fisheries Research Center, National Marine Fisheries Services, La Jolla, California, November 18-21, 1991.

Presented seminar, "On a unified theory for release-resampling of animal populations," Department of Statistics, Oregon State University, February 17, 1992.

Panel member, "Harbor Porpoise in Eastern North America: Status and Research Needs," Northeast Fisheries Science Center, National Marine Fisheries Service, May 5-8, 1992.

Special Achievement Award for Superior Performance, U.S. Fish and Wildlife Service, September 6, 1992.

Promoted from a Level GS 13 to a GS 14 via the Research Grade Evaluation Process (RGEP), U.S. Fish and Wildlife Service, November 15, 1992.

Participated in the BLM/IDARNG Integration Workshop regarding the Snake River Birds of Prey Area, Boise, Idaho, November 17-19, 1992.

Received the Director's Award for Outstanding Science for participation in The Colorado Cooperative F&W Research Unit, U.S. Fish and Wildlife Service, 1992.

Co-instructor of workshop on the analysis of marked animal re-sampling data, Montpellier, France, Feb. 15-19, 1993.

Participated in the Status of California Cetacean Stocks (SOCCS 1993) workshop, Southwest Fisheries Science Center, National Marine Fisheries Service, March 31, April 1 & 2, 1993.

Received a Distinguished Achievement Medal and a Bronze Medal from the ASA Section on Statistics and the Environment, Joint Statistics Meetings (SAS, IMS, ENAR, WNAR), San Francisco, California, August 1993.

Co-instructor of workshop "Design and Analysis of Distance Sampling Data: Theory and Application." Fort Collins, Colorado, October 25-29, 1993 and Nov. 1-5, 1993. *See* Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake. 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman & Hall, London, and the associated computer program DISTANCE.

Special Achievement Award for outstanding performance (i.e., Level 5), U.S. Fish and Wildlife Service, November, 1993.

Co-organized and conducted a workshop and data analysis effort, and wrote the report on a comprehensive statistical analysis of the demographic data on the Northern Spotted Owl. *See* Burnham, K. P., D. R. Anderson, and G. C. White. 1994. Estimation of vital rates of the Northern Spotted Owl, and Appendix J to the Supplemental Environmental Impact Statement on Management of Habitat Late-Successional and Old-Growth Forest Related Species Within the Range of the Northern Spotted Owl, U.S. Forest Service and BLM, February 1994.

Co-instructor of workshop "Design and Analysis of Distance Sampling Data: Theory and Application," University of Canberra, Canberra, Australia, April 19-22, 1994.

Presented seminar on distance sampling theory, to the University of Hong Kong, Department of Statistics, May 3, 1994.

Special Achievement Award regarding Northern Spotted Owl demographics, National Biological Survey, May 1994.

Co-instructor of workshop, "Design and Analysis of Distance Sampling Data: Theory and Application," Hedmark College, Evanstad, Norway, June 13-17 1994.

Distinguished Statistical Ecologist Award from International Congress of Ecology (INTECOL), given at the international meeting, Manchester, United Kingdom, August 21-26, 1994.

Member of the Scientific Program Committee at the fourth EURING conference, "State-of-the-Art Data Analysis for Studies of Marked Birds," Patuxent Wildlife Research Center, Laurel, Maryland, September 20-24, 1994.

Co-instructor of a workshop on distance sampling, University of St. Andrews, Scotland, September 26-30 1994.

Co-instructor of workshop "Design and Analysis of Distance Sampling Data: Theory and Application," University of Natal, Pietermaritzburg, South Africa, June 26-30, 1995.

Overseas examiner on the Ph.D. thesis of Richard Barker regarding capture-recapture theory in extended Jolly-Seber models, Massey University, New Zealand, December 1995.

Overseas examiner on the Ph.D. thesis of David Borchers regarding line transect theory extended to joint estimation of g(0) and f(0) with covariates for both components, University of Cape Town, South Africa, June 1996.

Co-presented workshop "Information theory based model selection and model selection uncertainty," Statistics Program and Wildlife Program, Montana State University, October 31-November 1, 1996.

Participated in workshop on monitoring guidance to the Desert Tortoise Research Council, Laughlin, Nevada, November 20-21, 1996.

Participated in a cooperative study on issues regarding the red-cockaded woodpecker (RCW), U.S. Army, Fort Bragg, North Carolina, February 26-28, 1997.

Associate Editor of Biometrics, May, 1997-2000.

Co-instructor of workshop on the analysis of striped bass tag recovery data, U.S. Geological Survey, Reston, Virginia, June 17-19, 1997.

Panel Member of a team of external reviewers for the St. Marys River Fisheries Assessment Plan, Great Lakes Fishery Commission, March 2002.

Co-instructor of workshop, "Survival estimation from data on populations of marked animals;" University of St. Andrews, Scotland, August 10-13, 1998.

Co-instructor of workshop "Line transect sampling methods for desert tortoise abundance estimation," Las Vegas, Nevada, October 4-8, 1998.

Co-leader of a data analysis workshop on the demographic capture-recapture and fecundity data for the northern spotted owl, Oregon State University, Corvallis, Oregon, December 7-15, 1998. *See*, Franklin, A. B., K. P. Burnham, G. C. White, R. J. Anthony, E. D. Forsman, C. Schwarz, J. D. Nichols, and J. Hines. 1999. Range-wide status and trends in northern spotted owl populations. U. S. Geological Survey, Biological Resources Division, Corvallis, Oregon. 56pp.

Expert for NMFS review of line transect monitoring data on dolphin abundance in the Eastern Tropical Pacific (ETP), Southwest Fisheries Science Center, National Marine Fisheries Service, January 21, 1999.

Attended the Technical Advisory Group overseeing design and implementation of a large-scale, 25 year monitoring program for the Mohave desert tortoise, Las Vegas, Nevada, January 25, 1999.

Twentieth Century Distinguished Service Award for Outstanding Contribution to Environmental Statistics, Ninth Lukacs Symposium "Frontiers of environmental and ecological statistics for the 21st century: synergistic challenges, opportunities and directions for statistics, ecology, environment, and society." Bowling Green State University, Bowling Green, Ohio, April 1999.

Co-instructor of workshop "Analysis of encounter data from marked animal populations," Colorado State University, June 7-11, 1999.

Co-instructor of workshop, "Statistical methods for studying animal populations," University of Nairobi, Nairobi, Kenya, June 27-July 2, 1999.

Special Thanks for Achieving Results (STAR) Award for participation in a USGS-BRD scientific panel that reviewed long-term studies of the Ecological Synthesis Team of the National Water-Quality Assessment Program, Department of Interior, June, 1999.

Instructor of workshop, "The foundations of AIC and its use in multi-model inference," University of Wyoming, October 8, 1999.

Participated in workshop, "Modeling demography of spotted owls in relation to habitat characteristics)," Oregon State University, November 18-19, 1999.

Attended the Atlantic States Marine Fisheries Commission meeting regarding analysis of tag-recovery data from the northeastern USA striped bass tagging program, Smithtown, Long Island, New York, February 29-March 1, 2000.

Technical review of Wild Horse Population Model Version 3.2, by S H. Jenkins, University of Nevada, Reno, March 2000.

Co-authored seminar "Model Testing and Selection in Wildlife Data Analysis," The Wisconsin Cooperative Wildlife Research Unit, March 28, 2000.

Presented seminar "The foundation of AIC and its use in multi-model inference," Washington Statistical Society (WSS), Patuxent Wildlife Research Center, Laurel, Maryland, May 8, 2000.

Co-instructor of workshop “New quantitative techniques for applied ecological problem solving.” Aspen Lodge, Estes Park, Colorado, May 22-23, 2000.

Co-instructor of workshop “Analysis of encounter data from marked animal populations,” Colorado State University, June 5-9, 2000.

Co-instructor or workshop “International Workshop on Wildlife Population Assessment,” University of Queensland, Brisbane, Australia, July 3-7, 2000.

Member of the Technical Advisor Group (TAG) to the CITES MIKE program, September 2000-July 2006.

Co-instructor of workshop “Information-theoretic methods: Alternatives to statistical null hypothesis testing,” Annual Meeting of The Wildlife Society, Nashville, Tennessee, September 12, 2000.

Co-instructor of workshop regarding the analysis of capture-recapture (and related) data using program MARK, Colorado State University, June 4-8, 2001.

Participated in sub-committee meeting “Review of Southern Hemisphere Minke Whale Abundance Estimates,” at the 53rd committee of the Scientific Committee of the International Whaling Commission (IWC), London, England, July 4-16, 2001.

Participated in workshop “Introduction to Distance Sampling Workshop,” University of St. Andrews, Scotland, July 25-27, 2001.

Received The Wildlife Society's 2001 Wildlife Publication Award in Outstanding Monograph Category. *See* Franklin, A. B., D. R. Anderson, R. J. Gutiérrez, and K. P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwest California. *Ecological Monographs*. 70:539-590.

Award for Science Excellence, U.S. Geological Survey, Cooperative Research Units, February 5, 2002.

Co-instructor of workshop “Analysis of encounter data from marked animal populations,” Colorado State University, June 3-7, 2002.

STAR Award (Special Thanks for Achieving Results), U.S. Geological Survey, August 2002.

Instructor of seminar “Model selection: Understanding AIC and multimodel inference, with contrasts to BIC.” University of Chicago, Chicago, Illinois, January 29-30, 2003.

Instructor of seminars “Advances in capture-recapture: parameters as random effects,” and “Model selection: AIC, BIC and Multimodel Inference,” UC Santa Barbara, February 10- 11, 2003.

Co-instructor of workshop “Analysis of encounter data from marked animal populations,” Colorado State University, June 2-5, 2003.

STAR Award (Special Thanks for Achieving Results) for my recent role on the MIKE TAG Team, U.S. Geological Survey, June 2003.

Instructor of seminar “Model selection: AIC, BIC and multimodel inference,” Victoria University of Wellington, New Zealand, December 15-17, 2003.

Participated in the workshop “Northern Spotted Owl Demography Workshop,” Oregon State University, January 4-11, 2004.

Member of Western North American Region of the International Biometrics Society (WNAR) Regional Committee, 2004-2006.

Participated in workshop “Chronic wasting disease risk analysis workshop: An integrative approach,” Fort Collins Science Center, U.S. Geological Survey, May 11-13, 2004.

Co-instructor of workshop, “Analysis of encounter data from marked animal populations,” Colorado State University, June 14-18, 2004.

Member of the Scientific Peer Review Panel during workshop, “Stephen's kangaroo rat monitoring workshop for MCB Camp Pendleton,” San Diego Field Station of the Western Ecological Research Center (USGS-BRD), San Diego, California, July 19-20, 2004.

Promoted to Senior Scientist (GS16), U.S. Geological Survey, August 8, 2004.

Attended the course “ST675K Bayesian Statistics,” taught by Dr. Jennifer Hoeting, Fall Semester, 2004, Colorado State University

Attended meeting of the U.S. Geological Survey Cooperative Research Units, Jacksonville, Florida, March 1-3, 2005.

Participated in workshop “Protecting Apes from Eboloa,” U.S. Fish and Wildlife Service, Arlington, Virginia, March 10-11, 2005.

Co-instructor of workshop “Analysis of Encounter Data from Marked Animal Populations,” Colorado State University, June 6-10, 2005.

Provided technical assistance to the USFWS Wetlands Status and Trends project meeting, U.S. Fish and Wildlife Service, La Crosse, Wisconsin, June 14-15, 2005.

President of **W**estern **N**orth **A**merican **R**egion of the International Biometrics Society, 2007

Participated in the workshop “San Clemente Island Fox Monitoring Planning Workshop,” U.S. Department of the Navy and the Conservation Biology Institute, San Diego, California, January 12-14, 2006.

Participated in workshop “MBI Workshop 5: Uncertainty in Ecological Analysis,” Mathematical Biosciences Institute with collaboration from the Department of Statistics, Ohio State University, Columbus, Ohio, April 3-6, 2006.

Instructor of workshop "Model Selection and Multi-model Inference from both information theory (i.e., Akaike Information Criterion (AIC)) and Bayesian perspectives," University of California, Davis, California, May 12-13, 2006.

Co-instructor of workshop "Analysis of Encounter Data from Marked Animal Populations," Colorado State University, Fort Collins, Colorado, June 5-9, 2006.

Member of The Interagency National Risk Analysis Working Group regarding Avian Influenza (AI) monitoring, funded by a support contract to Colorado State University from the Research, Surveillance, Monitoring, and Response for Wildlife Diseases, USDA/APHIS- National Wildlife Research Center, Fort Collins, 2006-2007.

Participated in workshop "Workshop on Bayesian Methods in Wildlife Population Monitoring," Program for Interdisciplinary Mathematics, Ecology, and Statistics, Colorado State University, June 14-16, 2006.

Instructor of seminar "Model based inference in ecology: recent extensions to likelihood theory," University of Oklahoma, Norman, Oklahoma, October 4-5, 2006.

Recipient of the distinguished Landmark Paper proclaim in 2006 with regard to Burnham, K. P., and D. R. Anderson. 2001. Kullback-Leibler information as a basis for strong inference in ecological studies. *Wildlife Research*. 28:111-119.

Recipient of the Meritorious Service Award, Department of the Interior, November 9, 2006.

Recipient of the Douglas L. Gilbert Award for 2006, Colorado Chapter of The Wildlife Society, January, 2007.

Member of the International Statistical Institute, February, 2007.

Speaker and Invited Scholar at workshop, "Model Selection and Statistical Learning, in honor of Hirotugu Akaike receiving the Kyoto Prize," UC San Diego, March 15, 2007.

Co-instructor of workshop, "Analysis of Encounter Data from Marked Animal Populations," Colorado State University, June 4-8, 2007.

Recipient of the Certificate of Recognition for 40 years of membership in the American Statistical Association, June 23, 2007.

Speaker of panel "OSU and environmental statistics," 50th Anniversary Celebration of the Oregon State University, June 29 and 30, 2007.

Speaker of seminar, "Challenges and opportunities for analysis of capture-recapture data" at the conference, "Recent developments in capture-recapture methods and their applications," University of Reading, England, July 11-13, 2007.

Member of the Scientific Peer Review Panel during the Pacific Pocket Mouse (PPM) Monitoring Workshop for Marine Corps Base Camp Pendleton (MCBCP), U.S. Geological Survey and Western Ecological Research Center, San Diego, California, September 6-7, 2007.

Co-instructor of workshop on AIC-based model selection, Department of Biological and Environmental Science, University of Jyvaskyla, Finland, November 5-7, 2007.

Instructor of workshop on AIC-based model, UC San Diego, March 7, 2008.

Co-instructor of workshop "Analysis of Encounter Data from Marked Animal Populations," Colorado State University, June 1-6, 2008.

Instructor of workshop, "NSO Demography Workshop," Oregon Cooperative Wildlife Research Unit, Oregon State University, January 9-18, 2009

Recipient of the 2009 Northern Spotted Owl Conservation Award, January 15, 2009.

Speaker of seminar "The fundamental ideas of AIC-based model selection and multimodel inference," Distinguished Lecturer Series, Texas A&M University, February 27, 2009.

Speaker of seminar "The fundamental ideas of AIC-based model selection and multimodel inference," Colorado State University, March 23, 2009.

Speaker of seminar "The fundamental ideas of AIC-based model selection and multimodel inference," CNRS-CEFE, Montpellier, France, April 3rd, 2009.

Member of the STAR panel organized by the Pacific Fishery Management Council, Southwest Fisheries Science Center, National Marine Fisheries Service, May 4-8, 2009.

Co-instructor of workshop, "Analysis of Encounter Data from Marked Animal Populations," Colorado State University, June 1-5, 2009.

Recipient of the U.S. Forest Service "Wings across the Americas" award for the long-term studies of the Northern Spotted Owl, March 2009.

ACADEMIC ACTIVITIES

Spring term 1989, co-taught FW 661, Design of Fish and Wildlife Studies.

Spring term 1990, co-taught FW663, Sampling and Analysis of Vertebrate Populations.

Fall terms 1990, 1992, 1994, 1996, 1998, 2002, 2004, 2006 & 2008, taught FW551, Design of Fish and Wildlife Studies.

Faculty member, Colorado State University, Program for Ecological Studies (PES), September 1991.

Fall semester, 1993, co-taught graduate seminar on finite sampling theory based sampling in wildlife and natural resources in general.

On the selection committee for Assistant Professor and Professor positions, Colorado State University, Department of Statistics, Fall 1999-May 2000.

Fall 2001, taught FW696 on the principles of probability sampling with emphasis on applications to natural resources and ecology.

Fall semester, 2002, taught a seminar section in EY592 (cross-listed as FW592) on philosophy of science for ecology.

Spring semesters, 2004 & 2006, co-taught FW663, Sampling Biological Populations, a course on marked animal data and distance sampling.

On the Search Committee for a Population Quantitative Ecologist position, Colorado State University, Department of Fishery and Wildlife Biology, August-October 2007.

Exhibit B

Ken Burnham: A Life in Science

Presented at the International Statistical Ecology Conference

9-11 July 2008, University of St Andrews

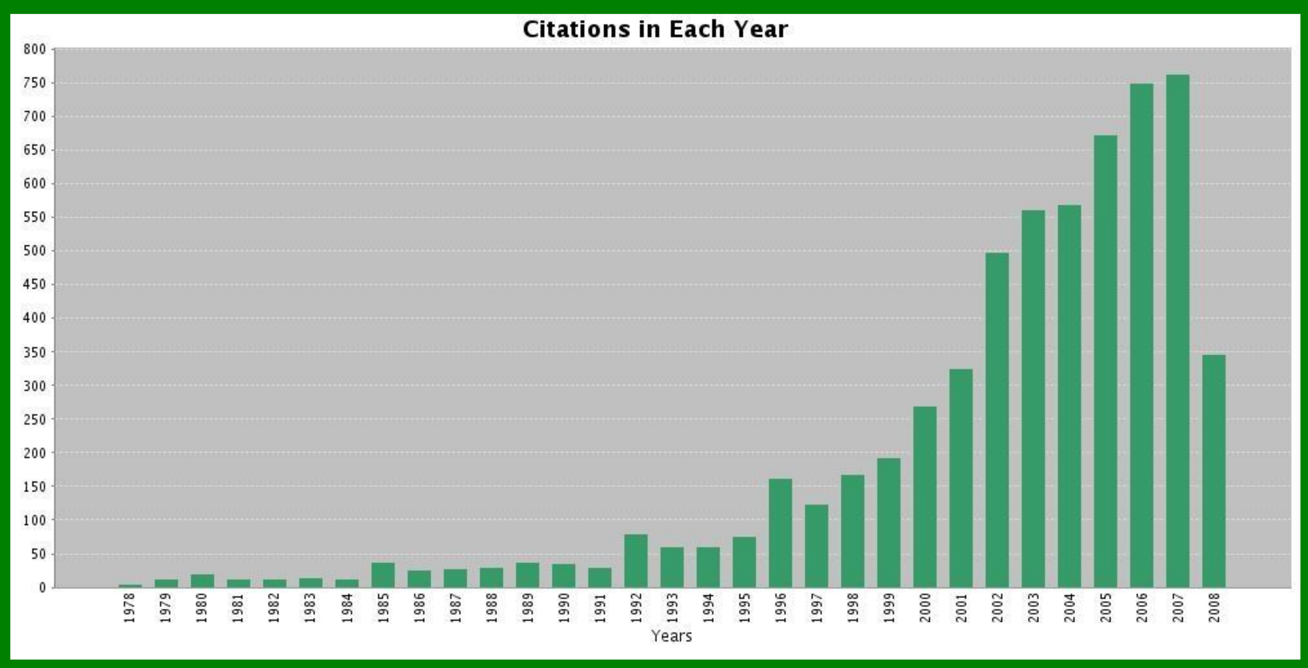


Figure: *Annual citations of Ken's work. Source – ISI Web of Science*

Highly cited Publications

Total number of publications — 1970s: 27 — 1980s: 43 — 1990s: 59 — 2000s: 49+

1970s

Burnham, K.P. and Overton, W.S. (1978) Estimation of the size of a closed population when capture rates vary among animals. *Biometrika* **65** 625-633

Burnham, K.P., and Anderson, D.R. (1976) Mathematical models for nonparametric inferences from line transect data. *Biometrics* **32**(2) 325-336

Otis, D.L., Burnham K.P., White, G.C. and Anderson, D.R. (1978) Statistical inference from capture data on closed animal populations. *Wildlife Monographs* **62**, 1 - 135

1980s

White, G.C., Anderson, D.R., Burnham, K.P. and Otis, D.L. (1982) *Capture-Recapture and Removal methods for sampling closed populations*. Los Alamos National Laboratory Rep. LA-8787-NERP, Los Alamos, New Mexico, USA. 235pp.

Brownie, C., Anderson, D.R., Burnham, K.P. and Robson, D.S. (1985) *Statistical inference from band recovery data – a handbook.* US Fish and Wildlife Service

Burnham, K.P., Anderson, D.R. and Laake, J.L. (1980) Estimation of density from line transect sampling of biological populations. *Wildlife Monographs*

Burnham, K.P., Anderson, D.R., White, G.C., Brownie, C. and Pollock, K.H. (1987) *Design and analysis methods for fish survival experiments based on release-recapture*. American Fisheries Society Monograph 5.

1990s

White, G.C. and Burnham, K.P. (1999) Program MARK: Survival estimation from populations of marked animals. *Bird Study,* **46** S120 -138

Lebreton, J.-D., Burnham, K.P., Clobert, J. and Anderson, D.R. (1992) Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. *Ecological monographs*, **62**(1) 67-118

Burnham, K.P., White, G.C., and Anderson, D.R. (1995) Model selection strategy in the analysis of capture-recapture data. *Biometrics* **51** 888-898

Burnham, K.P (1993) A Theory for combined analysis of ring recovery and recapture data *In: Marked Individuals in the Study of Bird Populations,* J.D. Lebreton and P.M.North (eds.) Birkhauser Verlag.

Buckland, S.T., Burnham, K.P. and Augustin N.H. (1997) Model selection: An Integral part of inference. *Biometrics* **53** 603-618

2000s

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (eds.) (2004) *Advanced Distance Sampling: Estimating Abundance of Biological Populations.* Oxford University Press.

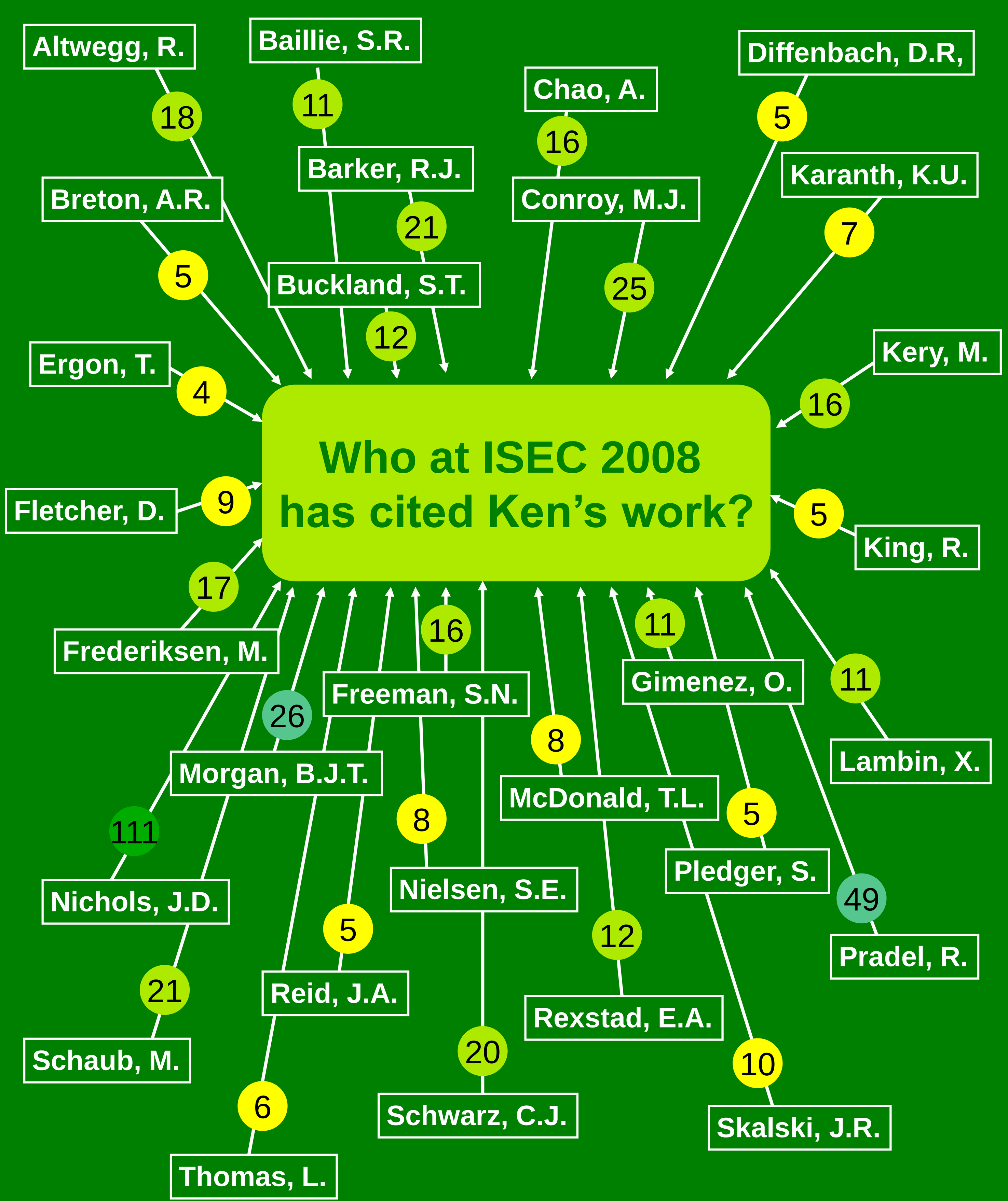
Burnham, K.P. and White, G.C., (2002) Evaluation of some random effects methodology applicable to bird ringing data. *Journal of Applied Statistics* **29**(1-4) 245-264

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. and Thomas, L. (2001) *An Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Oxford University Press.

Burnham, K.P. and Anderson, D.R. (2002) *Model selection and multimodel inference: A practical information theoretic approach*. 2nd Ed. Springer

1-10 | 11-25 | 26-50 | 50+

Number of citations of a paper contributed to by Ken



Academic Awards

1990 – Fellow of the American Statistical Association (ASA)

1993 – Distinguished Achievement Medal, ASA

1994 - Distinguished Statistical Ecologist INTECOL

2007 – President of Western North American Region of International Biometric Society

2007 – Elected member of the International Statistical Institute

Dr. Ken Burnham received special recognition at the International Statistical Ecology Conference in St. Andrews, Scotland, July 9-11, 2008. The Conference, organized and hosted by University of St. Andrews, The National Centre for Statistical Ecology, and the Centre for Research into Ecological and Environmental Modelling brought together ecological statisticians and quantitative ecologists from around the world. The evening of the poster session included a special event, as Conference organizers presented Ken Burnham with a poster highlighting his 35+ year career in the field of statistical ecology. The poster (see below) included a career timeline, marked by selected publications and contributions by Ken over the last few decades. The poster also included an interesting sample illustration of Ken's influence in statistical ecology, a list of Conference attendees and the number of times each had cited Ken's work in publications. Indeed, some attendees had cited Ken's papers > 100 times in their work. Seminal papers by Burnham underlie many of the most important classes of methods in statistical ecology (e.g., band recovery models, closed and open capture-recapture models, distance sampling, model selection), and the poster presentation provided a nice tribute to Ken and his pervasive influence in our field.

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Attorneys for Plaintiff THE METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA

UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA Partially Consolidated With: 1:09-cv-480 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	**REPLY DECLARATION OF DR. KENNETH P. BURNHAM IN SUPPORT OF PLAINTIFFS' MOTION FOR INJUNCTIVE RELIEF**
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	Date: July 26-29, 2011 Time: 8:30 a.m. Ctrm: 3 Judge: Hon. Oliver W. Wanger
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	

I, DR. KENNETH P. BURNHAM, declare:

1. My declaration is set forth in the following manner.

INTRODUCTION

2. In this declaration I will respond to the declaration of Mr. Frederick V. Feyrer ("Feyrer Decl.") in support of Defendants' Opposition to Plaintiff's Motion for Injunctive Relief.

3. In this declaration I will address three basic points: First, I will explain that Mr. Feyrer has failed to respond to one of my most fundamental criticisms of his work in the BiOp and in Feyrer (2011): namely that his analysis chains together a series of models, each of which contains a high degree of statistical uncertainty, without accounting for or testing the effect of that accumulation of error. (*See* Declaration of Kenneth P. Burnham in Support of Plaintiff's Motion for Injunctive Relief, Doc. 921 ("Burnham Decl.") at ¶¶ 21-23.) This criticism, which was also raised by the NRC, goes to heart of whether X2 is a useful or effective surrogate for smelt habitat and whether manipulating X2 is likely to benefit the smelt.

4. Second, I will explain that Mr. Feyrer has failed to respond to my point that his "habitat index" does not provide an appropriate metric of the quantity of smelt habitat because it excludes areas of known smelt habitat. The addition of the large habitat areas in Cache Slough and the Sacramento Ship Channel changes the denominator in Mr. Feyrer's index, which means that his results—such as his claim that there has been a 78% decline in the habitat index—are misleading about changes in actual smelt habitat.

5. Finally, I will discuss the central flaw in FWS's use of X2 as a management variable to benefit the smelt: there is no statistical evidence that changes in X2 affect the abundance of delta smelt. This was the conclusion of Kimmerer (2009), which found no relationship between spring X2 and smelt abundance. This was the conclusion of Maunder & Deriso (2011), which found, using a quantitative life-cycle model, that there is no evidence that X2 affects smelt abundance. And this was the conclusion of Mac Nally et al. (2010) and Thomson et al. (2010), both of which list Mr. Feyrer as a co-author. Mr. Feyrer does not offer any evidence to the contrary, but instead relies on a vague attack on the science of statistics itself. As I will explain, this attack is illegitimate and is indicative of the state of the Fall X2 Action in

general: a management plan with no apparent statistical support that is about to be implemented as an "experiment" without any clear plan for how to develop the data that could either support or refute it.

I. The Habitat Analysis in Feyrer (2011) and the BiOp Fails to Account for Significant Uncertainty that Renders it Invalid

A. There is no statistical support for the use of X2 as a surrogate for "suitable" smelt habitat

6. In my previous declaration, I explained that it was "scientifically improper" for Mr. Feyrer to chain the results of a number of separate modeling efforts together without accounting for the substantial error introduced at each step. (Burnham Decl. ¶¶ 21-22.) I noted that the NRC identified the same fundamental error, criticizing the Fall X2 Action because "the examination of uncertainty in the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses . . . with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step." (Burnham Decl. ¶ 23). And I concluded that Mr. Feyrer's analysis "violate[d] the most fundamental principle of statistical theory, which is that a statistical inference should include information on the uncertainty of that inference." (Burnham Decl. ¶ 22). Mr. Feyrer does not respond to any of these points.

7. In order to understand why this error is so fundamental, it is important to understand exactly what Mr. Feyrer has done in creating his "habitat index" and ultimately in choosing X2 as a surrogate for "suitable" smelt habitat. I have explained this step-by-step in my previous declaration, so I will only summarize briefly here. First, in Feyrer (2007), Mr. Feyrer modeled the relationship between three habitat variables—specific conductance (salinity), Secchi depth (turbidity), and temperature—and the presence or absence of delta smelt at a particular sampling site in the Fall Midwater Trawl. He found a predictive correlation between those three variables and the presence/absence of smelt, but the correlation was relatively weak: about 26% as R-squared.

8. In the second step of his analysis for Feyrer (2011) and the BiOp, Mr. Feyrer simply ignored the weakness of that correlation, and assumed that the three abiotic factors *defined* "suitable" smelt habitat. Using that definition, which masked the extent of uncertainty regarding the utility of those variables, he then used habitat-area modeling to translate the model-generated probabilities of presence/absence into a "habitat index" that would represent the extent of "suitable" smelt habitat.

9. Finally, in the third step, Mr. Feyrer modeled the relationship of X2 and the habitat index, from which he concluded that X2 could be used to predict and drive changes in the habitat index.[1] The management conclusion derived from this series of analyses, which is that moving X2 seaward will increase the range of locations where smelt will be found, is presented without any qualification regarding the substantial statistical uncertainty at each step. But this analysis is built on shaky foundations: each new layer of modeling and analysis puts more and more weight on that original weak correlation between the three abiotic habitat factors and smelt presence/absence—weight that, as a statistical matter, the correlation cannot bear.

10. But Mr. Feyrer repeatedly fails to acknowledge the fundamental weakness of his analysis. In his declaration, he defines his habitat index as "representing the surface area of the estuary standardized for salinity and water clarity conditions that are favored by delta smelt." (Feyrer Decl. ¶ 10.) However, the reality is that his index represents *one component* of the surface area of the estuary that delta smelt "favor," if at all, to a very low degree. This is a "habitat index" of very limited scope in terms of variables, volume, and explanatory power. And yet, by paragraph 12 of his declaration, Mr. Feyrer declares that X2, which is itself only a surrogate for his habitat index, actually *explains* "(a) where the habitat is located, (b) how much habitat exists, and (c) the suitability of the habitat." (*Id.* ¶ 12.) This overreaching, whereby Mr. Feyrer attempts to exaggerate the weak correlation of his original analysis in Feyrer (2007) into a universal conclusion regarding the influence of X2, is unscientific, improper, and unconvincing.

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[1] In Feyrer (2008) and the BiOp, Mr. Feyrer took an additional step of modeling the relationship between X2 and smelt abundance. I will discuss this analysis further below.

It is also the only support for the proposition that the location of X2 determines the amount of suitable smelt habitat. Despite this, Dr. Norris, for example, simply states that X2 defines "suitable" smelt habitat as if it were a plain statement of fact. (*See, e.g.*, Norris Decl. at ¶ 15)

11. Once again, this practice of ignoring the uncertainty built into the components of the model was the exact concern identified by the NRC, which noted that the chained analyses supporting the X2 action were "correlative with substantial variance being left unexplained at each step." (NRC Report at 41.) This statistical error is too large and too fundamental for Mr. Feyrer, or FWS, to ignore.

B. X2 is an improper surrogate for smelt "habitat suitability"

12. In my previous declaration I explained that one of the significant weaknesses in Mr. Feyrer's habitat analysis was that he only considered three abiotic variables, and no biotic variables. (Burnham Decl. at ¶ 19.) Such a limited selection of variables, which does not even account for basic biotic factors such as food supply or predator abundance, is unlikely to provide much insight into the true habitat requirements of a species. As I explained, "smelt will not survive in 'suitable' abiotic habitat if there is no food for them." (*Id.*)

13. Mr. Feyrer claims that I "miss the point." (Feyrer ¶ 13.) He claims that abiotic habitat is somehow *necessarily* more important than biotic factors to the survival of a species: "Abiotic habitat factors are the underlying foundation that determines where an organism can live and reproduce." (*Id.*) But there is simply no scientific support for this position, and Mr. Feyrer cites to none. Every species relies on both biotic and abiotic habitat factors to survive. One cannot survive without oxygen, but it is equally true that one cannot survive without food. The real question for any particular population is which habitat variables—biotic or abiotic—are actually *limiting* the population of the species. Mr. Feyrer claims that here salinity is limiting the smelt, and yet the evidence for this is very thin: smelt are found within a wide range of salinity zones and, as Mr. Feyrer's own work demonstrates, there is only a weak correlation between his ideal level of salinity and the presence/absence of smelt in the Delta. Moreover, Mr. Feyrer has been unable to demonstrate a link between changes in X2 and changes in smelt abundance. It

does not appear from the data that the smelt's abiotic habitat is actually *limiting* the smelt population.

14. Indeed, Kimmerer (2009) found, regarding a similar measure of smelt abiotic habitat, that "abundance of delta smelt did not vary with X2 . . . Despite the evident increase in the amount of habitat, delta smelt abundance appears to be regulated by factors so far unidentified." On the other hand, Maunder & Deriso (2011) did find that prey availability has a statistically significant effect on smelt abundance. Given this evidence, it seems more likely that smelt are limited by a biotic aspect of their habitat, food supply, rather than by salinity, an abiotic factor. As this example illustrates, the question of whether an abiotic factor or a biotic factor is more important to a species is a matter to be determined by rigorous scientific analysis, not unsupported assertion.

II. Mr. Feyrer's "Habitat Index" Excludes Essential Smelt Habitat

15. In my previous declaration, I explained that the "habitat index" Mr. Feyrer developed in Feyrer (2011) is misleading about the purported changes in "suitable" smelt habitat caused by the movement in X2. (Burnham Decl. ¶¶ 27-31.)[2] As I explained, in order for Mr. Feyrer's index of "suitable" habitat to have any utility in predicting changes in total real smelt habitat, the data on which the model was based must reasonably match up with the actual true area of smelt habitat. (Burnham Decl. ¶ 27.) This is not the case with Mr. Feyrer's index, which excludes large areas of known smelt habitat, such as the Sacramento Ship Channel and Cache Slough, and therefore misrepresents changes in actual smelt habitat.

16. Mr. Feyrer claims that this is unimportant because the Cache Slough and Sacramento Ship Channel habitat is all "suitable" under his analysis, and thus their addition to the analysis "would simply add a constant number of units to the habitat index, which would not affect the shape of the X2-habitat index relationship." (Feyrer Decl. ¶ 16.) This is true, but it

[2] I also expressed concern regarding Mr. Feyrer's methodological error of excluding a number of FMWT sites from his analysis on the basis that they were places were "delta smelt were rarely encountered." I accept Mr. Feyrer's conclusion that the addition of those extra sites would not have changed his modeling results, even if I continue to question the original erroneous decision to exclude them.

misses the point. Yes, the *shape* of the curve would be unchanged, but its *meaning* would be different. This is because the addition of habitat area effectively changes the denominator of the habitat index. For example, in Feyrer (2011), Mr. Feyrer asserts that "the habitat index has declined by 78% over the course of monitoring." However, the 78% figure is based only on the surface area that was included in Mr. Feyrer's model, which did *not* include the surface area of the Cache Slough and Sacramento Ship Channel sites. Adding those sites—and any other sites where smelt are located but which were not included in Mr. Feyrer's index—would mean changing the denominator of the percentage calculation, which would decrease the modeled percent change effect of X2 on smelt habitat.

17. Mr. Feyrer attempts to downplay this error by implying that the delta smelt populations in Cache Slough and the Sacramento Ship Channel may not actually be important to the species as a whole: "It is not clear how long year-round occupancy of that area has been occurring, or what proportion of the population might exist there." (Feyrer Decl. ¶ 16.) But this is because there has not been FMWT sampling at those sites until recently, and it is quite possible that there are populations of smelt in other locations that are not sampled.[3] As Mr. Feyrer concedes these fish "do not represent a separate, autonomous population." (*Id.*). They are delta smelt, and Cache Slough and the Sacramento Ship Channel are currently part of their habitat whether Mr. Feyrer's habitat index acknowledges it or not.

III. X2 Has No Measurable Effect on Smelt Abundance

18. Ultimately, the most significant weakness with the Fall X2 Action is that there is no statistical relationship between the location of X2 and changes in delta smelt population over time. For the NRC, this was the sticking point: "[t]he weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand." (Burnham Decl. ¶ 40.) This was true in 2010, when the NRC issued its report, and it is even more so now in 2011 when quantitative life-cycle models such as Maunder & Deriso

[3] The FMWT was designed to sample striped bass, not delta smelt, and there is no reason to assume that it reflects the exact contours of smelt habitat—as the recent additions of the Cache Slough and Sacramento Ship Channel sites indicate.

(2011) show no statistically significant relationship between X2 and abundance. The absence of a relationship between X2 and abundance seriously calls into question the utility of X2 as a management tool for delta smelt.

19. Mr. Feyrer's ad hoc analyses cannot make up for this absence. For example, his Figure 5, which shows the upper and lower boundaries of the graph of his habitat index and the FMWT abundance index says essentially nothing about X2 (which is not a variable in the graph) and very little about the effect of the habitat index on smelt abundance. (Feyrer Decl. ¶ 18.) Mr. Feyrer concedes that "there is substantial variability in the relationship between the abiotic habitat index and the abundance index," and this variability appears to overwhelm any effect of the habitat index. For example, at around 8,000 on the habitat index, the values for 1969 and 1970 are at the lower and upper bounds respectively. This graph is not convincing support for the conclusion that the amount of "suitable" habitat determines population size.

20. In his draft paper Feyrer (2008) attempted to model a direct link between the location of X2 and changes in smelt abundance, an analysis that was incorporated into the BiOp as Figure E-22. As I explained in my declaration, this analysis "was not incorporated into the final, peer-reviewed version of the published paper." (Burnham Decl. ¶ 34.) Mr. Feyrer states that he chose not to incorporate it into the published paper because he is currently using it as part of a larger life-cycle modeling effort. (Feyrer Decl. ¶ 19.) He states further that even though the X2/abundance analysis in Feyrer (2008) was "preliminary" "it did demonstrate that factors affecting delta smelt such as X2 can . . . have biologically meaningful effects to the species." (*Id.*) Finally, Mr. Feyrer states that he has "repeated the exercise with a variety of models (*e.g.*, log-linear and Ricker models) linking delta smelt life stages and the results are very similar." (*Id.*)

21. I do not understand why Mr. Feyrer's analyses using log-linear and Ricker models have not been made public if they provide support for the proposition that X2 affects delta smelt abundance. His declaration would have been a useful place to share those analyses. Or they would have provided valuable support for the June 6, 2011 Draft Adaptive Management Plan that is attached as Exhibit A to his declaration, which makes no mention of them in the section titled "Evidence for a link between habitat and abundance." (Feyrer Exhibit A, pg. 12.) It is an

essential part of the scientific process for researchers to share analyses with other scientists so that their results can be analyzed. Because neither Mr. Feyrer's life-cycle modeling effort nor his more basic log-linear and Ricker models have been made public, their results are purely speculative.

22. As mentioned above, these speculative results are contradicted by recent published results. For example, Dr. Kimmerer, like Mr. Feyrer, undertook a habitat analysis that found a biogeophysical correlation between the presence and absence of smelt and certain abiotic habitat factors. However, he took the analysis a step further and tested the relationship between spring X2 and smelt abundance. He found that despite the correlation between habitat and presence/absence "abundance of delta smelt did not vary with X2." Dr. Kimmerer's analysis, which simply compared values of spring X2 with subsequent abundance, could easily have been performed by Mr. Feyrer. It would be interesting and useful science to learn that spring X2 does not affect smelt abundance but fall X2 does. However, neither Mr. Feyrer nor anyone else has shown that this is the case.

23. What is most surprising is that Mr. Feyrer is a co-author on two recent quantitative life-cycle modeling articles, Mac Nally (2010) and Thomson (2010), both of which found no significant effect of X2 on smelt abundance. This also seems like useful information for considering whether there is a link between habitat and abundance, and yet it was not included in Mr. Feyrer's declaration.

24. Unable to show a statistically significant relationship between X2 and abundance, Mr. Feyrer attempts to call into question the very concept of statistical significance. But he seems not to understand the importance of statistical significance. By statistical significance, we mean that one has estimated the effect of a factor well enough to have useful, data-based evidence of the direction of its effect (positive or negative) and the size of its effect. It is possible that many factors have an effect on a species, but it takes data to estimate the *size* of that effect reliably. Science requires that an effect be statistically significant before we claim to know a reliable *quantitative estimate* of the effect, even if we *qualitatively* believe that there might be an effect. Without analyzing the data, there is nothing but opinion.

25. Finally, in Paragraph 21, Mr. Feyrer attempts to undermine the results of Maunder & Deriso (2011) by saying that their life-cycle model is just one among many, all of which reach "different conclusions about the relative importance of factors affecting delta smelt." (*Id.* at ¶ 21).[4] As a result, Mr. Feyrer concludes, "there is no single paper, model, or analysis that is the final truth on the matter." (*Id.*) This is undoubtedly true. Science is a process of re-evaluation wherein there is no "final truth" that is not subject to continual testing and revision. And yet this does not mean that we cannot evaluate different models of reality to see which is *better* supported by the available data. Over the past few decades scientists—including myself—have developed a number of well-established statistical techniques for quantifying the evidence between and across different models in order to determine which models match the data more effectively. These methodologies provide a way of distinguishing between models in a way that does not rely on assumption, common sense or opinion, but instead utilizes the data itself to measure the evidential support for a given model in a set of models.

26. In this case, in my opinion, the Maunder & Deriso (2011) quantitative life-cycle model is currently the best and most rigorous model available for delta smelt. As I explained in my previous declaration, the model considers a wide range of factors, uses the best data on the species, and employs standard statistical methods to account for uncertainty. (Burnham Decl. ¶ 38.) It is not perfect—no model ever is—but it is the best that is available. And it concludes that X2 has no statistically significant effect on smelt abundance.

CONCLUSION

27. In my previous declaration, I stated my concern that the Fall X2 Action is a poorly developed experiment that "would require, in my opinion, 30 or more years to provide any meaningful data, and even then the risk of finding no clear signal is very high due to the large number of confounding variables." (Burnham Decl. ¶ 11.) A recent independent peer review of

[4] Once again, it is curious that Mr. Feyrer fails to note here that all of the models *did* reach the same conclusion about the importance of the effect of the location of X2 on delta smelt: it is not important.

FWS's draft adaptive management plan simply confirms the validity of that concern.[5] In its report, the Peer Review stated that "[t]he reliance of Reclamation on a model and surrogate measures, e.g., fall habitat suitability index to assess the quality of the outcomes of the action to [delta smelt] should be reconsidered." (Exhibit A at 26.) Similarly, the Panel stated that Reclamation "should clearly articulate a conceptual model that explains the expected beneficial effect of the Fall outflow manipulation on [delta smelt] that includes cause-effect relationships rather than biogeophysical correlations." (*Id.* at 4.)

28. Having found that Reclamation had failed to support the adaptive management plan with anything more than "biogeophysical correlations" (*i.e.*, Mr. Feyrer's "habitat index"), the Panel criticized the adaptive management plan because there was no plan for collecting outcome data or even for what variables to measure: "[T]he plan fails to articulate explicit and measurable objectives—an essential element of any adaptive management plan." (*Id.* at 11.) Moreover, the Panel "strongly urge[d] Reclamation and other agencies to formulate an explicit work plan capable of evaluating changes in the health and condition of [delta smelt] in response to the X2 manipulation. The current document is deficient on the details regarding the plan's most important variables. In the absence of reliable abundance data, how will health and condition of the [delta smelt] population be evaluated?" (*Id.* at 4-5.)

29. These are major unanswered questions, and they are unlikely to be answered by the time the Fall X2 Action is supposed to be implemented. This is because the underlying analysis simply does not provide a strong support for the X2 action. As I have explained above, the evidence for a correlation between Mr. Feyrer's habitat variables and smelt presence/absence is weak, and the evidence for a relationship between X2 and smelt abundance is nonexistent. In the absence of any strong correlation, it is difficult to imagine how a useful X2 experiment could be designed. As the Peer Review demonstrates, FWS and Reclamation have not even taken the first steps to answering that question.

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[5] *See* Review Panel Summary Report: Draft Plan for Adaptive Management of Fall Outflow for Delta Smelt Protection and Water Supply Reliability, July 1, 2011, attached as **Exhibit A**.

I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this Declaration was executed on July 15, 2011 at Fort Collins, Colorado.

Kenneth P. Burnham
DR. KENNETH P. BURNHAM

Exhibit A

Exhibit A

Delta Science Program

Review Panel Summary Report

Draft Plan for Adaptive Management of Fall Outflow for Delta Smelt Protection and Water Supply Reliability.

Review Panel Members:

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University of New Orleans

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July 1, 2011

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Executive Summary

The US Fish and Wildlife Service (Service) issued a Biological Opinion (BiOp) on the Central Valley Project (CVP)/State Water Project (SWP) operations in 2008 that concluded that aspects of those operations jeopardize the continued existence of delta smelt (DS). The Reasonable and Prudent Alternative (RPA) that was issued with the BiOp calls for implementation of adaptive management of Fall Delta outflow in above-normal and wet years. The Fall outflow action is expected to improve habitat suitability and contribute to higher average DS abundances. The RPA calls for Delta outflow to be managed such that Fall X2 (the location of the 2 ppt isohaline) must average either 74 km or 81 km upstream from the Golden Gate during the month of September and October, respectively, if the water year containing the preceding spring was classified as wet or above normal. 2011 is classified as a wet year invoking the expectation of X2 at 74km. The RPA requires that adaptive management (AM) be used to assess the effectiveness of the action, including a feedback loop allowing the action to be refined in future years from learned information with the objective of improving outcomes. In 2010, the US Bureau of Reclamation (Reclamation) led a planning initiative to develop an adaptive management plan for Fall outflow, but external review suggested that greater benefits to understanding the consequences of the X2 location could be obtained from an active (or experiment-driven) AM approach rather than the passive approach proposed. The AM Plan was revised in 2011 to address these concerns and Reclamation and the Service requested an independent Science Review at the early stages of the plan revision. This Review Panel (Panel) was convened by the Delta Science Program in June 2011 and the present document serves as a review of the Panel's findings and recommendations. The Panel appreciated the opportunity for involvement in the early formative stages of the plan and developed the review in less than 3 weeks to allow recommendations to be fully considered during the final planning for the 2011 Fall outflow. The Panel made 17 primary recommendations, which are summarized below:

1. All parties interested in assessing the effectiveness of proposed actions for DS should engage in the development of the study and monitoring plan for the Fall 2011 action. It will be the largest high flow perturbation to the system in more than a decade and thus provides a rare and potentially unparalleled opportunity to both quantify the benefits to DS and to better understand the linkages between abiotic habitat characteristics, growth rates, survival and fecundity, and interactions with other species.
2. An explicit, succinct discussion of constraints on the provision of controls and replication needs to be incorporated into the Plan including an explanation of why controls and spatial replication within a given study year are not possible. This will ensure the expectations of the adaptive management aspects of the manipulation will be consistent among interested parties. In addition, the long-term AM Plan should include some discussion of statistical

procedures that can be employed to account for interannual variation in variables that might confound the interpretation of changes in DS abundance.

3. The Fall outflow adaptive management should be formulated as a test case for the draft Delta Stewardship Council guidelines on adaptive management.
4. Attention should be focused in the next few weeks on maximizing the scientific knowledge that can be generated during the 2011 Fall outflow, and in predicting how the X2 standard can be achieved for the minimum loss of storage and depletion of coldwater pools in the large reservoirs.
5. The details of the proposed manipulation and monitoring plan should be made available to the public and interested parties to allow others to contribute to monitoring and studies so as to maximize the capability to address DS and other fundamental questions regarding the functioning of the Delta ecosystem. Previous attempts at these types of major manipulations have been scaled back or inadequate monitoring programs were implemented to deduce findings. The opportunity should not be lost this year.
6. The proposed AM Plan should focus on improving the rigor and detail of conceptual models for the DS and other POD-associated species.
7. The revised AM Plan should include descriptions of planned methodologies for estimating vital rates, e.g., growth and fecundity of DS, as response variables.
8. Reclamation should clearly articulate a conceptual model that explains the expected beneficial effect of the Fall outflow manipulation on DS that includes cause-effect relationships rather than biogeophysical correlations. The proposed conceptual model will be the primary driver of the scientific questions to be addressed in the AM Plan.
9. Reclamation, the Service and other agencies should work to support the development and testing of the proposed Life-Cycle Model (Newman et al.). This model will be useful in furthering understanding but is unlikely to be useful for management actions within the next 2-3 years. It is important to continue this initiative, but for 2011 it is necessary to rely on the Conceptual Model approach.
10. The Fall outflow provides an opportunity to assess different approaches of achieving X2 and to test the accuracy of the model for management decisions regarding the placement of Fall X2. The magnitude of variation from normal and low flow years (for which much of the detailed monitoring data is already available) will provide a validation that greatly extends the understanding of the Delta ecosystem.
11. The Panel recommends that efforts are made to standardize the model version, bathymetric grids and boundary forcing used by all parties investigating Fall outflow scenarios with the UNTRIM model (or other hydrodynamic models). This will ensure the discussion focuses on actions and outcomes rather than the specifics of the model setup.
12. The panel strongly urges Reclamation and other agencies to formulate an explicit work plan capable of evaluating changes in the health and condition of DS in response to the X2 manipulation. The current document is deficient

on the details regarding the plan's most important dependent variables. In the absence of reliable abundance data, how will health and condition of the DS population be evaluated? The revised draft must state how health and condition will be evaluated with regard to methodology, sampling design, and coordination of personnel.

13. Parameters that measure the condition of predator and prey species should be targeted by 2011 monitoring and special studies. Those parameters that are found to be useful in explaining DS responses should be assimilated into long-term monitoring.
14. The Plan should incorporate monitoring of response variables in DS that have a clear demographic link to DS both at the individual and population level (otolith inferred growth rates, fecundity, condition factor).
15. Reclamation must show how the proposed monitoring and assessment program will evaluate change from historical data and ongoing monitoring programs.
16. The Fall outflow plan leadership team should include one individual who is given the freedom to ensure that the implementation and monitoring of the plan is her/his top priority and principal responsibility for the next year starting July 1, 2011. The Panel urges leadership at Reclamation and other invested agencies to be responsive to requests for resources, especially time commitments from the agencies most qualified scientists and managers.
17. When finalizing the plan, the authors should incorporate lessons from other large-scale ecosystem restoration or AM plans that have been implemented in other litigious and high-stake environments.

In summary, the panel believes that the proposed experiment/manipulation of X2 in a wet year represents a rare opportunity for a quantum leap in our fundamental understanding of Delta processes. This will help stakeholders develop a common knowledge of key linkages between enhancing outflow, rate of export flows and the benefits to the biological resources and have profound implications to the future management of the Delta.

1. Introduction

.1 Background

The US Fish and Wildlife Service (Service) issued a Biological Opinion (BiOp) on the Central Valley Project (CVP)/State Water Project (SWP) operations in 2008 that concluded that aspects of those operations jeopardize the continued existence of delta smelt (DS) and adversely modify DS critical habitat. The Reasonable and Prudent Alternative (RPA) that was issued with the BiOp calls for implementation of adaptive management of Fall Delta outflow (hereafter "Fall outflow") in certain water-year types. The Fall outflow action is expected to improve habitat suitability and contribute to higher average DS abundances.

The RPA is expressed in terms of X2, the nominal location of the 2 ppt isohaline. The RPA calls for Delta outflow to be managed such that Fall X2 must average either 74 km or 81 km upstream from the Golden Gate during the month of September and October, respectively, if the water year containing the preceding spring was classified as wet or above-normal. There is an additional storage-related requirement to enhance outflow in November that does not have a specific X2 target. The RPA requires that the effectiveness of the action is evaluated by a research and monitoring program, including a feedback loop allowing the action to be refined in future years from learned information with the objective of improving outcomes (i.e., adaptive management). The US Bureau of Reclamation (Reclamation) responded to the BiOp with a "provisional acceptance" letter. In 2009-10, Reclamation and the Service developed and initiated studies designed to increase understanding about Fall X2 and support future management decisions regarding the Fall action. Reclamation has developed a draft adaptive management (AM) plan that aims to facilitate water deliveries while avoiding jeopardy and adverse modification of DS critical habitat. Reclamation also wants a plan that can be carried out in a framework that increases scientific understanding to improve future management actions. There was also a commitment by Reclamation and the Service to defensible and transparent science.

A Review Panel (Panel) was appointed in early June 2011 to review the draft AM Plan and the Charge to the Panel (Appendix I) includes a list of the specific background documents provided for the review. During the Panel's 1.5 day deliberation, additional materials were requested from Reclamation. The planning time-frame for the Fall outflow AM actions is very short, requiring a rapid turn-around of panel reporting. Therefore, no additional materials were considered by the Panel beyond those received by June 17th, 2011. One of the pieces of information requested from Reclamation (additional information on monitoring programs referred to in the Report) was not available by 17th June. The Recommendations of the Panel are based on the information reviewed and discussions with agency staff during the Panel's in-person meeting. It is possible that some of the information called for by the Panel is already available. The Panel has erred on the side of stating what is needed over and above the information that was provided as review materials, rather than be concerned about such redundancy.

The AM Plan draft is still a work-in-progress, but the Panel acknowledges that the Service and Reclamation requested early independent scientific review, when there is still the opportunity to refine elements of the Plan. The following recommendations should be reviewed in the context of the preliminary nature of the draft AM Plan. The feasibility of Plan implementation will depend on how these recommendations are acted upon by Reclamation and their partners. The Panel agrees that it is possible, even at this late date, to implement an effective system manipulation in Fall 2011. The Recommendations included here are offered expeditiously to further that goal, recognizing that there is very limited time to properly plan and execute an effective manipulation.

1.2 Interpretation of 2008 RPA

The 2008 Biological opinion calls for the Service to direct and oversee the implementation of a formal adaptive management plan for the RPA with specific implementation deadlines. Furthermore, an adaptive management plan is described as including a clearly stated conceptual model, predictions of outcomes, a study design to determine the results of actions, a formal process for assessment and action adjustment, and a program of periodic peer review. It was clear during the Panel proceedings that considerable effort has been expended since the Biological Opinion was issued and many of the specific recommendations, e.g., the formation of a Habitat Study Group have been acted on at least in part in the last 2-3 years. In the draft AM Plan, Reclamation asks two fundamental questions (p6, Review of the RPA Action):

1. What kind of Action seems appropriate?
2. What are the most important specific uncertainties that affect management decisions pertaining to Fall outflow?

The ability of the Panel to provide detailed assessment of how Reclamation plans to meet the expectations of the 2008 Biological Opinion is limited by the information provided. For example, it was not clear until the Panel meeting that some of the draft AM Plan is based on the 2010 Habitat Study Group (HSG) and other materials not immediately available to the Panel or referenced in the Plan. A general assessment of the current Reclamation approach relative to the expectations laid out in 2008 can be summarized as follows:

- *description of the details of the proposed action.* There are several ways that the X2 objective could potentially be achieved, but no details of the timing and source of the freshwater flows were provided.
- *clearly stated conceptual model.* This was not provided and although a conceptual diagram is presented in a 2010 HSG document, few details are provided to support the mechanistic linkages included.

- *predictions of outcomes.* The outcomes of the action for the species and how they will be measured, e.g., in terms of growth, have not been articulated.
- *a study design to determine the results of actions.* A study design based mostly on existing monitoring plans was outlined but no details were provided relative to the action to be taken. Furthermore, it is not clear how the study and monitoring designs will gage change against an existing and developing baseline.
- *a formal process for assessment and action adjustment.* The action was not described in any detail, e.g., no mention of the water sources to be used (inflows vs. exports) and no triggers for adjustment were provided.
- *a program of periodic peer review.* No specific plans were laid out.

This review provides more detailed description of these topics and provides recommendations, where possible, aimed to guide the development of an adaptive management plan for the action in accordance with the 2008 Biological Opinion. Figure 1.1 outlines the steps required prior to September 2011 and how these may be influenced in later years by the development of information from new special studies, the key studies initiated in 2010 and the Newman et al. or other simulation models currently under development.

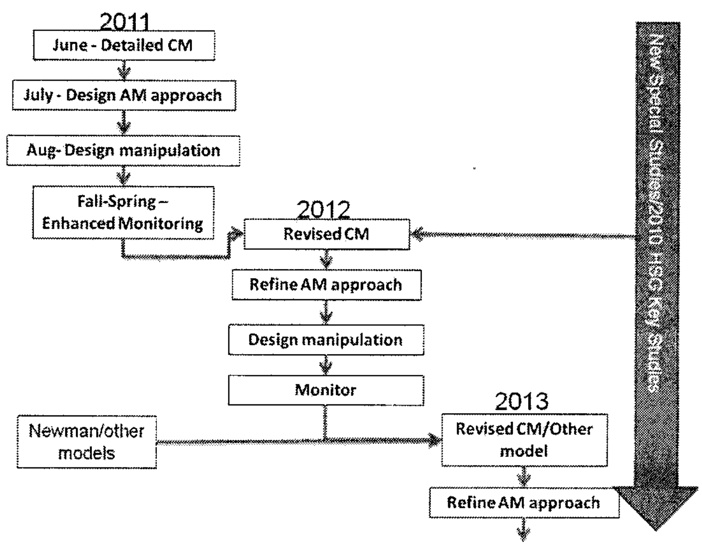


Figure 1.1 Outline of near term needs for exploration of the role of Fall outflow on DS, and how these may evolve over the next 2 years. CM is Conceptual Model, AM is Adaptive Management, and HSG is Habitat Study Group. This iterative cycle should continue beyond 2013.

Figure 11 of the draft Fall outflow management plan, Figure 1.1 and later sections of this report point to the importance of a well-designed X2 manipulation during Fall 2011. The adaptive management approach noted in Figure 1.1 requires, at the very least, articulation of the hypothesized outcome of the manipulation, and how the achievement of that outcome will be measured. As described later in this report, outcomes must be expressed in terms that are more directly relevant to the persistence and recovery of the species (e.g., growth), rather than in surrogate terms such as the provision of habitat or indices of abundance.

1.3 Importance of an Ecosystem Perspective

Habitat condition, food availability and health of the DS under various freshwater discharge regimes are closely linked to and reliant upon ecosystem-level processes. The function and overall condition of the Bay Delta as an ecosystem are of fundamental importance to the persistence of this as well as other native fish species. Ecosystem attributes and processes such as hydrodynamics, salinity, optical and thermal regimes, biogeochemical (nutrients, dissolved gases) and contaminant cycling, and food web dynamics (e.g., Rooney et al. 2006) are all critical elements for evaluating DS habitat condition. Questions of DS health and survival should be examined and quantified in relation to how the ecosystem functions. By assessing DS in the context of broader ecosystem function, more will be learned about the linkage of DS with other ecosystem issues that have either been directly or indirectly linked to DS health (Baxter et al., 2010); including harmful (toxic, hypoxia-generating) cyanobacterial (*Microcystis*) blooms, changes in planktonic community structure and function, pH, dissolved oxygen and contaminant levels, and how the effect of these potential stressors is mediated by salinity, turbidity, and temperature regimes.

The conceptual model used to link various external environmental and endogenous drivers to DS responses should incorporate species-level, community-level *and* ecosystem-scale perspectives. Taking this approach will add value to the overall assessment of impacts of Fall outflow manipulation on DS, since it will also provide useful information on other delta estuarine issues (e.g., pelagic organisms decline (POD), other native fish species, success of invasive species, composition and function of primary and secondary planktonic producers, macrophytes) that are considered to be influenced by current water management practices. One example of an ecosystem level effect related to changing Fall outflow recognized in the BiOp is the potential for significant depletion of the cold water pools in the reservoirs that could impact other species such as salmon in subsequent years. There will be other temperature and water quality effects driven by the flow characteristics in the Delta that need to be anticipated in the Fall outflow management plan.

1.4 Opportunity provided by the 2011 Water Year

Adaptive management is undertaken to learn from actions and to use that learning to improve the likelihood of success of future actions. The availability of water within the SWP/CVP systems this year due to high winter precipitation provides an excellent and rare opportunity to manipulate the system in accordance with the 2008 Biological Opinion. X2 has not been in such a seaward position in the Fall for over a decade. However, the Panel finds that specific planning for fall 2011 is not yet complete, the way in which the system will be manipulated has not yet been determined, and little more than standard monitoring has been considered to support learning. Moving X2 requires the expenditure of considerable resources but 2011 provides a commensurate opportunity for learning. All stake-holders interested in the future of the Bay-Delta environment and the reliability of water deliveries must engage to the maximum extent possible to capitalize on this opportunity which may not recur within the timeframe of the proposed adaptive management plan. The Action will likely be controversial and failure to adequately document the consequences will result in misinterpretation of outcomes and result in the same questions being posed during the next high flow event. Lastly, the Plan needs to contain a clear and convincing explanation of how anticipated driver and response measurements will be assessed against an established baseline. In other words, how will the effects of an above-normal or wet water year be evaluated on the basis of a historic and ongoing monitoring database?

Recommendation 1: All parties interested in assessing the effectiveness of proposed actions for DS should engage in the development of a study and monitoring plan for the Fall 2011 action. It will be the largest high flow perturbation to the system in more than a decade and, thus, provides a rare, and potentially unparalleled opportunity to both quantify the benefits to DS and to better understand the linkages between abiotic habitat characteristics, growth rates, survival and fecundity, as well as interactions with other species. The unique management and learning opportunity afforded by the high flows in 2011 should be better emphasized in the plan

2. The Framework

2.1 Clarity of structure of the AM Approach

The Department of Interior (DoI) guidance on adaptive management (Williams et al., 2009) includes a number of aspects some of which Reclamation has clearly integrated into the planning process and other elements that do not appear. It is important to recognize that agency-wide guidance has to be interpreted to local situations and that in this case not all components of the DoI approach are achievable. Notable here is the emphasis by DoI on the engagement of agency partners. Williams et al. (2009) note that the involvement of stakeholders from the beginning increases management effectiveness and the likelihood of achieving agreed-upon outcomes. The Panel understands that a Preliminary Workshop for stakeholders was held was held in May 2011, but it is unclear how input was incorporated into the Draft AM Plan or what the future stakeholder engagement will be for Fall 2011. Given the magnitude of resources to be devoted to the Action, this probably hinders broad acceptance of the plan and further exacerbates the mistrust that often characterizes attempts to balance efficient use of water resources with species recovery goals. It is possible that the plan was scheduled for release following Panel review. However, the release of any plan to stakeholders so close to implementation fails to fulfill the need for stakeholder engagement described in the DoI manual.

Furthermore and as described in more detail below, the plan fails to articulate explicit and measurable objectives – an essential element of any adaptive management plan. The DoI technical guide (Williams et al., 2009) calls for both set-up and iterative phases and the plan does conform to this format. However, the details of each, especially foundational aspects such as modeling are poorly presented. According to the DoI technical guide *'A formal approach to adaptive management uses the tools of structured decision analysis to inform and analyze the problem. A key step is to predict the effects of management actions that are relevant to the objectives. But predictions require models, whether conceptual or quantitative'* (Williams et al., 2009, page 12). Currently, the proposed mechanistic and Bayesian models appear more like overly complex appendages than integrated components of the AM approach. It is incumbent that a well-grounded conceptual model be developed as soon as possible as a guide for testing hypotheses, formulating the basis for evaluating change with respect to the relationship of drivers and responses, and justifying the work plan. The lack of clear use of detailed conceptual models to link actions to objectives is probably the greatest weakness of the plan provided to the Panel.

It is also important to note that the Fall outflow manipulation does not lend itself to the 'classic' active adaptive management approach. There is no opportunity for a control (there is only one X2 to manipulate at any given time) and any attempt at experimentation within a year by altering operational regimes (e.g., changing the position of X2 or the sources of water) during the September to October period would be confounded by changing externalities and/or the progressive life stage of DS. The Panel does not consider the lack of a true active adaptive management experiment as especially problematic. It means that expectations of the adaptive management approach must be modified – true experiments are simply not possible when the system cannot be replicated. However, well-planned and studied system manipulations can still result in both increased knowledge and a potential benefit to the species. Potential AM approaches for the Delta have been the subject of much discussion (e.g., Independent Science Advisors, 2009, the recently released draft of the Delta Plan). This manipulation provides an opportunity to demonstrate how such approaches can be used on a large scale in the Delta to inform central issues.

2.2 The Clarity of the Proposed Action

Reclamation has not explicitly defined the experimental manipulation in regards to water sources and pumping strategies that will result in desired movement of X2 and increase of DS habitat. This is a critical omission in the current draft report that requires immediate action. Forecasting and predicting the outcomes of the manipulation are contingent on this hydrological description of the experimental manipulation. Failure to describe the exact hydrological manipulation well in advance of the experiment potentially jeopardizes the success of the project.

The central issues that must be dealt with are the balance of increased inflow vs. decreased exports and how that will influence the proportions of Sacramento

River and San Joaquin River water in the area of DS habitat. Positioning of planktonic organisms, turbidity, and temperature are likely influenced by decisions regarding the water balance and weight of Sacramento River input. In addition, the energetic base of the food web is influenced (in potentially negative and positive ways) by the relative contribution of the San Joaquin River into the manipulation. The Panel recommends that the X2 manipulation must be explained in regards to an explicit hydrological budget prior to the start of the Fall outflow manipulation. This will allow a solid study design, predictions of the expected 2011 conditions and outcomes that both conserve coldwater pools and maximize the learning from the 2011 Fall outflow management to occur. Determining the water budget is a first-order, high-priority activity that must be formulated immediately. Failure to take immediate action on this task potentially undermines both the execution and scientific value of the proposed manipulation.

2.3 The Fall outflow Manipulation

2011 provides an unusual opportunity for a quantum leap in our understanding of the link between DS and Fall outflow. The stark reality of the situation is that such a high water year may not occur again for several years, and water availability will become an increasing source of conflict. It is essential that all agencies and interested parties involved in this ambitious and rare ecosystem-level manipulation be fully aware at all levels of the magnitude of the 2011 opportunity. Institutional failure to seize this ecological-hydrological moment in time may handicap future efforts at large-scale ecosystem restoration and experimentation. The Panel concludes that the immediate mobilization of financial and human resources is necessary at all staffing levels in multiple agencies to ensure proper implementation of the experiment.

The basis of the Plan framework is the manipulation of freshwater flow levels into the Delta (i.e., the treatment) coupled with subsequent monitoring of various abiotic and biotic variables that will be affected by this manipulation (i.e., the response variables). The predicted responses stem from the conceptual model linking flow to abiotic changes and then to biotic responses of DS (and their prey and predators). Unfortunately, the complexity of the physical structure of the Delta does not lend itself to the provision of a proper experimental control (i.e., an area that will not be affected by flow changes that can also be monitored). It is also very difficult to conduct spatial replication of treatments and controls. Although temporal replication (i.e., across years) might be possible, the uncertainty of when "wet years" may occur to allow replication of treatments, and the presence of confounding interannual variation on treatment effects make this form of replication problematic. In this regard, it must be made clear how the proposed monitoring and assessment program will evaluate change against a backdrop of existing and ongoing monitoring data. This is essential for quantifying the relationships between hydrologic forcing and biotic responses in the context of historic and future water discharge scenarios for the Delta. In summary, the major biotic response variable of interest is inadequately described in the Plan and presumably ultimately relates to increased abundance of DS or some correlate of DS biology with a clear conceptual link to abundance (e.g., growth, fecundity). These are *critical* aspects of the plan given the (normally) essential need for replicated controls in adaptive management experiments and in justifying expensive manipulations to managers and the public in general (Walters 2007).

Recommendation 2: An explicit, succinct discussion of constraints on the provision of controls and replication needs to be incorporated into the Plan including an explanation of why controls and spatial replication within years are not possible. This inclusion will ensure expectations of the adaptive management aspects of the manipulation are consistent among interested parties. In addition, the long-term adaptive management Plan should include some discussion of statistical procedures that can be employed to account for interannual variation in variables (e.g. differences in water temperature) that might confound the interpretation of changes in DS abundance or correlates of DS abundance (e.g., growth rate – see below) in response to changes in flow across temporally spaced replicates (e.g., 2011 versus 2014, etc).

Recommendation 3: The Fall outflow AM should be formulated to provide a test case for the draft Delta Stewardship Council guidelines on adaptive management. As noted, conditions in the Delta rarely allow for true experimentation. The AM approaches adopted here could result in an improved process for other applications of AM in the Delta.

Recommendation 4: Attention should be focused in the next few weeks on maximizing the scientific knowledge that can be generated, and in predicting how the X2 standard can be achieved for the minimum loss of storage and depletion of coldwater pools in the large reservoirs. As already stated, Reclamation and other interested parties should exploit the 2011 high flow adaptive management opportunity to the maximum extent possible, but it should be recognized that significant modifications to the plan for future years are likely to be made based on the findings of this high flow year. Implementation of a detailed design and logistical planning of an AM project on this scale would ideally have at least one year of preparation but the Panel thinks that significant advantage of this opportunity can still be taken. The limited time should be invested in the design of the Action, monitoring and analysis for 2011, rather than developing the perfect multi-year AM plan.

Recommendation 5: The details of the proposed manipulation and monitoring plan should be made available to the public and interested parties to allow others to contribute to monitoring and studies so as to maximize the capability to address DS and other fundamental questions regarding the functioning of the Delta Ecosystem. The Panel hopes that the research community, water users and NGOs may conduct supplemental monitoring to further our understanding of the ecosystem services provided by the Fall outflow manipulation. This has also been expressed as moving toward a 'single version of the truth' where the best-available science with a quantification of the inherent uncertainties is developed and separated from the difficult policy decisions that must be made (Nunes, 2011). The Panel expects that the 2011 manipulation will be significant enough to address some of the fundamental questions posed by Reclamation in the Draft AM Plan and presents an opportunity to invest in monitoring to draw defensible scientific conclusions. Whatever Fall action is adopted, the decision is likely to be criticized and contested. Previous attempts at these major manipulations have been scaled back or inadequate monitoring programs were implemented to deduce findings. This opportunity should not be lost.

3. Modeling

3.1 Conceptual Model

Numerical modeling, such as the Bayesian approach outlined in the draft AM Plan, has the potential to unite species-specific, seasonal conceptual models (e.g., Fall outflow relationships with DS) within the complete life cycle perspective and ultimately within a larger ecosystem context, enabling the development of well-supported and defendable predictive capabilities. However, in a discussion with the Panel, Dr. Ken Newman (Service) indicated his numerical modeling would be based on time-series data that span decades, and therefore data generated during the first years of the implementation of the AM Plan would have little influence on the model's performance. It is the opinion of the Panel that development of numerical models, while important, is beyond the scope of the proposed AM Plan (in the context of the Fall 2011 X2 manipulation) and should be regarded as a parallel effort that will benefit from improved rigor and detail in the species-specific conceptual models.

Conceptual models for individual POD-associated species should undergo continual development and evaluation until reasonable assurance can be attained regarding the stability of the models' representational rigor. Because this rigor should persist throughout the range of expected environmental variations, the opportunity to collect data under high-outflow conditions during Fall 2011 is particularly important.

Where possible, processes and linkages within conceptual models should be "disaggregated" to allow identification of the most promixal factors that work in concert to drive target response variables (e.g., species abundance or species health and condition). Once identified, driving factors can be represented by parameters that can be readily measured, and these parameters can be incorporated into either special studies or longer-term monitoring. Data for such parameters will likely be highly useful in the numerical models that are being developed in parallel to conceptual models.

The conceptual model for DS, as represented by Figure 11 of the draft AM Plan, identifies a linkage between Fall outflows and improved vital rates (improved survival and growth, resulting in improved spawning-stock biomass), which is equated with improvements in fecundity and subsequent recruitment. The conceptual model should be amplified to acknowledge that 1) size-specific fecundity may vary as a function of batch size and inter-spawning interval, 2) stock-recruitment relationships are largely unpredictable, and 3) the presently reduced state of the DS stock may make it more likely to exhibit compensatory density dependence. As stated above, the processes that affect vital rates need to be disaggregated and the parameters that best represent component processes need to be formally identified. The revised plan should include descriptions of planned methodologies for estimating vital rates as response variables.

3.2 Life Cycle Model (Newman et al.)

DS are elusive and difficult to study due to their small size, behavioral characteristics, short life cycle and the complex nature of the Delta. The POD and other studies have provided a solid foundation for a life-cycle model, and a series of ongoing studies has been implemented to address gaps in knowledge. A life-cycle model is being developed by Dr. Ken Newman (Service) and colleagues, although the work is still in its formative stages. The Newman model team effort is very strong scientifically and includes hydrodynamic modelers, ecologists and fish biologists with extensive experience in the Delta. The first task will be to synthesize available knowledge and to mine the extensive datasets that have been collected on DS. A model will then be developed on the basis of this available information and supplemental studies and monitoring will be initiated to fill the critical knowledge gaps.

It is expected that the AM Plan will 1) build on this synthesis of knowledge, 2) continue to address process-oriented knowledge gaps, 3) actively evaluate the validity of all linkages, 4) adaptively revise the conceptual model as new information is obtained, 5) coordinate with other Delta researchers, including the Newman team, in an attempt to reach reasonable consensus on the most accurate representation of the conceptual model, and 6) interact with the Newman team to guarantee that the conceptual model has maximum utility to the numerical, life-cycle modeling effort.

The concept of fully utilizing past data, archived samples, and new technologies (such as otolith studies) is also a very logical and prudent step. As an explicit attribute of an AM Plan, both life-cycle models and conceptual models can serve to identify knowledge gaps and help prioritize future research and monitoring programs. However, the Newman life-cycle model is unlikely to provide any guidance in management decisions for at least 2-3 years. This type of numerical modeling should definitely be a core component of the AM Plan in the future, but it cannot be relied upon as guidance for the 2011 Fall outflow action.

3.3 Integration with other modeling initiatives

Simulating the hydrodynamic flow structure, salinity, water temperature, turbidity and water quality, and the transport and fate of particles (including species that rely on '*tidal surfing*') is an immense challenge. However, in the past decade the modeling community has made great strides through organizations such as the California Water and Environmental Modeling Forum (CWEMF) that has allowed a constructive dialogue and objective comparison between modeling approaches. Therefore much is now known about the advantages and disadvantages of the various modeling approaches, the uncertainties associated with the hydrodynamic models and a general consensus on where the greatest sensitivities and gaps-in-knowledge exist.

Reclamation intends to use UNTRIM as the basic hydrodynamic model for simulating flows and particle tracking. UNTRIM is also being linked to a sediment transport model SEDIMORPH, although it is unclear whether the sediment transport and turbidity component will be operational in time for decisions related to study of the 2011 Fall outflow effects. Since UNTRIM is already being used for several concurrent studies, it is well understood and there is a cadre of experienced users. Enhanced monitoring in Fall 2011 will provide an opportunity to quantify the predictive capability of the model for future management actions and perhaps refine the model detail in areas where good agreement between observations and predictions are currently elusive. It is not clear which version of the model grid and calibration of the model will be used, or if the model, boundary forcing, bathymetric grid and calibration files will be open and available to other parties.

UNTRIM has probably been used to simulate X2 locations for different outflow scenarios. It is important for the AM Team to have direct access to the modeling team and to communicate findings. If there are multiple groups modeling the Fall outflow X2 scenarios, the Panel recommends that the same versions of model, bathymetry and boundary forcing – at least within federal and state agencies – are used, to avoid perceptions of 'dueling modelers'.

There is uncertainty about the source and persistence of turbidity in the Delta, for example: what proportion is organic compared with inorganic material, what are the causes of seasonal variability, how important are processes such as flocculation and resuspension? Despite the insightful papers by Kimmerer (2004), Schoellhamer (2011) and the current study by Wright and Schoellhamer, it is unclear if the organic contribution to turbidity, both in terms of organic particles and the role of organic substances in fine particle aggregation and settling, is being adequately addressed. The high flows of 2011 present a rare opportunity to supplement current studies and to increase understanding over a broader range of flow conditions – thus rigorously testing current model algorithms and conceptions about important processes.

Recommendation 6: The proposed adaptive management plan should focus on improving the rigor and detail of conceptual models for the DS and other POD-

associated species. Development of numerical models is beyond the present scope and should be regarded as a parallel effort that will be supported by improved conceptual models.

Recommendation 7: **The revised plan should include descriptions of planned methodologies for estimating vital rates, e.g., growth and fecundity of DS, as response variables.**

Recommendation 8: **Reclamation should clearly articulate a conceptual model for that explains the expected beneficial effect of the 2011 Fall outflow manipulation on DS that includes cause-effect relationships rather than biogeophysical correlations alone.** The proposed conceptual model will be the primary driver of the scientific questions to be addressed in the adaptive management plan. It was clear to the Panel that the Delta Scientific Community has been formulating a conceptual model since 2007 but only a simple version is described in the Report. Despite the uncertainties surrounding the life cycle of DS, it is important to work from a more detailed description, even if some of the linkages are presented as testable hypotheses. This will help focus the monitoring effort in 2011 and put it in context with regard to historic and ongoing (i.e. prior to the manipulation) monitoring efforts in order to best gage "change" in the system in response to this above-normal water year.

Recommendation 9: **Reclamation and other agencies work to support the development and testing of the proposed Life-Cycle Model (Newman et al.).** This model will be useful in furthering understanding but is unlikely to be useful for management actions within the next 2-3 years. It is very important to continue this initiative, but for 2011 it is necessary to rely on the Conceptual Model approach.

Recommendation 10: **The Fall outflow provides an opportunity to assess different approaches of achieving X2 and to test the accuracy of the model for management decisions regarding the placement of Fall X2.** The magnitude of variation from normal and low flow years (for which much of the detailed monitoring data is already available) will provide a validation that greatly extends the range of flow conditions. It also will allow further insights to turbidity patterns at high fall releases and extend relationships between suspended sediment and turbidity.

Recommendation 11: The Panel recommends that efforts are made to standardize the model version, bathymetric grids and boundary forcing used by all parties investigating Fall outflow scenarios with the UNTRIM model. This will ensure the discussion focuses on actions and outcomes rather than modeling specifics.

4. Monitoring

4.1 General Comment on Health and Condition

The ecosystem-level manipulation of the Delta's Fall X2 location should be founded on a scientifically sound conceptual model that predicts outflow effects on such factors as the amount and quality of DS habitat and improvements in DS abundance and condition. Characterizing the abiotic habitat is a central aspect of the experiment and this can be based on parameters such as salinity, turbidity, and temperature. Biogeochemical and biotic properties that further influence DS should also be examined, with an emphasis on DS health and condition. Quantifying change in the abundance of DS is challenging due to the population's low numbers, variability among abundance estimates, and the possibility that excessive sampling may be detrimental to the population; hence, measuring health and condition data are critical to the project's overall success. The draft AM Plan had little detail regarding evaluation of DS health and condition, but follow-up text provided by Reclamation included such material, leading the Panel to understand that Reclamation and others are planning a concerted effort to examine DS growth, fecundity, and eco-toxicology. We encourage such efforts and stress that these are fundamental dependent variables that must be articulated in detail in order to ensure the overall success of the project. Specific metrics of heath and condition that should be monitored are described below (see sections **4.3 and 4.4** below).

4.2 Water Quality

Water quality (WQ) plays a central role in the eco-physiological condition, fecundity, and survivability of the DS as well as other native fish species that use the Delta as a nursery and foraging habitat. WQ parameters that will need to be part of a monitoring program aimed at measuring and assessing DS health and population dynamics under variable freshwater discharge conditions can be partitioned along physical-chemical and biotic lines. From a physical-chemical perspective, freshwater discharge (and related flushing and residence times), salinity, temperature, light transmission (determined by turbidity, water color and photopigments, most notably chlorophyll *a*), pH, dissolved oxygen, nutrient (total and dissolved inorganic N and P) and specific contaminant (Hg, Cd, Cu, etc.) concentrations should be measured. From a biological perspective, phytoplankton biomass (as chlorophyll *a*) and composition, zooplankton biomass and composition, benthic grazers (invertebrates), and key fish species densities and fecundity should be determined. If possible, benthic macrophyte density should be determined. Ecosystem-scale processes that would be important to measure include primary production, respiration and benthic oxygen consumption (especially in areas prone to hypoxia). Many of these parameters are likely included within the planned monitoring programs, but given the lack of specific information provided to the Panel, they are laid out here for completeness.

It is highly desirable to link the presence and densities of specific biological stressors to the Bay Delta system to DS densities and fecundity. Key stressors include harmful algal bloom taxa, namely toxin producing cyanobacterial species (*Microcystis* spp.), whose toxins are known to adversely affect resident invertebrate and fish species (including possibly DS). *Microcystis* blooms appear to be problematic from a food web perspective, because even though these blooms can produce large amounts of biomass, they are either avoided or not captured and assimilated by key crustacean (copepods, cladocerans) zooplankton species that serve as food source for DS and other ecologically- and recreationally-important fish species (Lehman et al. 2008). Invasive planktonic and benthic grazers have led to a "state change" in segments of the SF Bay where phytoplankton biomass exhibited a precipitous and sustained decline, following the establishment and proliferation of exotic bivalves (Alpine and Cloern 1992; Cole et al. 1992; Thompson et al. 1996; Jassby 2008). Lastly, the expansion of invasive aquatic macrophytes, e.g., Brazilian waterweed (*Egeria densa*) may also play a role in declining dominance of phytoplankton in some regions of the Delta. Ongoing monitoring data for these and other biological stressors should be incorporated into assessments of biotic factors potentially influencing health and population dynamics of the DS.

4.3 Fish

Abundance-based inferences concerning predator-prey interactions can be misleading, and high "signal-to-noise" ratios or low frequencies of occurrence can dramatically reduce the statistical power of abundance data. For these reasons, the panel suggests emphasis should be placed on developing a weight-of-evidence approach for organism condition and health. This recommendation is superimposed upon existing and proposed efforts to monitor organism abundance.

Effort should be made to maximize the amount of condition-related information that is obtained from collected DS. In addition to condition factor (CF, weight x 100/length^3), measurable parameters include, but are not limited to, regression-based deviations from weight-at-length relationships (the use of archived specimens should be evaluated), direct estimates of fecundity, measurements of gonadosomatic and hepatosomatic indices, bulk lipid extraction or the possible use of C:N as a bulk lipid proxy (Post et al. 2007), lipid analysis (i.e., triacylglycerol to sterol ratio), and the creation of otolith-based growth-rate histories. Individual growth-rate histories can be matched to time series such as the outflow hydrograph and water temperature. These time-series comparisons will be limited by the short life span of the DS, but longer growth histories may be obtained from adult striped bass or by assembling individual series from archived DS otoliths, if these are available. Similar condition-oriented efforts should be directed toward important prey organisms using appropriate methods. For example, copepod egg production is commonly used as a growth or condition indicator.

4.4 Demographic Response

Owing to the low abundance of DS any positive response of population size to flow manipulation will be difficult to detect because any increases other than exceptionally high ones will be difficult to distinguish from sampling error. Other biological features of DS that are typically correlated with increased survival and population growth rates sizes, however, should be subject to less sampling error, owing to increased potential for replication, and thus be more sensitive to treatment effects. Three biological properties of DS that may be positively correlated with survival and population growth rates are individual growth rate and fecundity (which themselves should be positively correlated with each other in female DS) and CF. High individual growth rates are typically associated with increased survival of juvenile fishes as, for instance, larger fish of a given age are less susceptible to gape-limited predators (see review by Sogard 1997). Growth rates can be assessed for individual fish over daily periods by examining growth increments in otoliths (e.g., Sepúlveda 1994). In addition, fecundity is typically positively related to length in osmerids (Chigbu and Sibley 1994). The CF may be influenced by age, sex, season, stage of maturation, gut fullness, type of food consumed, amount of fat reserves, and the degree of muscular development. The CF, therefore, is usually positively associated with growth conditions experienced by, and performance of, individual fish. All of these features (growth rate, fecundity, CF), therefore, could be employed as proxy measures of positive demographic response of DS to Fall outflow treatment and should be added to the monitoring program.

<u>Recommendation 12</u>: The Panel strongly urges Reclamation and other agencies to formulate an explicit work plan for properly evaluating changes in the health and condition of DS in response to the X2 manipulation. The current document is woefully deficient on the details regarding the project's most important dependent variables. In the absence of reliable abundance data, how will health and condition of the DS population be evaluated? The Panel recommends that growth, condition, and fecundity be rigorously evaluated. **The revised draft must state how DS health and condition will be evaluated in regards to methodology, sampling design, and coordination of personnel.**

<u>Recommendation 13</u>: **Parameters that measure the condition of predator and prey species should be targeted by 2011 monitoring and special studies, and those parameters that are found to be useful should be assimilated into long-term monitoring.**

<u>Recommendation 14</u>: **The Plan should incorporate monitoring of response variables in DS that have a clear demographic link to DS both at the individual and population level (e.g. otolith inferred growth rates, fecundity, condition factor).**

Recommendation 15: Reclamation must show how the proposed monitoring and assessment program will evaluate change from existing and ongoing monitoring programs. Having a seamless before and after monitoring program for the proposed Action will facilitate understanding and quantifying the relationships between hydrologic forcing and biotic responses in the context of historic and future water discharge scenarios for the Delta.

5. Special Studies to improve understanding

The DoI technical guide on adaptive management (Williams et al., 2009) identifies '*assumption-driven research as central activities*'. In addition, Independent Science Advisors (2009) noted that research aimed at particular sources of uncertainty can be part of an adaptive management program. The panel has identified several areas where focused research or special studies can be used to reduce uncertainty surrounding the action and/or inform the implementation of future system manipulations.

5.1 Turbidity Studies

Researchers in the Delta have identified three primary mechanisms for generating turbidity, advection from the turbidity source through the Delta, wind resuspension, and from tidal flows. There is significant patchiness of turbidity with sharp fronts observed and lenses of higher turbidity water that are advected over large distances. Few details of the current Wright and Schoellhamer study were provided, but this study has the potential to investigate the relation between inorganic sediment, organic material and turbidity. Further, the study could also investigate the spatial heterogeneity of turbidity, the presence/absence of smelt with turbidity features and the spatial scale of these features. Data on DS, turbidity and salinity is primarily collected in main channels during routine monitoring. It would be useful to supplement these long term records with detailed observations of what is occurring in off-channel shallow areas. The ongoing sediment study and DS monitoring could be supplemented during this high flow year if these issues are not already being addressed. Applying some form of remote sensing to the problem of fine-scale patchiness may be productive, particularly in the more open waters of the Delta ecosystem.

5.2 Trophic Analyses

Although fish diet analyses are the most straightforward means of establishing the dominant linkages between fishes and their prey, observed diet compositions tend to reflect recent feeding in the general area of capture, and therefore can be easily biased by the distribution of the effort used to collect the fish. Fish should be collected at various tides and times of day to establish any consistencies in feeding times or tides. During implementation of the proposed AM Plan, particular care should be given to spatial and temporal changes in diet that occur as X2 shifts in response to outflow. Rare, sustained, high-outflow periods may result in changed prey assemblages. Spatiotemporal deviations in diet may also result from different prey assemblages being associated with different geographic sources of outflow (Sacramento River vs. San Joaquin River).

Once the diet of a given species has been adequately characterized for various stages and length classes, trophic levels can be calculated. Calculated trophic levels can then be corroborated using bulk stable isotopes. This process, which is extensively described elsewhere in the scientific literature (e.g., Vander Zanden and Vadeboncoeur 2002), yields a number of useful byproducts. One of these is the formal determination of the primary producers that constitute the trophic base – this is an essential component of the conceptual model that might otherwise remain unsupported by data. All types of primary producer should be evaluated in this process, including benthic microalgae and periphyton, which are often overlooked.

The trophic linkages identified by stable isotope analysis may be counterintuitive; many pelagic species have been demonstrated to have benthic linkages and demersal species have been shown to have pelagic linkages. As with diet data, trophic linkages vary over both space and time. For example, are centrarchids and other shoreline fishes more enriched in $d^{13}C$ than POD species? If so, this may be an indication of greater (indirect) dependence on periphyton, as suggested by Baxter et al. (2010, p. 103). Temporal shifts in trophic base between low and high outflow periods (or between high and low perimeter-to-area habitat ratios) can be formally tested using methods such as those presented by Schmidt et al. (2007).

Another useful byproduct is insight into the relative site fidelities of different species. Stable isotopes are rarely uniform across complex landscapes such as the Delta ecosystem. Fish that remain stationary will reflect local isotopic signatures, whereas those that move around or migrate systematically will integrate various aspects of the isotopic landscape, provided they continue to feed as they move. Attention must be paid to the types of tissues being analyzed, as these have different turnover rates and therefore represent different periods in the life of the fish.

5.3 Otolith microchemistry and Growth Ring Validation

A number of questions can be addressed using otolith chemistry. For example, do all DS have similar elemental profiles (core-to-margin laser-ablation transects), or do profiles from different individuals fall into groups according to their use of distinct habitats? Although DS may represent a single population in a genetic sense, there are different patterns of habitat use within the population.

Much of the utility of otolith microchemistry rests on the fact that elemental profiles reveal individual histories. Maturing DS in the estuary will retain elemental records of their earlier larval existences in fresh water, providing a natural tag for identifying individual origins. Do groups with different geographic origins have similar growth rates and potential contributions to recruitment, or do one or more geographic groups contribute disproportionately to the estuarine portion of the population? In addition, a laboratory study should be initiated using the captive population of DS to validate methods of daily growth ring analysis and the periodicity of formation. Validation of the daily growth ring deposition is critical for proper interpretation of growth rates of fishes inferred from otoliths.

5.4 Mesocosm studies

The experiment proposed in the draft AM Plan will be confounded by uncontrolled covariates of outflow, making detection of important processes difficult. As an alternative approach, controlled feeding experiments using captive organisms can be applied within aquaria or mesocosms, isolating and quantifying effects on the DS in its role as predator and as prey. A two-way factorial design including turbidity and water temperature may be appropriate.

Suggested special studies include additional diet analyses, stable-isotope-based analyses of trophic dependences, identification of individual fish habitat histories using otolith microchemistry, and mesocosm experiments for defining the controlled effects of temperature and turbidity on DS feeding and vulnerability to predation.

5.5 Linkages between Physical Habitat and Forage Food

The conceptual model that motivates this large experimental manipulation is partially reliant on the assertion that expansion of DS physical habitat also increases habitat quality due to increases in forage food. Native and non-native zooplankton abundances are known to be enhanced in the western portion of the Delta during the fall. These zooplankton populations likely contribute to the predicted enhancement of the "health and condition" of DS in this zone. The overall scientific success of the project would greatly benefit from an evaluation of zooplankton abundances, growth rates, and fecundity in the experimentally-manipulated zone of the Delta. The draft AM Plan had scant detail on planned zooplankton monitoring and evaluation, but additional materials provided by Dr. Anke Mueller-Solger document: 1) the extent of peer-reviewed publications on the foraging ecology of DS, 2) the existing capabilities of the delta science community for expertly characterizing delta zooplankton populations and ecological attributes (including growth, food quality, and fecundity), and 3) translation of zooplankton community ecology into a thoughtful conceptual model of the DS life-cycle and population dynamics. The Panel is highly supportive of special studies that examine zooplankton community ecology during and after the X2 experimental manipulation.

6. Organization, Logistics and Flow of Information

The Panel is extremely concerned about the limited amount of time between our review and implementation of one of the largest freshwater ecosystem-level manipulations ever conducted. The Panel has serious reservations about the successful implementation of this ambitious venture due to concerns regarding: 1) explicit clarity of the hydrologic manipulation of the system to achieve the X2 criteria, and 2) explicit clarity of the key independent and dependent variables that will be evaluated to document success of the experimental manipulation (discussed above).

The Panel is also concerned about whether the participating agencies of this ambitious plan are equipped to execute the plan at the level of commitment and performance that will satisfy: 1) the inherent costs of the X2 manipulation endeavor, 2) general public and scientific public buy-in on potential fish recovery, knowledge discovery and gains in public education. The Panel is concerned that a failure to effectively describe the experiment and document response will "haunt and handicap" individuals and agencies involved in the effort for years to come.

The Panel is impressed by the commitment of scientists and agency leaders to the Delta ecosystem in regards to efficient, strategic water conveyance and effective ecosystem management. The over-arching comments are simply geared to gaining the best and most useful data from a potentially once in a decade manipulation, that has little precedence in the freshwater or estuarine ecological literature. Panel comments are also geared to help focus all agencies involved on the incumbent task at hand. Reclamation and the Service will be saturated with commitments this summer and fall, but it is recommended that senior leadership in all agencies consider the following pragmatic recommendations from our panel:

- There needs to be extensive institutional commitment to the project in all ranks of organization, and the leaders of Reclamation, the Service, DWR, USGS, and others MUST view the experiment as high priority for the next year. Other projects and tasks will have to become secondary. The professional reputations of agency scientists, managers, and leaders are greatly affected by the execution, success, translation, and professional correspondence of this potentially once-in-a-lifetime experiment.

- The Panel urges agency leaders to provide their top-scientists and managers with all of the resources to not just implement, or even loosely exceed, the execution of the experiment, but to excel in the scientific discovery that allows substantial gains to both Delta science and societal awareness of the challenges and potential gains of ecosystem manipulations.

- Walters (2007) provided a summary of common issues that can compromise the successful planning, implementation, and veracity of conclusions derived from adaptive management in fisheries. One key characteristic of adaptive management initiatives that did not meet expectations was a lack of commitment by all participating agencies to provide a single individual <u>who is given the freedom to commit all the necessary time and energy to making sure the manipulation is implemented as his/her top priority.</u> It is, therefore, essential that the Fall outflow plan be under the overall direction of a single individual and that this individual be given the freedom and authority to ensure that the planning, implementation, and evaluation/ monitoring of the subsequent effects be her/his top priority.

Recommendation 16: **The Fall outflow plan leadership team should include one individual who is given the freedom to ensure that the implementation and monitoring of the plan is her/his top priority and principal responsibility for the next year starting July 1, 2011.** The Panel urges leadership at Reclamation and other invested agencies to be responsive to requests for resources, especially time commitments from the agencies most qualified scientists and managers.

7. Relevant Lessons from other Ecosystem Management programs

Implementation of adaptive management in other large ecosystems has helped set precedents and lessons from these programs may assist managers implementing adaptive strategies for Fall outflow.

7.1 Colorado River Ecosystem Downstream from Glen Canyon Dam

Ecosystem-level manipulations of freshwater ecosystems are unusual at spatial scales larger than headwater streams and small lakes, thus the proposed experimental manipulation of the fall freshwater zone of the Delta is noteworthy. While there are a growing number of adaptive management studies that can be used for context and insight when describing the importance of this Fall outflow, there are few explicit manipulations at this spatial-scale. One potential analog is the experimental flooding of the Colorado River using releases of Glen Canyon Dam water. The experimental water manipulations were relative short in duration (weeks) and involved three experimental releases. The experiments were motivated by the assertion that homogenized river flow had altered the river's geomorphology in a manner that was detrimental to native fish such as the threatened humpback chub population (endemic only to the Colorado River downstream of Glen Canyon Dam) and possibly beneficial to exotic fish species that are humpback chub predators. Improvement of the humpback chub's abiotic, physical habitat was predicted to improve spawning habitat and predator avoidance. Multiple state and federal agencies were involved in the project that required multiple years to prepare and assess. This was a high-profile experiment that required effective public relations throughout the general public, NGOs, agencies, and scientists. Refer to report: http://pubs.usgs.gov/of/2010/1128

7.2 Chesapeake Bay, Albemarle-Pamlico Sound and the Role of Emerging Technologies and Models

Chesapeake Bay and North Carolina's Albemarle-Pamlico Sound system are the US's largest estuarine ecosystem, and like many other estuaries, reveal a great deal of heterogeneity in the amounts and distributions of phytoplankton and suspended sediments. These entities are notoriously difficult to spatially assess and quantify in these hydrologically and biogeochemically dynamic estuaries. Aircraft-based remote sensing, including aircraft-based SeaWiFS, and Lidar have been effective in quantifying these optically-active constituents of the water column. Examples of the application of aircraft-based SeaWiFS in quantifying seasonal distributions of Chl *a* are provided for both systems (Figures 7.1 and 7.2). These technologies are applicable to the Bay Delta and estuary (see Harding and Miller 2009).

The use of technology to identify synoptic patterns in water quality parameters is one lesson from Chesapeake Bay and Albemarle-Pamlico Sound. While there are likely many more, another of relevance to this study is the use of models to assess change in the system in response to management actions. In October 2005 the Government Accounting Office (GAO, 2005) assessed reports used by the Chesapeake Bay program to identify progress toward their goals and noted 'Moreover, the credibility of these reports has been negatively impacted because the program has commingled various kinds of data such as monitoring data, results of program actions, and the results of its predictive model without clearly distinguishing among them'. The reliance of Reclamation on a model and surrogate measures, e.g., fall habitat suitability index to assess the quality of the outcomes of the action to DS should be reconsidered. Overreliance of models to predict outcomes based on cause-effect relationships within a model rather than through field data for Chesapeake Bay was seen as problematic by many. This re-emphasizes the need for Reclamation to focus on measuring growth and condition on DS as the outcome of the intended action.

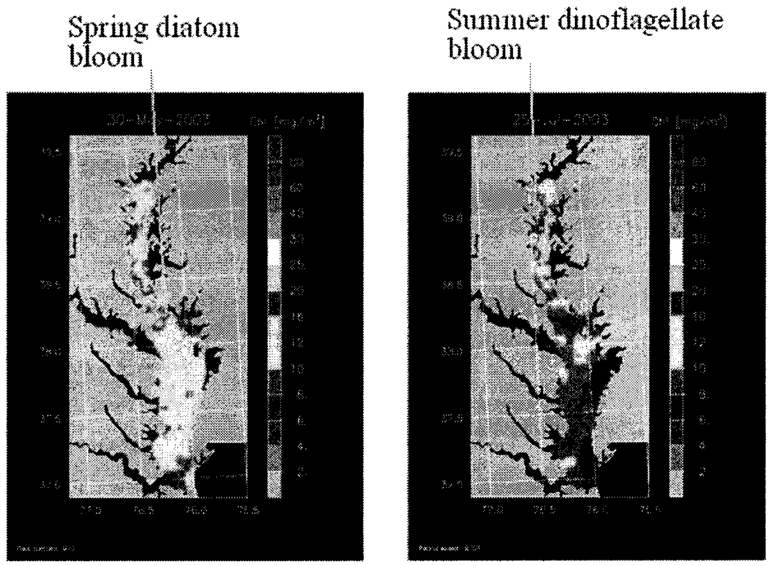
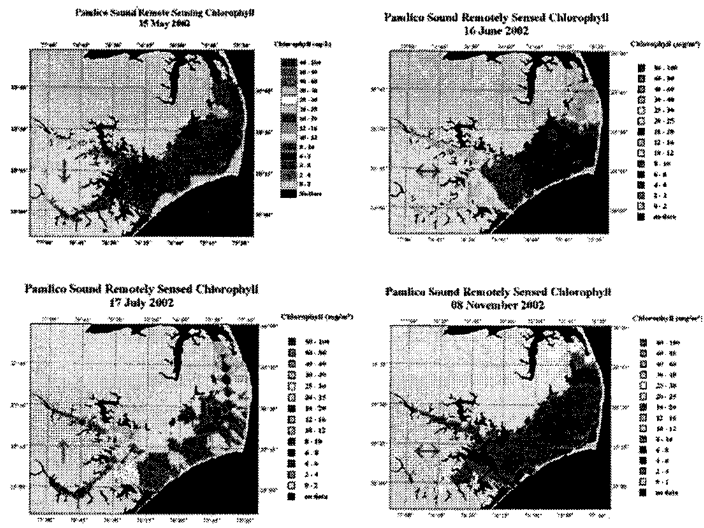


Figure 7.1: Contrasting spring and summer Chl-*a* distributions in the Chesapeake Bay, during May and July 2003. Surface water Chl *a* concentrations were estimated using aircraft-based SeaWiFS remote sensing (Courtesy L. Harding, Univ. of Maryland), calibrated by field-based Chl *a* data. In May,

when flow is high, a large diatom bloom extends into the lower Bay. During lower flow July a dinoflagellate bloom was observed in the upper Bay (From Harding and Miller, 2009).



Flow: high↑, low↓, moderate↔

Figure 7.2: Spatial relationships of phytoplankton biomass, as chlorophyll *a* (Chl *a*), and freshwater discharge to the Pamlico Sound System, NC. Surface water Chl *a* concentrations were estimated using aircraft-based SeaWiFS remote sensing (Courtesy L. Harding, Univ. of Maryland), calibrated by field-based Chl *a* data. Under relatively low-flow, long-residence time conditions, phytoplankton biomass is concentrated in the upper reaches of the Neuse and Pamlico R. Estuaries. Under moderate flow, phytoplankton biomass maxima extend further downstream. Under high flow (short residence time) phytoplankton biomass maxima are shifted further downstream into Pamlico Sound (figure adapted from Paerl et al. 2007).

7.3 Neuse River Estuary

Mechanistic models, based on long-term monitoring efforts have however been quite useful once the hydrodynamic "behavior" of an estuary, including its response to acute and chronic changes in freshwater input have been well characterized. One example is the nutrient-water quality response model that is in place in the Neuse River Estuary, the largest tributary of North Carolina's Albemarle-Pamlico Estuarine complex. This response model, a modification of the CE-Qual model (Bowen and Hieronymous 2003), has been effective in predicting, among other parameters, chlorophyll *a* exceedances of the North Carolina standard of 40 μg per liter for Total Maximum Daily (Nitrogen) Load Development aimed at controlling eutrophication and harmful algal blooms in this nitrogen-sensitive estuary (North Carolina Department of Environmental and Natural Resources, 2009). The successful application of this model for evaluating the TMDL is largely attributable to a long-term spatial-temporal intensive water quality monitoring program that has been in place since 1994 (Paerl et al., 2007). Further details of ModMon - http://www.unc.edu/ims/neuse/modmon/index.htm

7.4 Florida Everglades Restoration Program

Of all similar large-scale ecosystem management programs, perhaps the Everglades has the most resemblance to the challenges of the Sacramento Delta. The Senate Committee on Environment and Public Works in July 27, 2000 stated:

> *"The Committee does not expect rigid adherence to the Plan as it was submitted to Congress. This result would be inconsistent with the adaptive assessment principles in the Plan...Instead the Committee expects that the agencies....will seek continuous improvements of the Plan based on new information, improved modeling, new technology and changed circumstances."*

In a recent retrospective on the lessons learned on the incremental adaptive restoration strategy used in the Everglades, Dr. Ronnie Best, Coordinator of the Greater Everglades Ecosystem Science program stated that every program must have a champion and a dedicated coordinator of AM (Personal Communication, 2011). He also stressed that AM should be 'done BIG and LEARN'. Learning included science, modeling, financing, and permitting.

Further details are available in the Science Plan in Support of Ecosystem Restoration, Preservation and Protection in South Florida (DOI, 2006) [www.sofia.usgs.gov] and Facing Tomorrow's Challenges, USGS Science in the decade 2007-2017. USGS Circular 1309.

7.5 Other Florida Estuaries

Fish condition can be measured as deviations from weight-at-length relationships (Figure 7.3). In the Alafia River estuary of west-central Florida, these deviations clearly document distinct annual cycles in fish condition that are strongly correlated with freshwater inflow. In Figure 7.3, the negative relationship between inflow and condition reflects interaction between fish center of abundance (analogous to X2) and a downstream estuarine area that is highly prone to hypoxia during the summer rainy season. Note that the strength of this effect varied extensively among the eight years examined. Obtaining fish weights and lengths was automated using RS232 output from electronic calipers and balances, with the instrument output being organized by direct-data-entry software.

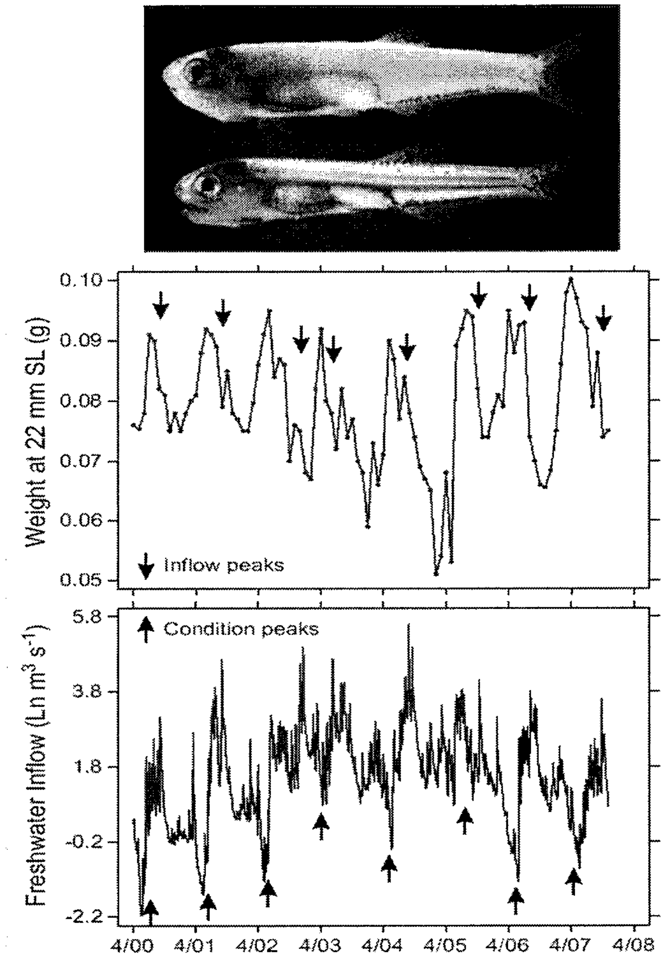


Figure 7.3: Example of fish condition co-variation with freshwater inflow (Alafia River estuary, west-central Florida). Variation in the condition of bay anchovy (*Anchoa mitchilli*) juveniles is apparent even without formal measurements (photo at top). Juveniles were collected during monthly sampling from April 2000 through November 2007, and monthly weight-length regressions were then created retrospectively using preserved specimens (a reference length of 22 mm was selected to avoid extrapolation of predicted means). Many estuarine taxa, including bay anchovy juveniles, move upstream and downstream as freshwater inflows vary (Flannery et al. 2002). High inflows during the summer rainy season (lower plot) cause the juvenile bay anchovies to be positioned downstream over a dredged ship channel at the mouth of the estuary. The ship channel is invariably density-stratified and hypoxic during summer. The fish become emaciated (upper plot) when their center of abundance is positioned over the hypoxic ship channel each summer (Peebles et al., MS in prep.).

Recommendation 17: When finalizing the plan, the authors should incorporate lessons from other large-scale ecosystem restoration or AM plans, especially those in other litigious environments such as the Everglades, Chesapeake Bay and the Colorado River. The biennial National Conference on Ecosystem Restoration (NCER) provides an opportunity for managers and scientists to share experiences of large-scale adaptive management (http://conference.ifas.ufl.edu/NCER2011/).

8. Summary Conclusions

The Draft Adaptive Management Plan for Delta Fall outflow provides a preliminary roadmap for the approach that Reclamation intends to adopt to address the RPA in the 2008 Biological Opinion. The BiOp was based on the best available knowledge at the time, but the 2011 high flow year offers an opportunity to demonstrate the effectiveness of the proposed action in the RPA. The Panel appreciates the opportunity for early review and found no fatal errors in the scientific approach, but critical details were not included in the plan description. In general, the manipulation planned appears feasible in terms of conceptual grounding and the fact that the response monitoring proposed will employ well-established techniques in water quality determination, habitat assessment, and fish biology. Much more detail, however, is required concerning the mechanics of flow manipulation (see **section 2.2**) in order to determine the feasibility of *how* flow is to be manipulated. In addition, the planned action and monitoring will only be feasible overall if the required coordination amongst agencies is complete, and the commitment to the appropriate and singular leadership outlined in **section 6** is provided.

The following summary conclusions are recommendations intended to assist Reclamation and the Service in planning the next few weeks leading up to the X2 releases or curtailed pumping.

I. Be bold and create an opportunity where the direct benefits to DS and challenges for water deliveries can be clearly quantified. This increased understanding will help the entire Delta Community stake-holders to plan and manage better in future years.

II. Focus on the Action and monitoring for 2011, making sure to functionally connect before,during, and after release event monitoring data and assessments. The fine details of AM in out years can be developed in the coming months. The final AM Fall outflow plan should also embrace an ecosystem approach that acknowledges that the Action will impact multiple species and biogeochemical processes due to the finite availability of cold water in any year.

III. Clearly define the Action. Obviously the objective is to achieve the X2 standard at the minimum cost to water deliveries. Will a steady state high flow be used or pulsing of flows during September and October, and will this be conducted in conjunction with curtailed pumping?

IV. Design the action and monitoring based on the results of models such as UNTRIM. The objective is to get desirable salinities and turbidities to coincide over large areas of potential habitat, and then see if DS utilize the habitat and understand the change in DS size and decrease in mortality. Simulation of the selected Action can then be used to design the monitoring program. The simulations should also make clear how the releases will be routed from the upstream reservoirs to the upstream boundaries of UNTRIM.

V. Monitoring of salinities, turbidity and DS location during the manipulation can be used to assess the accuracy of the UNTRIM model for particle tracking, salinity (and turbidity if SEDIMORPH algorithms are linked to UNTRIM). If the predictive capability of UNTRIM is proven to be reliable, the Action could be modified in real-time to maximize the amount of 'suitable' DS habitat.

VI. If the predictive capability of UNTRIM is proven to be reliable, the Action can be modified in real-time to ensure the X2 standard is achieved.

VII. The AM Plan should clearly define which data are being used for different monitoring objectives, including:
- annual baseline monitoring to provide trend and change information
- compliance monitoring to ensure that the X2 standard is achieved
- model refinement that will improve the confidence in the UNTRIM model results for future management decisions
- refinement of the DS conceptual model and Newman et al. DS life cycle model
- evaluation of the effectiveness of the RPA in sustaining the DS population
- quantification of the conventional wisdom regarding linkages between physical habitat criteria and the recovery of the DS population
- fundamental science questions that will resolve larger and more general questions about the Delta ecosystem (refer to the draft AM Plan and Section 5 of this report)

VIII. Consideration should be given to appointing an AM Coordinator and a logistics manager to conduct the monitoring programs and be responsible for the scientific outcomes.

IX. The study and monitoring plan should be made public, with an open invitation for complementary studies that could be conducted in tandem with the Fall outflow monitoring and special studies. This could create a quantum leap in the understanding of the functioning of the Delta system.

The 2011 Wet Year provides an opportunity for a quantum leap in our fundamental understanding of delta processes and help resolve some of the basic questions posed by the BiOp. If designed properly, the Fall 2011 Outflow release will allow stake-holders to develop a common knowledge of delta functions that will have profound implications to the future management of the Delta.

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Appendix I: The Scientific Review Panel Charge

DELTA SCIENCE PROGRAM
INDEPENDENT SCIENCE REVIEW

Adaptive Management Plan for Delta Fall outflow

PLAN GOALS AND ADAPTIVE MANAGEMENT

The goals of the plan are (1) to manage Fall outflow for conservation benefits to delta smelt while minimizing water supply and water supply reliability impacts; (2) to increase understanding about the effectiveness of Fall outflow for smelt conservation in order to adjust the action for better conservation effect or water efficiency.

REVIEW PANEL CHARGE

The Review Panel will be charged with assessing the Plan for Adaptive Management of Delta Fall outflow from several points of view, with emphasis on the use of the Plan as an adaptive management tool. Specific attention will be applied to the following criteria:

Purpose

- Is the plan responsive to recommendations in the 2008 US Fish and Wildlife Service Biological Opinion on the Central Valley Project and the State Water Project?
- Are the goals of the plan consistent with the goals of the Reasonable and Prudent Alternative?
- How well will the plan, as designed, meet its two major goals: (1) to manage Fall outflow for conservation benefits to delta smelt while minimizing water supply and water supply reliability impacts; (2) to increase understanding about the effectiveness of Fall outflow for smelt conservation in order to adjust the action for better effect and/or water efficiency?
- Is the plan clearly defined and described?
- Is the plan internally consistent and scientifically valid?
- Is it clear for what purpose and how the plan might be used?
- Will implementation of the plan adequately provide the information necessary for refining the goals and objectives, knowledge base and models, and approach of the plan over time?

Approach

- Are linkages between elements of the plan clear?
- Is the use of hypotheses, conceptual models and quantitative models clear and helpful? If not, how might this be changed or refined?
- Will the monitoring and evaluation program result in adequate detection of signal to noise (inherent variability)?
- Is the decision matrix for adaptive management clear and useful?
- Does the plan contain adequate provision for synthesis, evaluation, and reporting?
- What, if any, future role/need is there for additional scientific input and review?

Feasibility

- Is the approach described in the plan feasible to implement?
- If not, what can be done to improve feasibility of the approach?

The following background materials were provided to the Review Panel:

✓Final 2010 POD Report (http://www.water.ca.gov/iep/docs/FinalPOD2010Workplan12610.pdf

✓Coordinated Operations Biological Opinion (USFWS 2008) RPA Component 3 and associated explanatory material in the RPA and BiOp (http://www.fws.gov/sacramento/es/documents/SWP-CVP_OPs_BO_12-15_final_OCR.pdf)

✓Independent Review of Two Sets of Proposed Actions for the Operations Criteria and Plan's Biological Opinion (PBS&J, 2008) (http://www.fws.gov/sacramento/es/documents/Peer%20review%20of%20proposed%20actions%2011-19-08.pdf)

✓NRC March 2010 panel report

(http://www.nap.edu/catalog.php?record_id=12881

✓DOI Technical Guide

(http://www.doi.gov/initiatives/AdaptiveManagement/)

CERTIFICATE OF SERVICE

I hereby certify that on July 15, 2011, I electronically filed the foregoing with the Court by using the Court's CM/ECF system.

Participants in the case who are registered CM/ECF users will be served by the Court's CM/ECF system.

I further certify that the court-appointed experts are not registered CM/ECF users. I have emailed the foregoing document to the following:

REPLY DECLARATION OF DR. KENNETH P. BURNHAM IN SUPPORT OF PLAINTIFF'S MOTION FO RINJUNCTIVE RELIEF

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I declare under penalty of perjury under the laws of the State of California the foregoing is true and correct and that this declaration was executed on July 15, 2011, at San Francisco, California.

/s/ Teresa M. Mendoza

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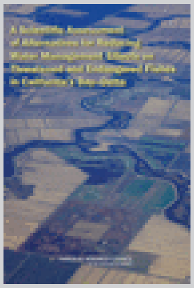

A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay Delta

ISBN
978-0-309-12802-5

104 pages
6 x 9
PAPERBACK (2010)

Committee on Sustainable Water and Environmental Management in the California Bay-Delta; National Research Council

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Committee on Sustainable Water and Environmental Management in the California Bay-Delta

Water Science and Technology Board

Ocean Studies Board

Division on Earth and Life Studies

NATIONAL RESEARCH COUNCIL
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THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, D.C. 20001

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Support for this study was provided by the Department of the Interior under contract no. 80221-A-G100. Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-12802-5
International Standard Book Number-10: 0-309-12802-1

Additional copies of this report are available from the National Academies Press, 500 5th Street, N.W., Lockbox 285, Washington, D.C. 20055; (800) 624-6242 or (202) 334-3313 (in the Washington metropolitan area); Internet, http://www.nap.edu.

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Preface

California, like many states, faces challenges related to water. Much of the state is too dry to support many human activities, such as municipal and industrial water use and irrigated agriculture, without supplementing the natural water supply. It has done this through an extensive series of engineering projects that include reservoirs, canals, levees, and pumps, largely to move water from the more humid north to the more arid and densely populated south. Much of California's natural surface-water supply flows into and through the Sacramento and San Joaquin watersheds into California's Bay-Delta, and from there through San Francisco Bay into the ocean. The delta itself is a biologically diverse estuarine ecosystem, and is the main point of diversion for water that is transported to the south.

As California's population and economic activity have increased, along with water diversions from the delta, conflicts over various water uses have increased as well, especially surrounding the bay-delta. Those conflicts have been brought to a head by restrictions on water diversions that have been required by two biological opinions, one by the U.S. Fish and Wildlife Service, covering delta smelt, and one by the National Marine Fisheries Service, covering salmon, steelhead, and sturgeon, to protect those fishes, which are listed as threatened or endangered under the federal Endangered Species Act. In addition, several recent dry years have exacerbated the situation. Conflicts over water are not new in California, but the current conflicts over the bay-delta appear to be unprecedented in their scale. Few parts of the state are unaffected by what happens to delta water.

Protecting all the listed species and preserving existing and projected uses of the region's water is a serious challenge. The complexity of the problem and the difficulty of identifying solutions have been highlighted by a plethora of scientific publications and arguments, in which many qualified and distinguished experts have reached differing conclusions. Nobody disagrees that engineering changes; the introduction of many exotic species, the addition of contaminants to the system, and the general effects of an increasing human population have contributed to the fishes' declines. There are, however, disagreements about the relative contributions of those factors and the appropriate remedies for them. This is the context in which the National Research Council was asked by Congress and the Department of the Interior to help resolve the issue by evaluating the scientific bases of the biological opinions. In response, the NRC appointed a special committee of experts to carry out a complex and challenging study in two phases.

In its first phase, the committee was tasked to focus on the scientific bases of the reasonable and prudent alternatives (RPAs) in the two biological opinions. The committee also assessed whether the RPAs might be in conflict with one another, as well as whether other options might be available that would protect the fishes with lesser impacts on other water uses. Finally, we were asked to consider the effects of "other stressors" on the fishes if sufficient time were available. The results of this first-phase analysis are the subject of this report. The committee did consider other stressors, but it did not evaluate them in depth. They will be more thoroughly addressed in a second report, scheduled to be published late in 2011, which will focus on broader issues surrounding attempts to provide more sustainable water supplies and to improve the ecological sustainability of the delta, including consideration of what ecological goals might be attainable.

The committee met in Davis, California for five days in January 2010. The committee heard presentations from representatives of federal and state agencies and a variety of other experts, and from members of several stakeholder groups and the public (see Appendix D). The information gathering sessions of this meeting were open to the public and widely advertised. The committee sought to hear from as many groups and individuals as possible within the time constraints. All speakers, guests, and members of the public were encouraged to provide written comments during and after the meeting. All presentations and written materials submitted were considered by the committee as time allowed. The committee thanks all the individuals who provided information.

This report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise in accordance with the procedures approved by the NRC's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the NRC in making its published report as sound as possible, and to ensure that the report meets NRC institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following for their reviews of this report: Joan G. Ehrenfeld, Rutgers University; Mary C. Fabrizio, Virginia Institute of Marine Science; Peter Gleick, Pacific Institute; William P. Horn, Birch, Horton, Bittner & Cherot;

D. Peter Loucks, Cornell University; Jay Lund, University of California, Davis; Tammy Newcomb, Michigan Department of Natural Resources; and Andrew A. Rosenberg, Conservation International.

Although these reviewers provided constructive comments and suggestions, they were not asked to endorse the report's conclusions and recommendations, nor did they see the final draft of the report before its release. The review of this report was overseen by Michael Kavanaugh, Malcolm Pirnie, Inc., who was appointed by the NRC's Report Review Committee and by Leo Eisel, Brown and Caldwell, who was appointed by the NRC's Division on Earth and Life Studies. They were responsible for ensuring that an independent examination of this report was conducted in accordance with NRC institutional procedures and that all review comments received full consideration. Responsibility for this report's final contents rests entirely with the authoring committee and the NRC.

I am enormously grateful to my committee colleagues for their diligence, enthusiasm, persistence, and hard work. The schedule for the preparation of this report was short, and without everyone's engagement, it could not have been completed. I also am grateful to David Policansky, Stephen Parker, Laura Helsabeck, Heather Chiarello, Ellen de Guzman, and Susan Roberts of the NRC staff for their efforts in facilitating the committee's meeting and for their work in helping to get this report completed on schedule in the face of historic snowstorms.

California will continue to face great challenges in managing, allocating, and using water, including managing California's Bay-Delta. We hope the committee's reports can help in that difficult process.

Robert J. Huggett
Chair

Contents

Acronyms and Abbreviations

AF	Acre-feet
BA	Biological Assessment
BO	Biological Opinion
(C)DFG	California Department of Fish and Game
(C)DWR	California Department of Water Resources
C.F.R.	Code of Federal Regulations
Cir	Circuit Court (federal system)
CVP	Central Valley Project
CVPIA	Central Valley Project Improvement Act
DCC	Delta Cross Channel
DOI	(U.S.) Department of the Interior
DSM2	Delta Simulation Model II
EDT	Ecosystem Diagnosis and Treatment
ESA	Endangered Species Act
EWA	Environmental Water Account
FMT	Fall Midwater Trawl (survey)
FWS	(U.S.) Fish and Wildlife Service
HORB	Head of Old River Barrier
MAF	Million acre-feet
M&I	Municipal and Industrial
NAS	National Academy of Sciences
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
OCAP	Operations Criteria And Plan
OMR	Old and Middle River
OSB	Ocean Studies Board of the NRC
PTM	Particle-Tracking Model
RBDD	Red Bluff Diversion Dam
RPA	Reasonable and Prudent Alternative
SWP	State Water Project
TAF	Thousand acre-feet
USBR	United States Bureau of Reclamation
U.S.C.	United States Code
USGS	United States Geological Survey
VAMP	Vernalis Adaptive Management Plan
WSTB	Water Science and Technology Board of the NRC
X2	Contour line of salinity 2

Summary

California's Bay-Delta estuary is a biologically diverse estuarine ecosystem that plays a central role in the distribution of California's water from the state's wetter northern regions to its southern, arid, and populous cities and agricultural areas. In addition to its ecological functioning and the ecosystem services it provides, there are numerous withdrawals of freshwater from the delta, the largest being pumping stations that divert water into the federal Central Valley Project (CVP) and the State Water Project (SWP), primarily for agriculture and metropolitan areas. Most former wetland and marsh areas of the delta have been drained for agriculture, and are protected by an aging collection of levees. Some of those areas also contain small urban settlements.

This hydrologic and engineered system has met the diverse water-related needs of Californians for decades. But operation of the engineered system, along with the effects of an increasing population of humans and their activities, has substantially altered the ecosystem. These ecosystem changes have contributed to changes in the abundance, distribution, and composition of species in the delta, including the decline of many native species and the successful establishment of many species not native to the region.

Recently, the Fish and Wildlife Service (FWS) and the National Marine Fisheries Service (NMFS) issued biological opinions under the federal Endangered Species Act (ESA) that required changes ("reasonable and prudent alternatives," or RPAs) in water operations and related actions to avoid jeopardizing the continued existence and potential for recovery of delta smelt, winter-run and fall-run Chinook salmon, Central Valley steelhead, and green sturgeon. Those changes have reduced the amount of water available for other uses, and the tensions that resulted have been exacerbated by recent dry years.

The RPAs are divided into many separate actions. The RPA in the FWS opinion, divided into six actions, applies to delta smelt and thus focuses primarily on managing flow regimes to reduce entrainment of smelt and on extent of suitable water conditions in the delta, as well as on construction or restoration of

habitat. The NMFS RPA, divided into five actions with a total of 72 subsidiary actions, applies to the requirements of Chinook salmon, steelhead, and green sturgeon in the delta and farther upstream. In addition to its focus on flow regimes and passage, it includes purchasing water to enhance in-stream flow, habitat restoration, a new study of acoustic-tagged steelhead, and development of hatchery genetics management plans. This committee did not evaluate all 78 actions and subsidiary actions in the two RPAs in detail. It spent most of its time on the elements of the RPAs that have the greatest potential to affect water diversions. It also spent time on elements whose scientific justifications appear to raise some questions.

Protecting all the listed species, as required by the ESA, while simultaneously trying to minimize impacts on existing and projected uses of the region's water, is a serious challenge. In addition, many anthropogenic and other factors, including pollutants; introduced species; and engineered structures such as dams, canals, levees, gates, and pumps adversely affect the fishes in the region, but they are not under the direct control of the CVP or the SWP, and thus are not subjects of the biological opinions.

The complexity of the problem of the decline of the listed species and the difficulty of identifying viable solutions have led to disagreements, including concerns that some of the actions in the RPAs might be ineffective and might cause harm and economic disruptions to water users, and that some of the actions specified in the RPAs to help one or more of the listed species might harm others. In addition, some have suggested that the agencies might be able to meet their legal obligation to protect species with less economic disruptions to other water users. Those concerns led the Department of the Interior and Congress to ask for advice from the National Research Council (NRC), which appointed a special committee of experts to carry out this study.

THE COMMITTEE'S CHARGE

The committee's charge includes the following tasks (the full statement of task is in Appendix A).

The committee was asked to undertake two main projects over a term of two years resulting in two reports. The first report, prepared on a very short timeline, was to address scientific questions, assumptions, and conclusions underlying water-management alternatives (i.e., the RPAs) in the two biological opinions mentioned above, and this is where the committee focused most of its attention. In addition, three specific issues were to be addressed. First, are there any "reasonable and prudent alternatives" (RPAs) that, based on the best available scientific data and analysis, would provide equal or greater protection for the listed species and their habitat while having lesser impacts to other water uses than those adopted in the biological opinions? Second, are there provisions in the biological opinions to resolve the potential for actions that would benefit one listed species while causing negative impacts on another? And finally, to the extent that time permits, the committee was asked to consider the effects of other stressors (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Bay-Delta. The committee's second report, due in late 2011, will address how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the Bay-Delta.

The committee's charge was to provide a scientific evaluation, not a legal one, and that is what the committee did. **Nothing in this report should be interpreted as a legal judgment as to whether the agencies have met their legal requirements under the ESA.** The committee's report is intended to provide a scientific evaluation of agency actions, to help refine them, and to help the general attempt to better understand the dynamics of the delta ecosystem, including the listed fishes.

THE COMMITTEE'S PRINCIPAL CONCLUSIONS

Context

The California Bay-Delta is a system that has undergone significant anthropogenic changes for more than a century. Those changes include water withdrawals; draining of wetlands; introduction of many nonnative species of plants and animals, some deliberate; construction of canals, gates, marinas, roads, levees, pumps, dams, and other structures that affect the hydrology of the system; the damming of almost all the major rivers and tributaries to the system, which also has altered the seasonal flow regime and other hydrologic aspects of the system; and the release of contaminants, pollutants, and nutrients into the system as a result of the above changes and the increase of agriculture, industrial and residential development, and other human activities. All these changes have affected the distribution, abundance, and composition of species in the delta, some of which have increased dramatically and some, including the species listed under the Endangered Species Act (Chinook salmon, delta smelt, steelhead, and green sturgeon), which have declined precipitously. The biological opinions with their associated RPAs that the committee has reviewed relate only to proposed changes in operations of the CVP and the SWP in the delta and methods to reduce the adverse effects on the listed species of those changes. Some restrictions on CVP and SWP water diversions have been initiated to protect the listed fish species, but so far have not produced measurable effects in slowing their declines.

The committee concludes that reversing or even slowing the declines of the listed species cannot be accomplished immediately. Even the best-targeted methods of reversing the fish declines will need time to take effect amid changing environmental conditions such as multi-year droughts and continued pressures on the system from other human-caused stresses. Especially for fishes whose populations are very low already, the effects of any actions will be difficult to detect at first, and detecting them will be made more difficult by the effects of other environmental changes and uncertainties inherent in sampling small populations.

The FWS Biological Opinion and RPA

The committee considered the six actions contained within the RPA, most of which were judged to have a sound conceptual basis. The committee then focused on the RPA actions that involved Old and Middle River (OMR) flows, the management of the mean position of the contour where salinity is 2[1] (X2), and the creation or restoration of tidal habitat for smelt. The first two actions involve significant requirements for water; the third does not.

The management of OMR flows is predicated on the concept that pumping of water for export from the south delta creates net negative (toward the pumps) flows, averaged over the tidal cycle, that cause delta smelt (and some juvenile salmon) to be experience increased mortality in the south delta, especially in winter. The RPA action limits the net OMR flows to levels that depend on conditions during this period, with a variety of environmental triggers and adaptive-management procedures. **Although there are scientifically based arguments that raise legitimate questions about this action, the committee concludes that until better monitoring data and comprehensive life-cycle models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt populations. Thus, the concept of reducing OMR negative flows to reduce mortality of smelt at the SWP and CVP facilities is scientifically justified.**

[1] This is often expressed as a concentration, e.g., "2 parts per thousand," but more recently it has been expressed as a ratio of electrical conductivities, hence it has no units.

However, there is substantial uncertainty regarding the amount of flow that should trigger a reduction in exports. In other words, the specific choice of the negative flow threshold for initiating the RPA is less clearly supported by scientific analyses. The biological benefits and the water requirements of this action are likely to be sensitive to the precise values of trigger and threshold values. There clearly is a relationship between negative OMR flows and mortality of smelt at the pumps, but the data do not permit a confident identification of the threshold values to use in the action, and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses that permit regular review and adjustment of strategies as knowledge improves.

The management of the mean position of X2 during the fall (Action 4 of the FWS RPA) is based on observations that relate smelt use of spawning habitat with various salinity regimes. X2 is interpreted by the agencies not as a single line, but rather as an indicator of the spatial pattern of salinity in the delta and thus as indicative of the extent of habitat favorable for delta smelt.

The relationships among smelt abundance, habitat extent, and the mean position of X2 as an indicator of available habitat are complex. The controversy about the action arises from the poor and sometimes confounding relationship between indirect measures of delta smelt populations (indices) and X2. Although there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes, the relationship of that distribution and smelt abundance indices is unclear. **The X2 action is conceptually sound in that to the degree that the amount of habitat available for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the derivation of the details of this action lacks rigor.** The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance). Each step of this logical train of relationships is uncertain. The relationships are correlative with substantial variance left unexplained at each step, yet the analyses do not carry the uncertainty at each step to the next step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions. **As a result, the committee concludes that how specific X2 targets were chosen and their likely beneficial effects need further clarification. It also is critical that the adaptive-management requirements**

included in the RPA be implemented in light of the uncertainty about the biological effectiveness of the action and its possibly high water requirements.

The tidal habitat management action in the RPA requires creation or restoration of 8,000 acres of intertidal and subtidal habitat in the delta and in Suisun Marsh. This action has not been controversial because it does not affect other water users. **The committee finds that the conceptual foundation for this action (Action 6) is weak because the relationship between tidal habitats and food availability for smelt is poorly understood. The details of its implementation are not fully justified in the biological opinion. The committee recommends that this action be implemented in phases, with the first phase to include the development of an implementation and adaptive management plan (similar to the approach used for the floodplain habitat action in the NMFS biological opinion), but also to explicitly consider the sustainability of the resulting habitats, especially those dependent on emergent vegetation, in the face of expected sea-level rise.** In addition, there should be consideration of the types and amounts of tidal habitats necessary to produce the expected outcomes and how they can be achieved and sustained in the long term. The committee supports the monitoring program referred to in Action 6, and appropriate adaptive management triggers and actions.

The NMFS Biological Opinion and RPA

The NMFS RPA for salmon, steelhead, and green sturgeon is a broad complex of diverse actions spanning three habitat realms: tributary watersheds, the mainstem Sacramento and San Joaquin Rivers, and the delta. **On balance, the committee concludes that the actions, which are primarily crafted to improve life-stage-specific survival rates for salmon and steelhead, with the recognition that the benefits also will accrue to sturgeon, are scientifically justified.** The strategies underpinning many of the individual actions are generally well supported by more than a decade of conceptual model building about the requirements of salmonids in the region, although the extent to which the intended responses are likely to be realized is not always clearly addressed in the RPA. Given the absence of a transparent, quantitative framework for analyzing the effects of individual and collective actions, it is difficult to make definitive statements regarding the merits of such a complex RPA. Indeed, absent such an analysis, the controversial aspects of some of the RPA actions could detract from the merits of the rest of the RPA.

In general, as described in detail in Chapter 6, the committee concludes that although most, if not all, of the actions in this RPA had a sound conceptual basis, the biological benefits and water requirements of several of the actions are, as with the delta smelt actions, likely quite sensitive to the specific triggers, thresholds, and flows specified. As a result, the committee recommends that the specific triggers, thresholds, and flows receive additional evaluation that is integrated with the analyses of similar actions for delta smelt.

In particular, the committee concludes that it is difficult to ascertain to what extent the collective watershed and tributary actions will appreciably improve survival within the watershed or throughout the entire river system. The committee concludes that the actions to improve mainstem passage for salmonids and sturgeon, in particular those concerning the Red Bluff Diversion Dam, are well justified scientifically. The committee recommends some kind of quantitative assessment framework for assessing survival be developed and implemented.

The management of OMR flows to reduce entrainment mortality of salmon smolts is similar in concept to the smelt OMR action, and like that action, **the committee concludes that its conceptual basis is scientifically justified, but the scientific support for specific flow targets is less certain. Uncertainty in the effect of the triggers should be reduced, and more-flexible triggers that might require less water should be evaluated.**

Another set of actions in this RPA focuses on managing exports and flows in the San Joaquin River to benefit outmigrating steelhead smolts. The actions are intended to reduce the smolts' vulnerability to entrainment into the channels of the south delta and the pumps by increasing the inflow-to-export ratio of water in the San Joaquin River. It thus has two components: reducing exports and increasing San Joaquin River inflows into the delta. **The committee concludes that the rationale for increasing San Joaquin River flows has a stronger foundation than does the prescribed export action. We further conclude that the action involving a six-year study of smolt survival would provide useful insight into the effectiveness of the actions as a long-term solution.**

The final two actions considered here were improving the migratory passage of salmon and sturgeon through the Yolo Bypass and the inundation of additional floodplain lands to provide additional rearing habitat for juvenile salmon. **The committee concludes that both actions are scientifically justified, but the implications for the system as a whole of routing additional flows through the Yolo Bypass for the system were not clearly analyzed.** In particular, the consequences of the action for Sacramento River flows and for the potential mobilization of mercury were not clearly described.

Other Possible RPAs

The committee's charge requires the identification, if possible, of additional potential RPAs that might have the potential to provide equal or greater protection to the fishes than the current RPAs while costing less in terms of water availability for other uses. **The committee considered a variety of possible actions not in the RPAs (see Chapter 6), and concluded that none of them had received sufficient documentation or evaluation to be confident at present that any of them would have the potential to provide equal or greater protections for the species while requiring less disruption of delta water diversions.**

Other Stressors

Based on the evidence the committee has reviewed, the committee agreed that the adverse effects of all the other stressors on the listed fishes are potentially large. Time did not permit full exploration of the issue in this first report, but examples of how such stressors may affect the fishes are described. The committee will explore this issue more thoroughly in its second report.

Modeling

The committee reviewed the models the agencies used to understand the basis for the resource agencies' jeopardy opinion and to determine to what degree they used the models in developing the RPAs. **The committee concluded that as far as they went, despite flaws, the individual models were scientifically justified, but that they needed improvements and that they did not go far enough toward an integrated analysis of the RPAs. Thus the committee concluded that improving the models by making them more realistic and by better matching the scale of their outputs to the scale of the actions, and by extending the modeling framework to be more comprehensive and to include features such as fish life cycles would improve the agencies' abilities to assess risks to the fishes, to fine-tune various actions, and to predict the effects of the actions.**

Potential Conflicts Between RPAs and Integration of RPAs

The committee concludes that the RPAs lack an integrated quantitative analytical framework that ties the various actions together within species, between smelt and salmonid species, and across the watershed. This type of systematic, formalized analysis, although likely beyond the two agencies' legal obligations when rendering two separate biological opinions, is necessary to provide an objective determination of the net effect of all their actions on the listed species and on water users.

An additional overall, systematic, coordinated analysis of the effect of all actions taken together and a process for implementing the optimized, combined set of actions is required to establish the credibility of the effort overall. The committee is aware that instances of coordination among the agencies certainly exist, including modification of actions to reduce or eliminate conflicting effects on the species. Indeed, the committee did not find any clear example of an action in one of the RPAs causing significant harm to the species covered in the other RPA. But coordination is not integration. The lack of a systematic, well-framed overall analysis is a serious scientific deficiency, and it likely is related to the ESA's practical limitations as to the scope of actions that can or must be considered in a single biological opinion. The interagency effort to clearly reach consensus on implications of the combined RPAs for their effects on all the species and on water quality and quantity within the delta and on water operations and deliveries should use scientific principles and methods in a collaborative and integrative manner. Similarly, this committee's efforts to evaluate potential harmful effects of each RPA on the species covered in the other RPA were hampered by the lack of a systematic, integrated analysis covering all the species together. Full documentation of decisions should be part of such an effort, as should inclusion of the environmental water needs of specific actions and for the entire RPA.

It is clear that integrative tools that, for example, combine the effect over life stages into a population-level response would greatly help the development and evaluation of the combined actions. There has been significant investment in hydrological and hydrodynamic models for the system, which have been invaluable for understanding and managing the system. An investment in ecological models that complement and are integrated with the hydrological and hydrodynamics models is sorely needed. Clear and well-documented consideration of water requirements also would seem well advised because some of the actions have significant water requirements. Credible documentation of the water needed to implement each action and the combined actions, would enable an even clearer and more logical formulation of how the suite of actions might be coordinated to simultaneously benefit the species and ensure water efficiency. **This recommendation for integration of models and across species responds to the committee's broad charge of advising on how to most effectively incorporate scientific and adaptive-management concepts into holistic programs for managing the delta, and likely goes beyond the agencies' legal obligations under the ESA, and will be addressed more thoroughly in the committee's second report.**

1
Introduction

California's Bay-Delta estuary is a biologically diverse estuarine ecosystem that plays a central role in the distribution of California's water from the state's wetter northern regions to its southern, arid, and populous cities and agricultural areas (Figure 1-1). The Bay-Delta region receives water flows from the Sacramento and San Joaquin Rivers and their tributaries, which drain the east slopes of the Coast Range, the Trinity Alps and Trinity Mountains in northern California, and the west slopes of the Sierra Nevada Mountains. Outflows from the Bay-Delta, through San Francisco Bay and into the Pacific Ocean, are met by tidal inflows, resulting in a brackish water ecosystem in many reaches of the Bay-Delta. In addition to its ecological functioning and the ecosystem services it provides, there are numerous withdrawals of freshwater from the Bay-Delta, the largest being pumping stations that divert water into the federal Central Valley Project (CVP), primarily for Central Valley agriculture, and the State Water Project (SWP), primarily for southern California metropolitan areas. Other water is extracted from Bay-Delta waterways for consumptive use within the delta region itself, and for municipal and industrial use around the margins of the delta, and returned to its waterways diminished in quantity and quality. Most former wetland and marsh areas of the delta have been drained for agriculture, and are protected by an aging collection of levees (Moyle et al., 2010). Some of those areas also contain small urban settlements.

This hydrologic and engineered system has met the diverse water-related needs of Californians for decades. But construction and operation of the engineered system, along with the effects of an increasing population of humans and their activities, have substantially altered the ecosystem. Current conditions include altered water-quality and salinity regimes and the magnitude and direction of flows in the delta, with rigorous management of the location of the contour where salinity is 2[1] (known as X2) through flow releases from upstream reservoirs. Consequent changes in the abundance, distribution, and composition of species in the delta have been compounded by the introduction and invasion

[1] This is often expressed as a concentration, e.g., "2 parts per thousand," but more recently it has been expressed as a ratio of electrical conductivities, hence it has no units.

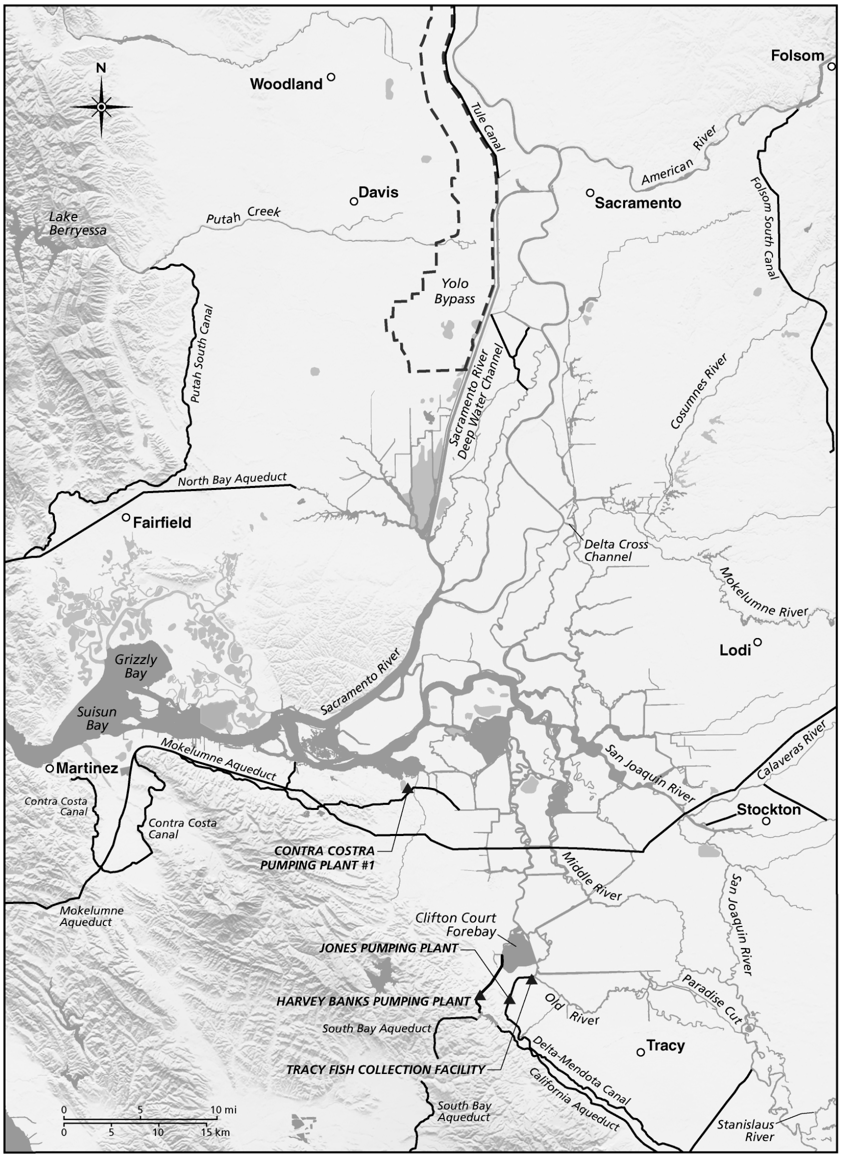

FIGURE 1-1 Map of the delta. SOURCE: Modified from FWS (2008).

of many species not native to the region.

Recently, several species of native fishes have been listed as threatened or endangered under the federal Endangered Species Act (ESA) and the California Endangered Species Act. This study focuses only on the federal ESA. The federal listings have led to Section 7 (of the ESA) consultations between the operators of the CVP (the U.S. Bureau of Reclamation, or USBR) and of the SWP (the California Department of Water Resources, or DWR) and the Fish and Wildlife Service (FWS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Game (DFG). Those consultations led to the issuance of opinions by the Services that required changes ("reasonable and prudent alternatives," or RPAs) in water operations and related actions to avoid jeopardizing the continued existence and potential for recovery of delta smelt (*Hypomesus transpacificus*), winter-run and fall-run Chinook salmon (*Oncorhynchus tshawytscha*), Central Valley steelhead (*Oncorhynchus mykiss*), and green sturgeon (*Acipenser medirostris*). The impacts of the RPAs on water users and the tensions that resulted have been exacerbated recently by series of dry years. In the longer term, climate change presents uncertainties and challenges with its anticipated impact on precipitation, snowpack, streamflow, and rising sea level, which will affect not only salinity and riparian habitats in the delta but likely also will threaten the integrity of the extensive system of levees (1,100 miles in length).

The RPAs are divided into many separate actions. The RPA in the FWS opinion (FWS, 2008), divided into six actions, focuses primarily on the flow and storage regimes as affected by diversions (pumping water to the south) and on reducing entrainment, with some focus on habitat. The NMFS RPA (NMFS, 2009) is divided into five actions with a total of 72 subsidiary actions. In addition to its focus on flow regimes, storage, and passage, it includes purchasing water to enhance in-stream flow, habitat restoration, a new study of acoustic-tagged steelhead, and development of hatchery genetics management plans. This committee did not evaluate all 78 actions and subsidiary actions in the two RPAs in detail. It spent most of its time on the elements of the RPAs that have the greatest potential to affect water diversions. It also spent time on elements whose scientific justifications appear to raise some questions.

Protecting all the listed species and preserving existing and projected uses of the region's water is a serious challenge. As the NMFS biological opinion (NMFS, 2009) says, "the current status of the affected species is precarious," and "it has been difficult to formulate an RPA that is likely to avoid jeopardy to all listed species and meets all regulatory requirements." Adding to this difficulty is the existence of the many anthropogenic and other factors that adversely affect the fishes in the region but which are not under the direct control of the

CVP or the SWP, and thus are not subjects of the biological opinions[2]. These include other human modifications to the system, including pollutants; invasive species and altered species composition; and engineered structures such as dams, canals, gates, pumps, and levees.

The complexity of the problem of the decline of the listed species and the difficulty of identifying solutions to it have led to disagreements, including concerns that some of the actions in the RPAs might cause harm and economic disruptions to many water users, and that some of the actions specified in the RPAs to help one or more of the listed species might harm others.

SYSTEM OVERVIEW

Overview of System Hydrology

We briefly describe the Sacramento-San Joaquin delta (Figure 1-1) and the two massive water storage and delivery projects that affect the area. Several publications go into great detail describing the delta and the operations of the federal and state water systems (DWR, 2006, 2009a, 2009b; USBR, 2006).

The Central Valley Project (CVP) operated by the U.S. Bureau of Reclamation and the State Water Project operated by the California Department of Water Resources provide water to farms and cities in an area encompassing the majority of the land and population of California. The two projects constitute the largest agriculture and municipal water-supply system in the United States. Water supplying both projects ultimately comes mainly from California's two major river systems—the Sacramento and the San Joaquin—with substantial imports from the Trinity River. Water also is stored in several major reservoirs as well, including Shasta (capacity 4.6 million acre-feet[3], or MAF), Oroville (3.4 MAF), Trinity (2.4 MAF), New Melones (2.4 MAF), San Luis (2 MAF), Don Pedro (2 MAF), McClure (Exchequer) (1 MAF), and Folsom (1 MAF), as well as many smaller ones. Releases from those reservoirs are used to help manage flows and salinity in the delta, as well as being used for agriculture, municipal and industrial uses, recreation, flood protection, and hydropower.

The CVP provides about 5 MAF of water to agriculture each year (about 70 percent of the CVP's supply), 0.6 MAF for municipal and industrial (M&I) use

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[2] Those other mainly adverse changes are considered as part of the "environmental baseline."

[3] An acre-foot is the amount of water required to cover an acre of land to a depth of one foot; it is equal to 43,560 cubic feet, 325,851 gallons, or 1,234 cubic meters of water.

(serving about 2 million people) and 1.4 MAF to sustain fish, wildlife, and their habitats. The SWP provides about 70 percent of its water to M&I customers (about 20 million people) and 30 percent to agriculture (about 660,000 acres of irrigated farmland). The largest SWP contractor is the Metropolitan Water District of Southern California, which receives about 50 percent of SWP deliveries in any one year. At least two-thirds of the population of California depends on water delivered from these projects as a primary or supplemental source of supply. Other important functions provided by both projects include flood protection, recreation, power generation, and water quality to preserve fish and wildlife.

Both projects preceded and accommodated the explosive growth of California's economy and population. The CVP was begun in the mid to late 1930s and the SWP was begun in the 1960s. Dozens of reservoirs and lakes, pumping facilities, and over 1,200 miles of pipelines and canals make up the two interdependent water-supply and delivery systems.

The Sacramento-San Joaquin Delta

In the middle of both systems and connecting the northern water supply reservoirs and southern water demands is the Sacramento-San Joaquin Delta (Figure 1-1). Thus, the delta is an integral part of the water-delivery infrastructure for both the SWP and CVP. While the focus of this report is the determination of the effects of water allocations for fish, there are many other requirements that must be met in the delta to maintain flows and quality for the many uses of water delivered by the SWP and CVP projects.

Two major pumping plants draw water from the channels and rivers feeding the delta. The SWP pumping plant (Banks Pumping Plant) can deliver an average flow of nearly 6,700 cubic feet per second (cfs) to Clifton Court Forebay for transport to users south of the delta. The Jones Pumping Plant withdraws water primarily from Old River and has the capability of 4,600 cfs to contractors in southern California. Relatively small amounts of water are extracted for the Contra Costa canal (up to 195,000 af or 195 thousand acre-feet {TAF} per year) and the North Bay Aqueduct (up to 71 TAF per year) (FWS, 2008). In addition, diversions occur upstream of the delta. These diversions affect the location of X2, the amount of water that can be withdrawn at the pumps, the flow in the San Joaquin River, and other factors.

THE PRESENT STUDY

The statement of task (Appendix A) charges the NRC committee to review the scientific basis of the Services' RPAs and advise on how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the delta. To balance the need to inform near-term decisions with the need for an integrated view of water and environmental management challenges over the longer-term, the committee was tasked to produce two reports. This first report focuses on the scientific bases of the water-management alternatives (RPAs) in the two biological opinions and whether there might be possible alternative RPAs that would be as or more protective of the fishes with lesser impacts on other water uses. The committee also has considered "other stressors," as specified in its statement of task. These are stressors not necessarily directly associated with the water projects; they are part of the "environmental baseline," a concept related to the Endangered Species Act that refers to other anthropogenic modifications of the environment. As such, they are not addressed by the RPAs, because RPAs must address operations of the water projects.

In this first report, most of the committee's focus has been on the question of the scientific bases of the water-management alternatives (RPAs) in the biological opinions, with a smaller focus on potential conflicts between the RPAs, potential alternative RPAs, and other stressors. The committee's second report will focus on broader issues surrounding attempts to provide more sustainable water supplies and to improve the ecological sustainability of the delta, including consideration of what ecological goals might be attainable.

To prepare this report, the committee met in Davis, California for five days in January 2010. It heard presentations from representatives of federal and state agencies and a variety of other experts, and from members of the public, and began work on the report. The committee was able to consider information received by February 8, 2010. Additional writing and two teleconferences occurred in February, and the report was reviewed according to the NRC's report-review procedure (the reviewers are acknowledged in the preface).

2

The Legal Context of This Report

SCOPE OF THE COMMITTEE'S TASK

The committee was asked "to review the scientific basis of actions that have been and could be taken to simultaneously achieve both an environmentally sustainable Bay-Delta and a reliable water supply." While this committee's review is scientific, and not legal, the committee nonetheless recognizes the importance of the legal context within which its evaluation takes place. The standard of review applicable in legal challenges to the opinions and associated RPAs provides a useful reference. In such lawsuits, courts will invalidate the RPAs only if they are demonstrated to be "arbitrary, capricious, an abuse of discretion, or otherwise not in accordance with law" (Administrative Procedure Act, 5 U.S.C. § 706(2)(A)). Courts are reluctant to second-guess technical agency judgments and may not substitute their judgment for that of the agency, particularly in cases where there are scientific uncertainty and differing scientific views. *See* Aluminum Co. of America v. Bonneville Power Administration, 175 F.3d 1156 (9th Cir. 1999); Trout Unlimited v. Lohn, 559 F.3d 946 (9th Cir. 2009). Thus, while the committee can come to different conclusions than the agencies did in their biological opinions, that would not be a *legal* justification for deeming them inadequate, as long as the agencies adequately considered the available scientific data and their conclusions are supportable by the evidence. Similarly, the RPAs should not be considered *legally* inadequate simply because different alternatives could be scientifically justified, as long as the agencies could reasonably believe that their RPAs would avoid the likelihood of jeopardy.

Some aspects of the committee's task require it to make determinations beyond the scope of the agencies' legal obligations or authority when issuing a biological opinion and RPAs. For example, the committee's charge includes consideration of the effects of stressors such as pesticides, ammonium, and invasive species on federally listed and other at-risk species in the Bay-Delta—stressors likely beyond the action agencies' legal authority to regulate, unless the effects are indirectly changed by the RPAs. Any such considerations by this committee in this or in its second report would have no bearing on the question of whether or not the biological opinions and RPAs are legally adequate. Instead, such considerations should be interpreted in contexts apart from the biological opinion and RPAs, such as the Bay-Delta Conservation Program (development of a habitat conservation plan); the State Water Resources Control Board's development of flow criteria for the delta; the Delta Stewardship Council's development of a delta plan; and others.

POTENTIAL VIOLATIONS OF ESA SECTION 7 AND SECTION 9

In each biological opinion, the relevant wildlife agency concluded that the proposed federal action—implementation of the water projects' operations plan—was likely to "jeopardize" the continued existence of species listed as endangered and to adversely modify their critical habitat. This would violate Section 7 of the Endangered Species Act (ESA), which requires agencies to "insure" that any actions they authorize, fund, or carry out are not likely to jeopardize endangered species or to destroy or adversely modify the species' critical habitat (16 U.S.C. § 1536 (a) (2)). As defined by agency regulations, "jeopardy" means that the proposed action "reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of [relevant endangered species] in the wild by reducing the reproduction, numbers, or distribution of that species" (50 C.F.R. § 402.02). As required by the ESA, the wildlife agencies suggested "reasonable and prudent alternatives" (RPAs) that would allow the action to go forward without violating Section 7 (16 U.S.C. § 1536 (B) (3) (A)).

In addition to the jeopardy determinations (generally, applying to species as a whole), both biological opinions found that the proposed action would "take" individual members of the endangered populations in violation of Section 9 of the ESA. By regulation, the "take" of an endangered species includes "an act which actually kills or injures wildlife" and may include "significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering" (Babbitt v. Sweet Home Chapter of Communities, 515 U.S. 687 (1995)).

The resource agencies, the National Marine Fisheries Service and the Fish and Wildlife Service, issued an "incidental take statement," in the present case, setting forth reasonable and prudent measures necessary and appropriate to minimize the effect of the proposed action on endangered species. If the action agencies (the Bureau of Reclamation and the California Department of Water

Resources) comply with those measures, including monitoring and reporting requirements, then any "takes" that result from project operations will be deemed "incidental," and they will be exempt from the prohibitions of Section 9.

STANDARDS FOR THE PREPARATION OF BIOLOGICAL OPINIONS

Best Available Data

Under the ESA, the agencies must develop their biological opinions and associated RPAs using the "best scientific and commercial data available" (16 U.S.C. § 1536 (a) (2)). Courts have emphasized the qualifier *available,* explaining that perfect data are not required. Action can be taken based on imperfect data, so long as the data are the best available. In addition, the above requirement does not remove the agency's discretion to rely on the reasonable judgments of its own qualified experts, even if others, even a court, might find alternative views more persuasive (see Aluminum Co. v. Bonneville Power Admin., 175 F.3d 1156 (9th Cir. 1999).

Thus, the courts afford the agencies significant deference in determining the best data available for developing the RPAs. Therefore, even if this committee might have relied on different data or come to different conclusions than the agencies did, it does not follow that the RPAs are legally insufficient. Rather, this committee's conclusions and recommendations should be seen as applying to future work beyond the scope of the agencies' legal obligations.

Economic Considerations

Although the economic impact of species protections may be relevant under the ESA, its influence is limited. For example, economic concerns *may not* be part of the decision whether or not to list species as endangered or threatened, but *must be* considered when the agencies designate critical habitat (16 U.S.C. § 1533). When developing biological opinions and RPAs, the Ninth Circuit acknowledged that the wildlife agencies may go beyond "apolitical considerations" and that if two proposed RPAs would avoid jeopardy to the relevant species, the agencies "must be permitted to choose the one that best suits all of its interests, including political or business interests." Southwest Center for Biological Diversity v. U.S. Bureau of Reclamation, 143 F.3d 515 (9th Cir. 1998); *See also* Bennett v. Spear, 520 U.S. 154 (1997) (asserting that the "best scientific and commercial data" provision is . . . intended, at least in part, to prevent uneconomic [because erroneous] jeopardy determinations"). Nevertheless, the lower courts have been reluctant to second-guess agency opinions on the basis of economic arguments (Aluminum Co. cited above).

Effects of the Proposed Action and the Environmental Baseline

In preparing biological opinions, agencies must evaluate the "effects of the [proposed] action" on the species or its critical habitat. Other adverse modifications of the species' habitats or negative effects on their populations are considered part of the "environmental baseline." The agencies' analysis includes consideration of:

1) direct effects;
2) indirect effects ("those that are caused by the proposed action and are later in time, but still are reasonably certain to occur");
3) interrelated actions ("those that are part of a larger action and depend on the larger action for their justification");
4) interdependent actions ("those that have no independent utility apart from the action under consideration"); and
5) cumulative effects ("those effects of future State or private activities, not involving Federal activities, that are reasonably certain to occur within the action area of the Federal action subject to consultation") (50 C.F.R. §§ 402.02 and 402.14(g)(3-4)).

STANDARDS FOR THE PREPARATION OF REASONABLE AND PRUDENT ALTERNATIVES (RPAs)

Although RPAs are not binding on the action agency, adherence to the RPAs provides the agency with a safe harbor from claimed violations of the ESA. As the U.S. Supreme Court explained, "the action agency is technically free to disregard the Biological Opinion and proceed with its proposed action, but it does so at its own peril (and that of its employees), for 'any person' who knowingly 'takes' an endangered or threatened species is subject to substantial civil and criminal penalties, including imprisonment" (Bennett v. Spear, 520 U.S. 154 (1997)).

Under agency regulations, the RPAs must satisfy each of the following four requirements:

1) Project purpose: RPAs must be capable of implementation in a manner consistent with the intended purpose of the action.
2) Scope of agency authority: RPAs must be consistent with the scope of the action agencies' legal authority and jurisdiction.
3) Feasibility: RPAs must be economically and technologically feasible; and
4) Avoid jeopardy: The directors of FWS and NMFS must believe that the RPAs would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat (50 C.F.R. § 402.02).

Although RPAs must avoid the likelihood of jeopardy, they are not required to promote recovery of the affected species. In other words, no RPA has the responsibility of mitigating all the adverse effects—the "environmental baseline"—that may be causing the decline of a listed species. They must only avoid the likelihood that the *proposed action* will cause jeopardy.

3

The Life Histories of the Fishes

INTRODUCTION

Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*Oncorhynchus mykiss*), and green sturgeon (*Acipenser medirostris*) are anadromous species; that is, they spawn in freshwater but spend a portion of their life in saltwater. Delta smelt (*Hypomesus transpacificus*) are resident within the brackish and freshwater habitats of the delta. In both anadromous and resident life-history strategies the fish migrate from their natal habitat into their adult habitat and then back to the spawning habitat, completing the life cycle. The fish do not simply drift between their habitats, but have evolved specific life-stage behaviors to meet the challenges they confront. These behaviors are cued by the fishes' physiology and by environmental conditions, which together drive the timing and movement of the individuals through their life cycle. Because all species spend time in the delta, they share some environmental conditions and challenges, but their different life histories cause them also to face unique challenges. Many of the challenges are the result of anthropogenic modifications to the delta and river habitats, and these challenges are of particular concern (see Chapter 5). Some, but not all, of them are addressed in the RPAs. The information on the fishes' life histories presented below illustrates the complexity of their interactions with their environments and the potential importance of apparently small changes in the timing, direction, and magnitude of variations in flow, salinity, turbidity, water temperature, and other environmental conditions.

FISHES OF THE SALMON FAMILY

The delta provides habitat for two species of Pacific salmon, Chinook salmon (hereafter "salmon") and the rainbow trout-steelhead complex. Pacific salmon typically are anadromous. There are many exceptions, however, such as rainbow trout, which although apparently genetically identical to steelhead, are not anadromous; and there is a great deal of variation in their life histories (Williams, 2006).

When adult salmon, steelhead, and sturgeon return from the ocean and begin their upriver migration, they experience several challenges, including physical and water-quality blockages. Here the delta water system has had a great impact on populations, for 80 percent of the historical spawning habitat for Chinook salmon (Clark, 1929) and much of it for the other species has been blocked by the storage reservoirs of the Central Valley (Lindley et al., 2006). Summer temperatures in the Central Valley waterways can reach potentially lethal levels for salmon, increasing their susceptibility to disease and decreasing metabolic efficiency (Myrick and Cech, 2001, 2004). The timing of adult salmon runs leads them to avoid most of the detrimental effects of high summer temperatures because they enter the delta and swim upriver to their spawning habitats and hatcheries in the spring, autumn, and winter. Wild spawning fish excavate redds in stream reaches with loose gravel in shallow riffles or along the margins of deeper runs (NMFS, 2009), where temperatures are cooler and eggs buried in the gravel receive a sufficient flux of oxygenated water through interstitial flow. The eggs incubate for several months and after emerging the young fry either immediately begin their migration back to the ocean or spend several weeks to a year in freshwater before migrating. Because of this diversity, juvenile salmon and steelhead pass through the delta throughout the year; however, the timing and size of the migrants generally corresponds to specific runs (Lindley et al., 2006; Williams, 2006).

Salmon and steelhead undergo a complex set of physiological changes in preparation for their migration to the ocean known as "smoltification," after which the young fish are known as "smolts." The alteration of the fish's physiology to successfully osmoregulate in saltwater after beginning life in freshwater is a significant challenge that can be exacerbated by human-caused environmental changes (e.g., NRC, 2004b). Most Central Valley Chinook salmon migrate to the ocean within a few months of hatching and the smolts are less than 10 cm long, although some remain in freshwater for up to a year. Juvenile steelhead migrate to sea after one to three years in freshwater, and can be as large as 25 cm in length. Young migrating Chinook are much more vulnerable to entrainment in adverse flows than the stronger-swimming steelhead smolts.

Juvenile salmon migrants experience predation during their downstream migration through the Sacramento River or through the interior delta on their way to the sea. Fish that enter the central delta, driven by the strong tidal and pumping-induced flows, are moved through a labyrinth of channels, which further delays their migration and exposes them to additional predators (Perry et al., 2010). Finally, fish that enter the Old and Middle Rivers (OMR) can be drawn towards the SWP and CVP pumps (Kimmerer, 2008a). Juvenile salmon that successfully pass through the delta enter the ocean and spend one or more years there before returning to freshwater to spawn. Ocean survival is particularly dependent on the conditions the fish experience during the first few months they enter the saltwater (Lindley et al., 2009). Fish that are drawn into the central and southern delta by reverse flows are more vulnerable to predation than those that take a more direct path to the ocean, and other aspects of changed environmental conditions also expose them to predators (for more detail, see Chapter 5).

GREEN STURGEON

The Central Valley green sturgeon (*Acipenser medirostris*) is an anadromous fish that can reach 270 cm (nearly nine feet) in length with a maximum age of 60 to 70 years (Moyle et al., 2002). The historical distribution of green sturgeon is poorly documented, but they may have been distributed above the locations of present-day dams on the Sacramento and Feather Rivers (Beamesderfer et al., 2007). Information on the distribution of green sturgeon in the San Joaquin River is lacking. Mature green sturgeon enter the Sacramento River from the ocean in March and April. The Red Bluff Diversion Dam can impede their migrations (Heublein et al., 2009). After spawning, green sturgeon may immediately leave the river or hold over in deep pools until the onset of winter rains (Erikson et al., 2002; Heublein et al., 2009). Individuals then migrate back to the ocean and return to freshwater to spawn every two to four years (Erickson and Webb, 2007; Lindley et al., 2008)

Based on adult spawning behavior and the habitats required for green sturgeon embryo development, reproductive females likely select spawning areas with turbulent, high velocities near low-velocity resting areas. Green sturgeon spawning areas are presumed to be characterized by coarser substrates upstream of lower gradient reaches, which usually have slower velocities. Eggs and milt are released in turbulent water above deep, complex habitats; fertilized eggs drift into deeper areas and stick onto the substrate. Eggs require cool temperatures for development and hatch after approximately a week. Larval and juvenile green sturgeons are bottom-oriented and nocturnally active until a few months of age (Kynard et al., 2005). Juvenile green sturgeon migrate into seawater portions of natal estuaries as early as one and a half years old (Allen and Cech, 2007), and eventually emigrate to nearshore coastal waters by three years old. Subadults are migratory, spending their next 12 to16 years foraging in the coastal ocean and entering western estuaries during the summer (Moser and Lindley, 2007). In the ocean, green sturgeon inhabit the coastal shelf out to 100m depth with occasional, rapid vertical ascents near or to the surface (Erickson and Hightower, 2006).

DELTA SMELT

The delta smelt is a near-annual species; most individuals complete their life cycle in one year, but some survive for two years and reproduce again. Delta smelt reside in brackish waters around the western delta and Suisun Bay region of the estuary, being commonly found in salinities of 2 to 7, but the range they occupy extends from 0 (freshwater) to 15 or more (Moyle, 2002). In the winter (December to April), pre-spawning delta smelt migrate to tidal freshwater habitats for spawning, and larvae rear in these areas before emigrating down to the brackish water (Bennett, 2005). Delta smelt inhabit open waters away from the bottom and shore-associated structural features. Although delta smelt spawning has never been observed in the wild, information about related members of the smelt family suggests that delta smelt use bottom substrate and nearshore features during spawning. Juvenile and adult stages, 20-70 mm in length, are generally caught in the western delta and Suisun Bay in the landward margin of the brackish salinity zone, which may extend upstream of the confluence zone of the Sacramento and San Joaquin Rivers. Historically pre- and post-spawned fish were observed throughout the delta. In wet years, spawning adults often were observed in the channels and sloughs in Suisun Marsh and the lower Napa River.

In the brackish habitat of the western delta the flow is tidal with a net seaward movement, and so to maintain position, the juvenile fish appear to coordinate swimming behavior with the tides, occurring near the surface on the flood tides and at depth on the ebbs. However, in other regions, adaptive tidal behavior has not been observed and fish simply move with the tides, which may promote horizontal exchange to adjacent shallow water habitats. The FWS biological opinion emphasizes the complexity of this behavior (p. 651) and thus the above description is a general one that does not capture details that might be important.

The brackish zone also has higher densities of other fishes and zooplankton, suggesting that it may serve as a nursery habitat for delta smelt and other fishes (Bennett, 2005). The spawning movement of adults from their brackish habitat in the western delta landward to the freshwater portions of the delta is triggered by high flows and turbidity pulses.

This diversity of paths from the low-salinity (brackish) zone to the freshwater spawning habitats suggests that delta smelt do not have fidelity to specific structural habitats as do salmon. Instead, their upstream movement is directed by a combination of physiological and environmental cues that involve salinity, turbidity, and both net and tidal flows through the channels of the delta and its tributaries. Additionally, since 2005, approximately 42 percent of the current delta smelt population is in the Cache Slough complex north of the delta, and may represent an alternative life-history strategy in which the fish remain upstream through maturity (Sommer et al., 2009).

Historically, the complete delta-smelt life cycle occurred unobstructed throughout the delta. Human-caused changes in delta water quality and hydrodynamics have disrupted the cycle and since 2005, delta-smelt population densities have been extremely low in the traditional habitats in the central and south delta (*http://www.dfg.ca.gov/delta/data/*), and pump salvage[1] also has been extremely low, about four percent of the 50-year average index (*http://www.dfg.ca.gov/delta/data/townet/indices.asp?species=3*). Analyses seeking causes for the declines to the present condition have focused on relationships between abundance, salvage, water exports, delta flows, turbidity, and food. Kimmerer (2008b) found that delta-smelt survival between summer (juvenile) and fall (adult) was related to zooplankton biomass, suggesting that high zooplankton abundances contributed to delta-smelt abundance and residence time in the southern delta, and thus increased entrainment risk at the pumps. Grimaldo et al. (2009) found that between 1995 and 2005 the inter-annual variation in adult delta-smelt salvage was best correlated with turbidity and the interaction of OMR[2] flows and X2[3]. The annual salvage of age-0 delta smelt (fish hatched in that year, around 27 mm in length) was best correlated with spring abundance of zooplankton, OMR flows, and turbidity. Additionally, Grimaldo et al. suggested that differences in temporal patterns of entrainment of delta smelt between years may be a measure of the degree to which their physical habitat overlapped with the hydrodynamic footprint of negative OMR flows towards the pumps. However, the year-class strength of adult delta smelt was not related to salvage, al-

[1] "Salvage" refers to fish caught in the pumps and retrieved alive to be released elsewhere in the system. It often is used as a surrogate estimate for "take" by the pumps.
[2] The term "OMR flows" refers to flows in the Old and Middle Rivers (see Figure 1-1), which are affected by the pumping of water for export. At high negative flows, that is, flows away from the sea towards the pumps in the south, the normal seaward flow associated with ebb tides can be completely eliminated.
[3] "X2" refers to the salinity isohaline of salinity 2 (a contour line of equal salinity). Sometimes X2 is used as shorthand for the mean position of that isohaline, measured in kilometers upstream from the Golden Gate Bridge over the outlet of San Francisco Bay. Managing the position of X2 is a major aspect of the delta smelt Biological Opinion and RPA; it is managed by adjusting flows of fresh water from delta reservoirs, as well as by adjusting pumping rates.

though the position of X2 was correlated with salvage at an intra-annual scale when OMR flows were negative. Other analyses showed a similar correlation (e.g., FWS, 2008).

While the correlation between OMR flows and salvage is substantial (Kimmerer, 2008b), their effect on population dynamics is not clear (Bennett, 2005; Grimaldo et al., 2009). Indirect factors could have contributed to population declines through a reduction in the size and abundance of food in the brackish zone. Overall zooplankton abundance is correlated with delta smelt survival (Feyrer et al., 2007; Grimaldo et al., 2009; Kimmerer, 2008b). Zooplankton abundance has been reduced through several factors, including the introduction of the overbite clam (*Corbula amurensis*), an efficient grazer of zooplankton in the low-salinity zone, and changes in nutrients that have altered the phytoplankton population so that cyanobacteria, which can reduce the food supply for zooplankton, have increased while diatoms have declined (FWS, 2008). The change in zooplankton species, associated with the success of invasive species in changed environmental conditions, also is probably important. It has been suggested that the position of X2 affects the size of delta smelt habitat and thus it affects the susceptibility of juvenile and adult delta smelt to pump entrainment (Feyrer et al., 2007, Kimmerer, 2008a). Furthermore, the mean position of X2 has moved inland about 10 km over the past 15 years (FWS, 2008, p. 180). However, there is no direct evidence relating these indirect effects to population numbers of smelt (Bennett, 2005; Kimmerer, 2002). In addition, delta smelt are now largely absent from the central and southern delta, while a significant portion of the remaining population exists in the Cache Slough complex to the north. These changes increase the uncertainty surrounding current estimates of delta smelt population changes in response to alterations in delta hydraulics.

4

Use of Models

MODELING SCENARIOS

Modeling of baselines and future project actions is a standard practice of evaluating impacts. Both biological opinions relied on the use of modeling scenarios (known as Studies) provided by the Operations Criteria and Plan (OCAP) biological assessment (BA) (*http://www.usbr.gov/mp/cvo/ocap_page.html*), although the extent to which such results were used in each biological opinion and in the formulation of RPAs varied significantly. The "proposed action" with reference to ESA is the continued operation of the CVP and SWP with additional operational and structural changes (USBR, 2008, Table 2-1) to the system. The U.S. Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR) provided the results of the modeling conducted for simulating baseline conditions, future system components, operational strategies, and the water supply demands. In addition to simulating the water-supply deliveries of the project, the modeling also attempted to mimic the project operations associated with the regulatory environments described in operating criteria described in D-1485, D-1641,CVPIA Section 3406 (b)(2) and the Environmental Water Account (EWA) (USBR, 2008). A major difference in the current and future scenarios is the extent to which EWA is used. The purpose of EWA was to enable diversion of water by the SWP and CVP from the delta to be reduced at times to benefit fish species while minimizing uncompensated loss of water to SWP and CVP contractors (USBR, 2008, Chapter 2). The EWA is intended to replace the water loss due to pumping curtailments by purchasing surface water and groundwater from willing sellers and through increasing the flexibility of operations. The simulations include both a "full EWA" characterizing the full use of EWA assets as well as a "limited EWA" focusing only on a limited number of assets. The EWA is currently under review to determine its future (FWS, 2008, p. 34) and the RPA actions were not based on it.

Another factor that changed from current to future conditions is the way water demand by CVP/SWP users is simulated. Demands have been pre-processed using either contractual amounts and/or level of development (existing versus future). Some demands were assumed to be fixed at contractual amounts whereas in other cases they varied according to the hydrologic conditions. This topic will be considered in the committee's second report.

While several study scenarios were developed for the OCAP biological assessment (USBR, 2008), the use of modeling results in the biological opinions was largely limited to a smaller set of scenarios (Table 4-1).

Study 7.0 describes the existing condition (circa 2005), whereas Study 7.1 presents the existing condition demands with near future facilities as well as the projected modification to EWA. Study 8 describes the future condition corresponding to the year 2030 (USBR, 2008, pp. 9-33, 9-53, 9-54). Study series 9 constitutes a future condition representing modified hydrology (warm and warmer, dry and wet) along with a projected sea level rise of one foot.

CENTRAL ISSUES CONCERNING MODEL USE IN THE BIOLOGICAL OPINIONS

The USFWS and NMFS supplemented the modeling results provided by USBR and DWR with their own modeling efforts and available science on the implications of management actions on species. The primary suite of models provided to FWS and NMFS include (USBR, 2008, Chapter 9):

(a) Operations and hydrodynamic models: CalSim-II, CalLite, the Delta Simulation Model II (DSM2), including particle-tracking models (PTMs, which also are considered as surrogates for biological models)

TABLE 4-1 Key scenarios used for biological opinions of FWS and NMFS

Study	Level of Development (Year)	Environmental Water Account (EWA)	Future Project Facilities[1]	Climate and Sea Level Rise
7.0	2005	Full EWA	No	No
7.1	2005	Limited EWA	Yes	No
8.0	2030	Limited EWA	Yes	No
9.0-9.5	2030	Same as in Study 8.0[2]	Yes	Yes

[1] Future project features include South Delta Improvement Program (Stage 1), Freeport Regional Water Project, California Aqueduct and Delta-Mendota Canal intertie
[2] According to the OCAP BA (USBR, 2008), Study suite 9 is identical to Study 8.0 except for climate change and sea-level rise

(b) Temperature models: Reclamation Temperature, SRWQM, and Feather River Mode
(c) Biological models: Reclamation Mortality, and SALMOD

The modeling framework used by the agencies is diagrammed in Figure 4-1.

The USFWS, in its biological opinion, used available results from a combination of tools and data sources, including CalSim-II, DSM2-PTM, DAYFLOW historical flows, and statistical models based on observational data and particle-tracking simulations (FWS, 2008, p. 204). NMFS analyses included results from coupled CalSim-II simulations with various water-quality and biological models for a few of the life stages (NMFS, 2009, p. 64).

The CalSim-II model, the primary tool used to evaluate the water-resources implication of the proposed actions, was developed by the DWR and the USBR to simulate water storage and supply, streamflows, and delta export capability for the Central Valley Project (CVP) and the State Water Project (SWP). CalSim-II simulates water deliveries and the regulatory environment associated with the water-resources system north of the delta and south of the delta using a

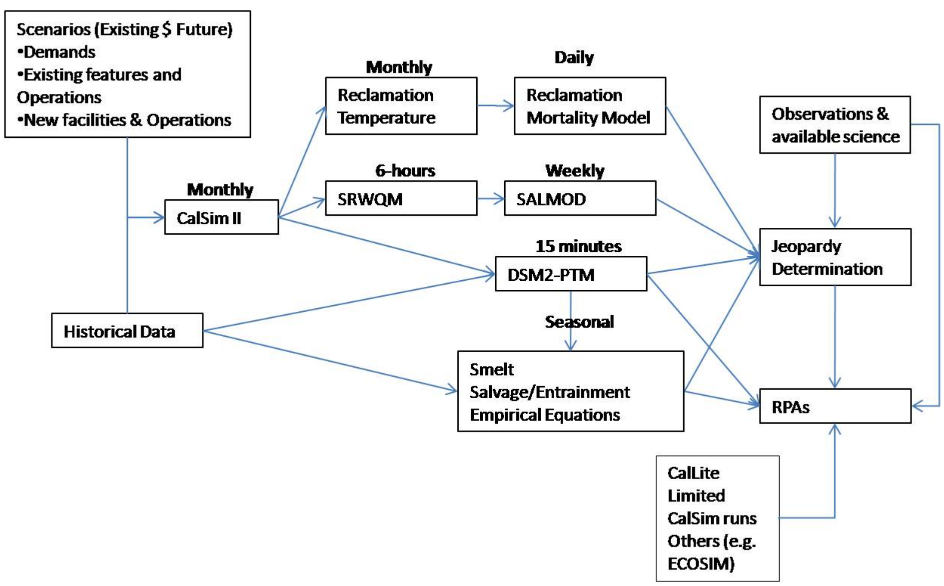

FIGURE 4-1 Modeling framework used in NMFS and USFWS biological opinions and RPAs.

single time step (one month) optimization procedure based on a linear programming algorithm. CalSim-II represents the best available planning model for the CVP-SWP system, according to a CALFED Science Program peer review by Close et al. (2003) (USBR, 2008, p. 9-4). However, many users have suggested that its primary limitation is its monthly time step, and the model should be used primarily for comparative analysis between scenarios and discouraged its use for absolute predictions (Ferreira et al., 2005; USBR, 2008, Chapter 9). In response to the peer review by Close et al. (2003), DWR and USBR provided a list of development priorities (Table 2, DWR/USBR, 2004), including the use of a daily time step, but it is not clear how many of such planned improvements have been incorporated into the version of CalSim-II used in the biological opinions.

Several other tools and models were central in effects analysis and developing RPAs, including hydrodynamic and water-quality (DSM2, USBR's temperature, SRWQM), habitat (SALMOD), and statistical and particle-tracking models (salvage, DSM2-PTM). Some of these models have already been evaluated in the literature for their individual strengths and limitations, though some (SALMOD and USBR's mortality models) have not yet been formally peer reviewed. We first review some of the challenges of applying these individual models in the determination of RPAs, and then focus on examining the modeling process, including how the models contributed to the development of RPAs, and where the uncertainties and vulnerabilities in that process lie.

Model Scale and Management Implications

Very generally, the tiered modeling approach (Figure 4-1) applied the results of CalSim-II as input to various hydrodynamic and ecological models to predict impacts of project operations and, to a very limited extent, to explore RPAs. At one level, model simulations were also used or performed to investigate the feasibility of some proposed actions. For example, CalSim-II was used at the planning level to investigate whether the USBR could meet the 1.9 MAF (at the end of September) required by actions I.2.3 and I.2.4 (maintaining cold water supplies necessary for egg incubation for the following summer's cohort of winter-run), and to recommend storage conservation in severe and extended droughts (NMFS, 2009, p. 596). Similarly, examination of CalSim results and hydrologic records demonstrated to the agencies that the first year of a drought sequence is particularly critical to storage and operations in the following drought year (NMFS, 2009, p. 596). The benefits of using models at this planning level, especially given the importance of water-year types, is clear, and there is little controversy about this application of the models.

At another level, model scenarios were examined to investigate the relationships between operations and impacts on various life stages of the fish across the water-year types and operations scenarios. For example, NMFS used DWR's Delta Survival Model (Greene, 2008) to estimate mortality of smolts associated with three CalSim-II Study scenarios (7.0, 7.1, 8.0). The USFWS used statistical models of salvage and total entrainment (Grimaldo et al., 2009; Kimmerer, 2008) to investigate the effects of proposed operations by comparing actual and predicted salvage and entrainment losses under modeled OMR flows (FWS, 2008, p. 211).

While some challenges exist in linking models in this tiered approach (see next section), concerns and controversies appear to be largely directed at the various forms of statistical relationships of salvage versus OMR flows, extrapolation of these relationships that describe impacts on single life stages to assess the population impacts on species, and the use of biological models without full consideration of their underlying uncertainties. In particular, this nested sequence of statistical models does not allow for uncertainties at one step to influence predictions at the next step. As a result, some of the RPA actions, especially those involving X2 and OMR flow triggers, are based on less reliable scientific and modeling foundations than others. In these cases, the incomplete data and resolution of the models do not closely match the resolution of the actions.

Adequacy of Current Models

Life-cycle Models

Both agencies have been criticized for the lack of adequate life-cycle models to address population level responses (e.g., Deriso, 2009; Hilborn, 2009; Manly, 2009). Nonlinear and compensatory relationships between different life-history stages are common in many fish species. Moreover, many life-history traits exhibit significant patterns of autocorrelation, such that changes in one life-history trait induce or cause related changes in others. These patterns can most effectively be understood through integrated analyses conducted in a modeling framework that represents the complete life cycle. However, complete life-cycle models were not used in either biological opinion to evaluate the effects of changes in operations. The agencies acknowledge that further model development is required, including the "cooperative development of a salmonid life-cycle model acceptable to NMFS, Reclamation (USBR), CDFG, and DWR" (NMSF biological opinion, p. 584). While one life-cycle model (Interactive Object-Oriented Salmon simulation) was available for winter-run salmon from the OCAP BA (USBR, 2008), this model was rejected based on model resolution and data limitation issues (NMFS, 2009, p. 65). Similarly, a better life-cycle model for delta smelt is critically needed (PBS&J, 2008). Such life-cycle models for delta smelt are currently under development. The committee recommends that development of such models be given a high priority within the agencies. The committee also encourages the agencies to develop several different modeling approaches to enable the results of models with different structure and assumptions to be compared. When multiple models agree, the confidence in their predictions is increased.

Particle-Tracking Models (PTMs)

Particle-tracking models (PTMs) are models that treat eggs and larval fishes as if they were particles and simulate their movements based on hydraulic models of flows. Criticisms have applied to the use of PTMs, which rely on some key assumptions (e.g., neutral buoyancy, no active swimming) that have been challenged at least for some life stages (Kimmerer and Nobriga, 2008) on the basis that fish live and move in three dimensions. Other limitations of the use of PTMs in this case include the reliance on the one-dimensional DSM2, use of random-walks to simulate lateral movements, and the lack of simulation of fish behavior. In view of these limitations, PTMs as used in this case may not be suitable for predicting the movement of fish of some life stages (juvenile and adults) where behavior becomes relevant to the question of potential entrainment (Kimmerer and Nobriga, 2008). The NMFS acknowledges these limitations, noting that "The acoustic tagging studies also indicate that fish behavior is complex, with fish exhibiting behavior that is not captured by the 'tidal surfing' model utilized as one of the options in the PTM simulations. Fish made their way downstream in a way that was more complicated than simply riding the tide, and no discernable phase of the tide had greater net downstream movement than another" (NMFS, 2009, p. 651).

However, while fish seldom behave like passive particles, results based on passive particles can provide insights. For example, the NMFS used a combination of models to simulate mortality rates of salmonids for three CalSim-II scenarios. The results were used to compare the inter- and intra-annual impacts of the three scenarios (NMFS, 2009, p. 381). Further, the agencies advocate improving the model through further study, such as Action iV.2.2, which includes an acoustic tag experiment in part to evaluate action benefits and in part to improve PTM results (USBR, 2008, p. 645). Thus, while there is uncertainty regarding the accuracy of the mortality losses, the use of the models in a comparative way is probably acceptable. However, it should be made clear how the model is used, and the explicit consideration of the PTM assumptions and uncertainties should be more clearly documented in the biological opinions.

Although there has not been an assessment of the degree to which these limitations affect the conclusions, PTM results were used for RPA development. Although the DSM2 has been calibrated adequately for OMR flows, there is no clear evidence concerning the accuracy of the PTM's ability to simulate smelt entrainment in relation to how the models are used for jeopardy determination and RPA development. This is particularly important because a number of actions driven by the RPAs recommend trigger values for OMR to curtail exports. As discussed in a later section, the science surrounding these OMR triggers is less clear than for many other aspects of the RPAs, and this trigger may result in significant water requirements. The committee's recommendations for improving the modeling and associated science are intended to improve the best science available to the agencies. The committee will address such improvements in greater detail in its second report.

Other Biological Models

The NMFS used other biological models to simulate the effects of operations on various life stages of salmon. These models involve several key assumptions and data limitations that influence the reliability of their results.

For example, SALMOD, developed by the USGS, was used by the NMFS to investigate the population level responses of the freshwater life stages to habitat changes caused by project operations (NMFS, 2009, p. 269). A variety of weekly averaged inputs are required, including streamflow, water temperature, and number and distribution of adult spawners (USBR, 2008, p. 9-25). This model provides some valuable insight, but requires greater consideration of the model assumptions (e.g., linear stream, habitat as primary limiting factor, independence of food resources on flow and temperature, density independence for some life stages) and uncertainties. Otherwise, the use of this model is limited to comparative, rather than absolute, analysis of RPA actions. Further, it would be important to investigate the sensitivity of the model to initial conditions and input data, particularly those prone to measurement error (e.g., number and distribution of spawners) to provide some indication of the reliability of model outputs. While SALMOD has not been thoroughly peer-reviewed, criticisms of similar modeling approaches (e.g., NRC, 2008) have highlighted some key issues with habitat-suitability models (e.g., the need for greater clarity concerning the assumption that habitat is a limiting factor and the need for a thorough assessment of the representativeness of the areas sampled) and have provided extensive discussions of the use of models in an adaptive-management approach, which is relevant to this committee's recommendations. Finally, the NMFS acknowledges that SALMOD is most appropriately applied to large populations that are not sensitive to individual variability and environmental stochasticity (NMFS, 2009, p. 270), which means that the predictions for the relatively small population in the delta river system are subject to considerable uncertainty. The uncertainties again highlight the need for an adaptive management approach.

The NMFS also used results from the USBR's salmon mortality model (Hydrologic Consultants, Inc., 1996) to examine daily salmon spawning losses for early life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) due to exposure of high temperatures. Temperature-exposure mortality criteria for the three life stages are combined with modeled temperature predictions and spawning distribution data to compute percents of salmon spawning losses. Because simulations of river temperatures are run on a daily or shorter time step, downscaling of monthly CalSim-II data is required (USBR, 2008, Attachment H-1). Moreover, the monthly temperature models do not adequately capture the range of daily temperature variability (USBR, 2008, pp. 9-109). In addition, several assumptions (e.g., density independence) and important data limitations (USBR, 2008, pp. L-6, L-7) challenge the reliability of this model. Finally, while this model has been applied in other systems, it is not thoroughly peer reviewed and no analysis of sensitivity or uncertainty has been performed. Addressing these model shortcomings would help increase confidence in the analyses.

Developing, Evaluating, and Applying Best Available Models

As the agencies work within the constraints of best available science, some recognition of the adequacy and reliability of the models should be reflected in the management decisions by making them adaptive. The following five factors, in particular, need better documentation.

1. *Incompatible temporal resolution and implications for management decisions.*

The individual models used in this tiered analysis approach have a broad range of temporal resolutions (Figure 4-1). Care must be exercised in such situations so that the linkages of models with different temporal and spatial resolutions do not result in propagation of large errors that may influence decisions derived from the modeling results. For example, CalSim-II uses a monthly time step whereas the DSM2 uses a 15-minute time step. Although the tidal boundary condition in DSM2 is pre-processed at 15-minutes, average monthly flow, simulated by CalSim-II, is provided as the upstream flow boundary condition at many delta inflow points. The linkage of CalSim-II and DSM2 attempts to smooth out the step change in monthly simulated flows (USBR, 2008, pp. 9-14, 9-15), but this is not necessarily adequate to simulate the fluctuations of flows within the month. The use of the monthly time step certainly could have a significant influence on such performance measures as OMR flows, particularly when such flows are recommended in RPAs for triggering export curtailments. USFWS and NMFS should provide a comparison of daily versus monthly average simulations of DSM2 for a historical period to ascertain the reliability of using monthly CalSim output as input to DSM2.

The incompatibility of temporal resolutions is particularly important given that flows in the delta are strongly influenced by tides. The flows at such locations as Old River and Middle River are characterized by two flood-ebb cycles per day, with positive and negative values of much larger magnitude than the average net flow at these locations (Gartrell, 2010). In view of the fact that OMR flows have sub-hourly hydrodynamic components, averaging over a longer period such as 5 to 14 days to define the thresholds in the implementation of the RPAs could produce unnecessary changes in water exports. The use of monthly average flows produced by CalSim-II could further add to the concerns regarding the recommended thresholds of OMR flows. In view of these modeling uncertainties, further clarification as to how the modeled OMR flows were used for jeopardy determination and hence for the development and implementation of RPAs is needed.

2. Inconsistent use of baselines.

Both biological opinions use historical data along with modeling results of the CALSIM-II scenarios. Study 7.0, which represents the existing condition, is expected to be closest to historical conditions. However, important differences between the two (historical and existing conditions) could exist due to differences in demands and more importantly due to deviations in operations. Because of the simplifying assumptions used in CalSim-II historical simulations, the FWS BO opted to use actual historical data to develop their baseline (FWS, 2008, p. 206) and continued to compare historical data with the modeling results of the numerous scenarios described above (see, for example, Figures E-3 through E-19).

The results suggest that often, actual data are very different in magnitude in comparison to Study 7.0 and furthermore, most scenarios (Studies 7, 7.1, 8, and study series 9) are clumped together with relatively small differences between them in relation to the magnitude of differences with the historical data. In view of these differences, the validation of Study 7.0 and consequently others, becomes even more important for the purpose of RPA development.

The use of historical data to make inferences is very typical and appropriate in the biological opinions. However, since the evaluation of project actions and the development of RPAs are based on the evaluation of modeling scenarios, which appear to greatly differ from historical data, a comparison of the two sets of data (historical and simulated) may incur errors in interpretation. The committee recommends that the biological opinions provide a better justification for the reasonableness of the baseline scenario, Study 7.0, as well as the comparison of scenario results with historical data.

3. *Challenges in calibrating and validating any of the models to historical observations and operations.*

It is a standard practice to ensure the appropriate use of models through the processes of calibration and testing (ASTM, 2004; NRC 2008). Validation of CalSim-II is described in Appendix U of the OCAP BA (USBR, 2008), which provides a comparison of Study 7.0 (existing condition) with the recent historical data. A review of those results shows that there are significant deviations of the historical data from the simulated storages and exports that may be of the same magnitude as the differences between the scenarios being evaluated. Thus, while the tool itself performs well, some questions remain regarding the gross nature of generalized rules used in CalSim-II to operate CVP and SWP systems, relative to actual variability of dynamic operations (USBR, 2008, pages 9-4). In their peer review of the CalSim-II model, Close et al. (2003) suggested that "Given present and anticipated uses of CalSim-II, the model should be calibrated, tested, and documented for "absolute" or non-comparative uses." It is not clear if the agencies that developed the model have responded to this suggestion in a comprehensive manner. As emphasized above, a clear presentation of the realism of Study 7.0 with respect to recent operations or observations would help avoid the criticism as to the results of Study 7.0 as well as other derivatives of it (Studies 7.1, 8.0 and series 9).

The OCAP BA (USBR, 2008) provides sufficient information on the calibration and testing of temperature models, and the time steps vary among models, although all used the monthly output of CalSim-II in predictions. Thus, they appear to be adequate for predicting temperature variation and making comparisons at the monthly time scale. Information on the calibration of DSM2 and PTM is provided in part by DWR, which has been posted online (*http://modeling.water.ca.gov/delta/studies/validation2000/*) results of the calibration of this 1-D, hydrodynamic model of the delta. Based on the information provided, it appears to adequately mimic the historical data at a daily time-scale. However, the DSM2 simulations should demonstrate that the range of negative OMR flows used for calibration covers the high negative flows simulated by CalSim-II for future scenarios. There has been an attempt to test PTM (Wilbur, 2001), but clearly this tool needs further improvements. Wilbur (2001) reports that the existing velocity profiles used in PTM consistently over-predict the field observations (i.e., the predicted velocities exceed the observed velocities).

In addition, with the potential for changes in the historical patterns of climate and hydrology, calibrating models with historical data alone may be less meaningful for projection of future operations. Thus, in addition to providing support for model improvement and adaptive management, a more robust monitoring program will also support calibration and testing of models with more relevant representation of the current and future system. For example, drought-induced low flows of the past several years provide opportunities to calibrate and test models under infrequent but foreseeable conditions. Realistic modeling of the system that incorporates what actually happens in an operational setting with climate outlook will be important in the future.

The biological models such as USBR's mortality model and SALMOD are essentially uncalibrated for the system, and further concerns about these models were addressed in previous sections.

4. Challenges of the Tiered Modeling Approach.

Temperature, OMR flows, and X2 performance measures are particularly challenged by the tiered modeling approach, with limitations related to data availability and inconsistency in model resolution (spatial and temporal) and complexity (USBR, 2008, pp. 9-31). However, the use of models may still be beneficial in planning and triggering adaptive management needs. For example, for NMFS implementation of Action II.2 (Lower American River Temperature Management), forecasts will be used to simulate operations and compliance with thermal criteria for specific life stages in months when salmon would be present

(NMFS, 2009, p. 614). However, if the USBR determines that it cannot meet the temperature requirement, and can demonstrate this through modeling of allocations and delivery schedules, consultation with the NMFS will occur. In this example, modeling results are used to evaluate the feasibility of meeting criteria, rather than trying to derive direct loss estimates. The RPA then leads to a process for adaptive management of the temperature operations based on updates to the hydrologic information. Thus, despite the particularly challenging example of managing temperature, the use of models appears to have allowed for flexibility.

However, no qualitative or quantitative analysis of the magnitude of errors across these model linkages and the resulting uncertainties are presented. While not required for the justification of RPAs, failing to consider error propagation across the models makes it difficult to evaluate the reliability of meeting the RPAs and their ability to provide the intended benefits.

5. Lack of an integrative analysis of RPAs

Numerous RPA actions proposed in both biological opinions cover new projects as well as operational changes. However, the information provided to the committee did not include a comprehensive analysis of all RPA actions, either individually or, more important, jointly, with respect to their ability to reduce the risks to the fish or to estimate system-wide water requirements. Clearly, the agencies lacked properly linked operations/hydrodynamic/biological models at the appropriate scales for RPA development. The agencies should be complimented for using historical data as well as best available science when modeling was not adequate. However, the proposed RPAs could incur significant water supply costs, and there should be an attempt to provide an integrative analysis of the RPAs with quantitative tools. The committee also acknowledges the challenges associated with estimating water requirements for some RPAs, particularly those based on adaptive management strategies, but explicit and transparent consideration of water requirements and biological benefits of specific actions and of subsets of actions would provide the basis for a smoother implementation of the RPAs.

The committee recommends that the agencies consider investigating the use of CalSim-II and other quantitative tools (e.g., PTM, life-cycle models) to simulate appropriate RPA actions of both biological opinions. These linked models would allow an integrated evaluation of the biological benefits and water requirements of individual actions and suites of actions, and the identification of potential species conflicts among the RPAs. Although not required by the ESA, such an integrative analysis would be helpful to all concerned to evaluate the degree to which the RPAs are likely to produce biological benefits and to quantify the water requirements to those who might be affected by the future actions of the two biological opinions. In addition to further model development, efforts to improve documentation of model use would be beneficial. Documentation should include a record of the decisions, assumptions, and limitations of the models (e.g., NRC, 2008).

Thus, we find that, while used appropriately in this analysis, the PTM and biological models for both salmon and smelt should be further developed, evaluated, and documented**.** The models show promise for being quantitative tools that would allow for examination of alternative ideas about key relationships underlying the RPAs. In addition, complete life-cycle models capable of being linked to these other models should be developed. Although developing, testing, and evaluating such models would require a significant investment, the committee judges that the investment would be worthwhile in the long term.

CONCLUSION

Modeling is useful for understanding the system as well as predicting future performance. As long as modelers understand and accurately convey the uncertainties of models, they can provide valuable information for making decisions. The committee reviewed the models the agencies used to determine to what degree they used the models in developing the RPAs. The biological opinions have used results of a variety of operations, hydrodynamic, and biological models currently available to them for RPA development. However, the agencies have not developed a comprehensive modeling strategy that includes the development of new models (e.g., life-cycle and movement models that link behavior and hydrology); such models may have provided important additional information for the development of RPAs. Nonetheless, the agencies should be complimented for combining the available modeling results with historical observations and peer-reviewed literature. The committee also compliments the agencies for the extensive discussion and presentation of the rationale for the particular types of actions proposed in the RPAs.

The committee concluded that as far as they went, despite flaws, the individual models were scientifically justified, but that they needed improvements and that they did not go far enough toward an integrated analysis of the RPAs. The committee has raised several important issues related to the modeling process used, including the model scale and management information; the adequacy of models, particularly the particle-tracking model and the lack of life-cycle models; incompatibilities in both temporal and spatial scales among the models and between model output and the scale of the RPA actions; the use of baselines; inadequate calibration and testing of modeling tools (in some cases); and inadequate model documentation. A more-thorough, integrative evaluation of RPA actions with respect to their likelihood of reducing adverse effects on the listed fishes and their likely economic consequences, coupled with clear documentation would improve the credibility and perhaps the acceptance of the RPAs. Thus the committee concluded that improving the models by making them more realistic and by better matching the scale of their outputs to the scale of the actions, and by extending the modeling to be more comprehensive and to include features such as fish life cycles would improve the agencies' abilities to assess risks to the fishes, to fine-tune various actions, and to predict the effects of the actions. Three-dimensional models are more expensive and time-consuming than simpler models, but they can contribute valuable understanding if used appropriately (e.g., Gross et al., 1999; Gross et al., 2009).

In addition, the committee concludes that opportunities exist for developing a framework to improve the credibility, accountability, and utility of models used in implementing the RPAs. The framework will be particularly important for some of the more-complex actions, such as those involving Shasta and San Joaquin storage and flows, which rely heavily on model predictions. The committee plans to address such issues, including the framework mentioned above, in more detail in its second report.

5

Other Stressors

INTRODUCTION

Declines in the listed species must be considered in the context of the many changes that are occurring in the "baseline" factors in the region. While the CVP and SWP pumps kill fish, no scientific study has demonstrated that pumping in the south delta is the most important or the only factor accounting for the delta-smelt population decline. Therefore, the multiple other stressors that are affecting fish in the delta environment as well as in the other environments they occupy during their lives must be considered, as well as their comparative importance with respect to the effects of export pumping. These factors and their impacts, only some of which originate within the delta itself, will be described in greater detail in the committee's second report. Some are described here to highlight their potential importance and to underscore that a holistic approach to managing the ecology of imperiled fishes in the delta will be required if species declines are to be reversed. The factors described here are not meant to be exhaustive, but are intended to demonstrate that the effects of these factors are numerous and, in some cases, not only potentially very important but also under-characterized. Moreover, while individual relationships with these stress factors are generally weakly understood, the cumulative or interactive effects of these factors with each other and with water exports are virtually unknown and unexplored (Sommer et al., 2007).

CONTAMINANTS

It has long been recognized that contaminants are present in the delta, have had impacts on the fishes, and may be increasing (Davis et al., 2003; Edmunds et al., 1999; Linville et al., 2002). Contamination of runoff from agricultural use of pesticides has been documented and has been shown to affect invertebrates and other prey, as well as on some life stages of fish (e.g., Giddings, 2000; Kuivila and Foe, 1995; Weston et al., 2004). Kuivila and Moon (2004) found that larval and juvenile delta smelt coincide with elevated levels of pesticides in the spring. Pyrethroid insecticide use has increased in recent years. Such insecticides have been found in higher concentrations in runoff, and may be toxic to macroinvertebrates in the sediment (Weston et al., 2004, 2005); it is toxic to the amphipod *Hyalella azteca*, which is found in the delta (Weston and Lydy, 2010). The use of pyrethroids increased substantially in the recent years during which the decline of pelagic organisms in the delta became a serious concern as compared to earlier decades (Oros and Werner, 2005). Among other identified contaminants that may also have effects are selenium and mercury. Histopathological studies have shown a range of effects, from little to no effect (Foott et al., 2006) to significant evidence of impairment depending on species, timing, and contaminant biomarker.

ALTERED NUTRIENT LOADS

Nutrients have received recent attention as a potential stress factor for phytoplankton, zooplankton, and fish populations for several reasons. First, research by Wilkerson et al. (2006) and Dugdale et al. (2007) found that phytoplankton (diatom) growth in mesocosm experiments did not occur under *in situ* ammonium levels, and only increased when ammonium levels were reduced. They interpreted this finding to mean that diatom growth was suppressed under ambient ammonium levels, and only after ammonium concentrations began to be drawn down did diatoms begin to use nitrate, an alternate nitrogen form, and then proliferate.

With respect to nutrient loading effects, declines in phosphate loading may be related to declines in chlorophyll-*a* throughout the Sacramento-San Joaquin delta (Van Niewenhuyse, 2007). While these results show that chlorophyll-*a* in the water column declined coincident with the decline in phosphate in 1996, phosphate levels, both inorganic and organic, are not at extremely low concentrations in the water. Nevertheless, the effects of the rapid and substantial change in the ratio of inorganic nitrogen to inorganic phosphate in the system have yet to be adequately explored.

CHANGES IN FOOD AVAILABILITY AND QUALITY

Significant changes in the food web may have affected food abundance and food quality available to delta smelt. From changes in zooplankton to declines in chlorophyll to increases in submerged aquatic vegetation, these changes have enormous effects on the amount and quality of food potentially available for various fish species (e.g., Bouley and Kimmerer, 2006; Muller-Solger et al., 2006). The benthic community was significantly changed after the overbite clam, *Corbula amurense*, became dominant in the late 1980s; such changes have effects on food availability that may cascade through the food web to affect the abundance of delta smelt.

In addition to changes in food availability, other changes in the food web have had potentially large impacts on smelt. Since 1999, blooms of the cyanobacterium *Microcystis* have increased and are especially common in the central delta when water temperatures exceed 20°C (Lehman et al., 2005). Although delta smelt may not be in the central delta during the period of maximum *Microcystis* abundance, during dry years the spread of *Microcystis* extends well into the western delta so that the zone of influence may be greater than previously thought (Lehman et al., 2008). Most recently it has been demonstrated that the *Microcystis* toxin, microcystin, not only is present in water and in zooplankton, but histopathological studies have shown liver tissue impacts on striped bass and silversides (Lehman et al., 2010).

INTRODUCED FISHES

The delta is a substantially altered ecosystem, and that applies to the fish species present as well. Some environmental changes likely enhance the spread of nonnative species (for example warm, irregularly flowing water around dams or diversions can favor warm-water species) (FWS, 2008, p. 147), as can the presence of riprap to support banks (Michny and Hampton, 1984). Thus, the spread of nonnative species may be, at least in part, an effect of other ecosystem changes. Once nonnative species become established, they further alter the ecosystem. Some species, such as American shad (*Alosa sapidissima*) and striped bass (*Morone saxatilis*), native to the Atlantic and Gulf coasts of North America, have been present in the delta region since the late 19th century (Lampman, 1946; Moyle, 2002). Striped bass (along with the native Sacramento pikeminnow, *Ptychocheilus grandis*) have been implicated as predators on juvenile Chinook salmon, especially when they congregate below the Red Bluff Diversion Dam (Tucker et al., 2003) and other structures; at the Suisun Marsh Salinity Control Gates they were the dominant predator on juvenile Chinook salmon (Edwards et al., 1996; Tillman et al., 1996). Other introductions are more recent, and some might be more threatening to native species. For example, the silverside, *Menidia beryllina*, is becoming more widespread in the delta and likely preys on juvenile delta smelt (Moyle, 2002) or competes for similar copepod prey (Bennett and Moyle, 1996). Largemouth bass (*Micropterus salmoides*) and many other members of its family (Centrarchidae), along with various species of catfish (family Siluridae), native to the Mississippi and Atlantic drainages, also are increasing, while the lone member of the centrarchid family that was native to the region, the Sacramento perch (*Archoplites interruptus*), no longer occurs in the delta (Moyle, 2002). All the above species include fish in their diets to a greater or lesser degree, including various life stages of delta smelt at times. In addition, other species, such as common carp (*Cyprinus carpio*) and threadfin shad (*Dorosoma petenense*), are not significant piscivores, but likely compete with delta smelt for food or otherwise affect their environment. Finally, the wakasagi (*Hypomesus nipponensis*), an introduced Japanese smelt very similar to the delta smelt, is becoming increasingly widespread in the delta. It interbreeds and competes with the delta smelt and might prey on it, and its presence in the delta complicates the assessment of delta smelt populations and salvage because it is so similar to the delta smelt that it is not easy to distinguish between the two species (Moyle, 2002). Delta smelt have co-existed with many of these alien fishes for more than 100 years before the recent declines, and so the decline of smelt cannot be attributed entirely to their presence, but some species have increased recently and their effects on smelt and salmonids—including on the potential for smelt populations to recover—have not been well studied.

IMPEDIMENTS TO PASSAGE, CHANGES IN OCEAN CONDITIONS, FISHING, AND HATCHERIES

Clark (1929) estimated that 80 percent of the original spawning habitat available to Chinook salmon in California's Central Valley had been made unavailable by blockages, mainly dams, by 1928. A similar loss of habitat has occurred for Central Valley steelhead as well (Lindley et al., 2006). Dams, diversion points, gates, and screens also affect green sturgeon. Ocean conditions vary, and in general they fluctuate between periods of relatively high productivity for salmon and lower productivity (Hare et al., 1999; Mantua and Hare, 2002). Lindley et al. (2009) concluded that ocean conditions have recently been poor for salmon, although there has been a long-term, steady deterioration in freshwater and estuarine environments as well. Sport and commercial fishing for salmon, sturgeon, and steelhead has been tightly regulated both at sea and in freshwater, and in 2008, there was a complete closure of the commercial and recreational fishery for Chinook salmon (NMFS, 2009, p. 145). However, Chinook salmon make very long oceanic migrations and their bycatch in other fisheries cannot be totally eliminated (NRC, 2005). Hatchery operations have been controversial, but it is almost impossible to operate hatcheries without adverse genetic and even ecological effects on salmon (NRC, 2004b; NMFS, 2009, p. 143) or steelhead (NMFS, 2009, p. 143).

DISEASES

Histopathological studies have revealed a range of diseases of potential concern in the delta. For example, parasites have been found in threadfin shad gills, but not at a high enough infection rate to be of alarm, but evidence from endrocrine disruption analyses shows some degree of intersex delta smelt males, having immature oocytes in the testes (Anderson et al., 2003). Other investigators have found myxosporean infections in yellowfin goby in Suisun Marsh (Baxa et al., In Progress). These and other measures suggest that parasitic infections, viral infections, or other infections are affecting fish, and that interactions with other stressors, such as contaminants, may be having increasing effects on fish.

CLIMATE CHANGE

Climate change could have severe negative consequences for the listed fishes. There are at least three reasons why this is of concern. First, the recent meteorological trend has runoff from the Sierra Nevada shifting from spring to winter as more precipitation falls as rain rather than snow, and as snowmelt occurs earlier and faster because of warming, increasing the likelihood and frequency of winter floods and altered hydrographs, and thus changes in the salinity of delta water (Knowles and Cayan, 2002, 2004; Roos, 1987, 1991). Alteration of precipitation type and timing of runoff may affect patterns in reproduction of the smelt and migration of salmon and sturgeon (Moyle, 2002). Additionally, effects of sea-level rise will increase salinity intrusion further upstream, again impacting fish distributions that rely on salinity gradients to define habitat; their habitat will be reduced. Lastly, as climate warms, so too does the water. This will impact fish distributions in several ways. Temperature is a cue for many biological processes, so many stages of the life cycle are likely to be affected. Moreover, warmer water will mean proportionately more days in which the temperature is in the lethal range, ~25°C (Swanson et al., 2000). The effects of these climate consequences are less suitable habitat for delta smelt in future years as well as threats to the migration of anadromous species like salmon and sturgeon.

CONCLUSION

Based on the evidence summarized above, the committee agreed that the adverse effects of all the other stressors on the listed fishes are potentially large. Time did not permit full exploration of this issue in this intense first phase of the committee's study. The committee will explore this issue more thoroughly in its second report.

6

Assessment of the RPAs

INTRODUCTION

The RPAs include many specific actions that fall into several categories for each species. The RPA in the FWS biological opinion for delta smelt focuses on limiting OMR negative flows in winter to protect migrating adults (Actions 1 and 2) and to protect larval smelt (Action 3) from entrainment at the export pumps. It also aims to protect estuarine habitat for smelt during the fall by managing the position of X2 (Action 4). Action 5 is to protect larval and juvenile smelt from entrainments by refraining from installing the Head of Old River Barrier (HORB) depending on conditions; if the HORB is installed, then the Temporary Barrier Project's gates would remain open. Finally, Action 6 calls for restoration and construction of 8,000 acres of intertidal and tidal habitat.

The RPA in the NMFS biological opinion for Chinook salmon, Central Valley steelhead, and green sturgeon is divided into far too many specific actions (72) to summarize here, but the biological opinion describes 10 major effects of the RPA on the listed species. They include management of storage and releases to manage temperature in the Sacramento River for steelhead and salmon; maintaining flows and temperatures in Clear Creek for spring-run Chinook salmon; opening gates at the Red Bluff Diversion Dam (RBDD) at critical times to promote passage for salmon and sturgeon; improving rearing habitat for salmon in the lower Sacramento River and in the northern delta; closure of the gates of the Delta Cross Channel (DCC) at critical times to keep juvenile salmon and steelhead out of the interior delta and instead allowing them to migrate out to sea; limiting OMR negative flows to avoid entrainment of juvenile salmon; increased flows in the San Joaquin River and curtailment of water exports to improve survival of San Joaquin steelhead smolts, along with an acoustic tagging program to evaluate the effectiveness of this action; flow and temperature management on the American River for steelhead; a year-round flow regime on the Stanislaus River to benefit steelhead; and the development of Hatchery Genetics Management Plans at the Nimbus (American River) and Trinity River hatcheries to benefit steelhead and fall-run Chinook salmon.

Rather than review every action and every detail, the committee comments on the broader concepts at issue and general categories of actions. Three important goals are to consider how well the RPAs are based on available scientific information; whether there are any potential RPAs not adopted that would have lesser impacts to other water uses as compared to those adopted in the biological opinions, and would provide equal or greater protection for the listed fishes; and whether there are provisions in the FWS and NMFS biological opinions to resolve potential incompatibilities between them. In addition we assess the integration of the RPAs within and across species and across all actions.

Addressing these goals requires explicitly recognizing the fundamental differences in the main conflicting arguments. There is concern, on one hand, that the increasing diversions of water from the delta over a period of many decades and the alteration of the seasonal flow regime have contributed to direct effects on populations of native species through mortality at the pumps, changes in habitat quality, and changes in water quality; and to indirect, long-term effects from alterations of food webs, biological communities, and delta-wide habitat changes. The RPAs propose that their collective effects will offset the impacts of the proposed operations of the SVP and the CWP by manipulating river flows and diversions, along with other actions. An alternative argument is that the effects of water diversions on the listed fishes are marginal. It is argued that the changes imposed by the RPAs would result, therefore, only in marginal benefits to the species, especially now that the delta environment and its biota have been altered (to a new ecological baseline) by multiple stressors. Those stressors obviously include water exports, but this argument suggests a smaller role for water exports in causing the fish declines and hence a smaller role for managing the exports to reduce or halt those declines. However, even with the copious amounts of data available, it is difficult to draw conclusions about what variable or variables are most important among the pervasive, irregular, multivariate changes in the system that have occurred over the past century.

The committee's charge was to provide a scientific evaluation, not a legal one, and that is what is presented below. Nothing in this report should be interpreted as a legal judgment as to whether the agencies have met their legal requirements under the ESA. The committee's report is intended to provide a scientific evaluation of agency actions, to help refine them, and to help the general attempt to better understand the dynamics of the delta ecosystem, including the listed fishes.

DELTA SMELT

Actions Related to Limiting Flow Reversal on the Old and Middle Rivers (OMR)

The general purpose of this set of actions is to limit the size of the zone of influence around the water-diversion points at critical times. The actions would limit negative OMR flows (i.e., toward the pumps) by controlling water exports during crucial periods in winter (December through March) when delta smelt are expected to be in the central delta (FWS, 2008). The data supporting this approach show an increase in salvage of delta smelt as OMR flows become more negative. However, there are important disagreements about how to express salvage and the choice of the trigger point or threshold in negative flows above which diversions should be limited.

An important issue is whether and how salvage numbers should be normalized to account for delta smelt population size. An increase in salvage could be due to an increase in the number of smelt at risk for entrainment, an increase in negative flows that bring smelt within range of the pumps, or both. Thus, an increase in salvage could reflect a recovery of the smelt population or it could reflect increasingly adverse flows toward the pumps for the remaining smelt population. The biological opinion (FWS, 2008) recognizes this relationship, and that is why salvage is used to calculate the percentage of the population entrained, rather than absolute numbers (FWS, 2008, Figures E-4 and E-5). However, the historical distribution of smelt on which the relationship with OMR flows was established no longer exists. Delta smelt are now sparsely distributed in the central and southern delta (*www.dfg.ca.gov/delta/data*), and pump salvage also has been extremely low, less than four percent of the 50-year average index. Since 2005, a significant portion of the remaining smelt population, 42 percent (Sommer et al., 2009), is in the Cache Slough complex to the north and is therefore largely isolated from the central delta. These changes in the distribution of delta smelt increase the uncertainty surrounding current estimates of the population and its likely response to alterations in delta hydraulics, and until the numbers of smelt rise closer towards the pre-2005 levels, they do not provide a reliable index for incorporation into models for the effects of pumping on smelt salvage.

Different authors have taken different statistical approaches to analyzing the data to interpret the relationship between OMR flows and effects on smelt, and thus chose different thresholds at which OMR flows should be limited. The choice of the limit to negative flows in the RPA gives the benefit of the doubt to the species. But there are important uncertainties in the choice. The different trigger points suggested by the different analyses have important implications for water users. The committee concludes that until better monitoring data and comprehensive life-cycle and fish-movement models are available, it is scientifically reasonable to conclude that high negative OMR flows in winter probably adversely affect smelt. We note as well that actions 1 and 2 of the FWS RPA are adaptive in that they depend for their implementation on a trigger related to measured turbidity and measured salvage numbers; they also may be suspended during three-day average flows of 90,000 cfs or greater in the Sacramento River at Rio Vista and 10,000 cfs or greater in the San Joaquin River at Vernalis. However, the portion of the existing smelt population in the Cache Slough complex appears not to move downstream towards the brackish areas (Sommer et al., 2009) and thus they should be largely insulated from the effects of the OMR flows and actions 1 and 2.

The biological benefits and the water requirements of this action are likely to be sensitive to the precise values of trigger and threshold values. There clearly is a relationship between OMR flows and salvage rates, but the available data do not permit a confident identification of the threshold values to use in the action, and they do not permit a confident assessment of the benefits to the population of the action. As a result, the implementation of this action needs to be accompanied by careful monitoring, adaptive management, and additional analyses.

Some monitoring and reporting is required in RPA component 5 (monitoring and reporting). However, more should be required, recognizing limits to the agencies' and operators' human and fiscal resources. Given the uncertainties in any choice of a trigger point, a carefully designed study that directly addresses measures of the performance (effectiveness) of the action is essential. This could include monitoring of variables like salvage at the pumps and numbers of delta smelt adults and larvae at the south ends of OMR channels during pumping actions, but it should also include other variables that might affect both salvage and populations. History shows that salvage and delta smelt indices have been insufficient for such an analysis alone, partly because the populations are small and partly because of the uncertainties in the salvage numbers (e.g., to what degree do they accurately reflect mortality, and to what degree are they affected by sampling error?). This deficiency in the data needs to be remedied. But other "proximate" measures such as monitoring of flows over the tidal cycle between and during the pumping limitations could help to understand the driving mechanism for the predicted entrainment mortality associated with pumping. Measuring mean daily discharges also is not sufficient. Temperature, salinity, turbidity, and possibly other environmental factors should also be monitored at appropriate scales as this action is implemented, to determine the availability of suitable habitat in the south delta during periods of reduced pumping. Information also is needed on how fish movement is affected by the immediate water-quality and hydraulic environment they experience. Because the effectiveness of the pumping needs to be expressed in terms of the population, the influence of pumping needs to be identified in more life-stage and area specific measures, In particular, the relevance of the Cache Slough complex needs to be resolved in assessing the effectiveness of pumping restrictions. In addition, because uncertainty is high regarding several aspects of this action, it would be helpful to include an accounting of the water requirements. Ongoing evaluation of performance measures could ultimately reduce the water requirements of actions and increase the benefits to the species. Addressing the effectiveness of the proposed actions on a long-term basis could also support consensus conclusions about the effectiveness of specific actions and increase public trust. To the degree that such studies could be jointly planned and conducted by the agencies and other interested parties, transparency and public trust would be enhanced.

X2 Management for Delta Smelt

Although the mean position of X2, the isohaline (contour line of equal salinity) of total salinity 2, is a measure of the location of a single salinity characteristic, it is used in this system to indicate the position and nature of the salinity gradient between the Sacramento River and San Francisco Bay. The position of X2 is measured in kilometers from the Golden Gate Bridge. In the RPA, it has been used by the agencies as a measure of the amount of smelt habitat—influenced by salinity as well as temperature and turbidity, which are also driven by the river-estuary interaction—and thus to approximate the seasonal extent and shifting of that habitat within the ecosystem. By this reasoning, the position of X2 affects the size of delta smelt habitat (Feyrer et al., 2007; Kimmerer, 2008a).

The RPA's action 4 (FWS, 2008, page 369) proposes to maintain X2 in the fall of wet years at 74 km east of the Golden Gate Bridge and in above-normal years at 81 km east. (The action was restricted to wetter years in response to consultation with the NMFS, which expressed concern that in drier years, this action could adversely affect salmon and steelhead [memorandum from FWS and NMFS to this committee on coordination, January 15, 2010].) The action is to be achieved primarily by releases from reservoirs. The objective of the component is to manage X2 to increase the quality and quantity of habitat for delta smelt growth and rearing.

The relationship between the position of X2 and habitat area for delta smelt, as defined by smelt presence, turbidity, temperature, and salinity (Nobriga et al, 2008; Feyrer et al., in review), is critical in designing this action. A habitat-area index was derived from the probability of occurrence estimates for delta smelt (fall mid-water trawl survey, FMT) when individuals are recruiting to the adult population. Presence/absence data were used because populations are so small that quantitative estimates of populations probably are unreliable. The authors show a broad relationship between the FMT index and salinity and turbidity, supporting the choice of these variables as habitat indicators. The statistical relationship is complex. When the area of highly suitable habitat as defined by the indicators is low, either high or low FMT indices can occur. In other words, delta smelt can be successful even when habitat is restricted. More important, however, is that the lowest abundances all occurred when the habitat-area index was less than 6,000 ha. This could mean that reduced habitat area is a necessary condition for the worst population collapses, but it is not the only cause of the collapse. Thus, the relationship between the habitat and FMT indexes is not strong or simple. Above a threshold on the x-axis it allows a response on the y-axis (allows very low FMT indices).

The controversy about the action arises from the poor and sometimes confounding relationship between indirect measures of delta smelt populations (indices) and X2. The weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand. In addition, although the position of X2 is correlated with the distribution of salinity and turbidity regimes (Feyrer et al., 2007), the relationship of that distribution and smelt abundance indices is unclear. The X2 action is conceptually sound in that to the degree that habitat for smelt limits their abundance, the provision of more or better habitat would be helpful. However, the examination of uncertainty in the derivation of the details of this action lacks rigor. The action is based on a series of linked statistical analyses (e.g., the relationship of presence/absence data to environmental variables, the relationship of environmental variables to habitat, the relationship of habitat to X2, the relationship of X2 to smelt abundance), with each step being uncertain. The relationships are correlative with substantial variance being left unexplained at each step. The action also may have high water requirements and may adversely affect salmon and steelhead under some conditions (memorandum from FWS and NMFS, January 15, 2010). As a result, how specific X2 targets were chosen and their likely beneficial effects need further clarification.

The X2 action for delta smelt includes a requirement for an adaptive management process that includes evaluation of other possible means of achieving the RPA's goal and it requires the establishment and peer review of performance measures and performance evaluation. It also requires "additional studies addressing elements of the habitat conceptual model" to be formulated as soon as possible and to be implemented promptly. Finally, it requires the FWS to "conduct a comprehensive review of the outcomes of the Action and the effectiveness of the adaptive management program ten years from the signing of the biological opinion, or sooner if circumstances warrant." This review is to include an independent peer review; the overall aim is to decide whether the action should be continued, modified, or terminated. It is critical that these requirements be implemented in light of the uncertainty about the biological effectiveness of the action and its high water requirements.

Tidal Habitat Action

The proposed RPA calls for the creation or restoration of 8,000 acres of intertidal and associated subtidal habitat in the delta and in Suisun Marsh. A separate planning effort also is under way for Suisun Marsh. The justification provided in the biological opinion is that the original amount of approximately 350,000 acres of tidal wetland has been reduced to less than 10,000 acres today, that the near-complete loss of tidal wetlands threatens delta smelt by reducing productivity at the base of the food web, and that delta smelt appear to benefit from the intertidal and subtidal habitat in Liberty Island, which includes tidal wetlands. This action has been less controversial than the others because it does not directly affect other water users.

However, although the concept of increasing and improving habitat to help offset other risks to smelt is conceptually sound, the scientific justification provided in the biological opinion is weak, because the relationship between tidal habitat and food availability for smelt is poorly understood, and it is inadequate to support the details of the implementation of this action. The opinion notes the importance of high-quality food sources to delta smelt and the association of these food resources with tidal habitats (including wetlands), and it references recent monitoring data from Liberty Island showing that such freshwater tidal habitats can be a source of high-quality phytoplankton that contribute to the pelagic food web downstream (p. 380). However, the specifics of which attributes of tidal habitat are essential to providing these food sources are not addressed.

In addition, the California Department of Fish and Game has raised questions about the details of this action (Wilcox, 2010). They include questions about the relative benefits of vegetated tidal marsh as opposed to open water; the extent to which invasive clams may divert new primary production; the amount of suitable productivity exported from restoration areas; the potential effect of the restored habitat on predation; the importance of productivity from vegetated tidal marsh directly or indirectly to the smelt; and the degree to which other fish species might use the habitat, possibly to the detriment of the smelt In briefings to the panel, the importance of ongoing studies in resolving these issues was identified. Identifying the characteristics of the "intertidal and associated subtidal habitat" that the action is expected to produce is needed to ensure that expectations of the outcomes, in terms of both habitat type and species benefits, are clear to all. The relative roles of areas of emergent vegetation, unvegetated intertidal and shallow, highly turbid subtidal habitat must be identified for the action to be effectively implemented.

The committee recommends that this action be implemented in phases, with the first phase to include the development of an implementation and adaptive management plan (similar to the approach used for the floodplain habitat action in the NMFS biological opinion), but also to explicitly consider the sustainability of the resulting habitats, especially those dependent on emergent vegetation, in the face of expected sea-level rise. In addition, there should be consideration of the types and amounts of tidal habitats necessary to produce the expected outcomes and how they can be achieved and sustained in the long term. More justification for the extent of the restoration is needed. The committee supports the monitoring program referred to in Action 6, and appropriate adaptive management triggers and actions.

SALMONIDS AND STURGEON

The NMFS RPA for salmon, steelhead, and green sturgeon is a broad complex of diverse actions spanning three habitat realms: tributary watersheds, the mainstem Sacramento and San Joaquin Rivers, and the delta. On balance, the actions are primarily crafted to improve life-stage-specific survival rates for salmon and steelhead, with the recognition that the benefits also will accrue to sturgeon. The committee agrees with this approach. The conceptual bases of the strategies underpinning many of the individual actions are generally well-founded, although the extent to which the intended responses are likely to be realized is not always clear. Given the absence of a clear, quantitative framework for analyzing the effects of individual and collective actions, it is difficult to make definitive statements regarding the merits of such a complex RPA. Indeed, absent such an analysis, the controversial aspects of some of the RPA actions could detract from the merits of the rest of the RPA.

The assortment of actions among the three habitat realms (watersheds, mainstem rivers, and delta) is designed to improve survival and to enhance connectivity throughout this system. This approach is consistent with the contemporary scientific consensus on improving ecosystem functioning as a means to improve productivity of anadromous and other migratory species (e.g., NRC 1996, 2004a, 2004b; Williams 2005). Watershed actions would be pointless if mainstem passage conditions connecting the tributaries to, and through, the delta were not made satisfactory.

Watershed and Mainstem River Actions

Watershed-level actions that are implemented in the tributaries are organized and formulated to meet the needs of specific listed populations in that system. The actions target limiting factors specific to those locales and populations. In general, the rationale for conducting the actions appears to be well-founded. However, it is difficult to ascertain to what extent, or even whether, the collective actions will appreciably reduce the risk to the fishes within the watershed or throughout the entire river system. We suggest that inclusion of some type of quantitative analysis using a tool like Ecosystem Diagnosis and Treatment (EDT) model during the planning process may have provided an even stronger justification for the set of actions selected (*http://jonesandstokes.com/*). We understand there is a recent application of EDT in the lower San Joaquin River, by Jones & Stokes, thus providing a precedent for its use in California's Central Valley. EDT is presented here as an example of a quantitative modeling approach that integrates the effects of various actions to produce relative changes in productivity and abundance. The committee emphasizes the need for a quantitative assessment framework, and does not necessarily specifically advocate the use of EDT.

The RPA also prescribes actions to improve mainstem passage conditions, most notably at the Red Bluff Diversion Dam (RBDD). The objective is to provide unobstructed upstream passage at the RBDD, to ensure more efficient access of adult salmonids to restored watersheds, and access for adult sturgeon to spawning grounds. Without such actions connectivity could not be fully realized. Furthermore, the passage improvement at the diversion dam, in combination with increased water delivery from storage reservoirs, is expected to improve smolt survival during downstream migration. This component is well justified scientifically, although the absence of a system-wide salmon survival model limits our ability to evaluate the extent to which this action contributes to improved survival for the populations in question.

Smolt Survival Near and Through the Delta

The net survival of salmonid smolts though the mainstem rivers and the delta under different water-management operations is of keen interest. Several RPA actions are intended to improve survival of the juveniles as they migrate seaward. Some of these actions have significant water requirements, and so they are controversial. The common goal of these actions is improve smolt survival by retaining a high proportion of the migrating smolt population in the mainstem Sacramento and San Joaquin Rivers. This involves two general approaches: block entrances to the interior delta, or manipulate currents in major channels to reduce the transport of smolt towards the pump facilities and possible entrainment or locations where they may be lost to predation, starvation, or disease. Here we focus on three pivotal actions: the closure of the Delta Cross Channel, the manipulation of OMR flows, and water-management actions in the lower San Joaquin River.

Delta Cross Channel (DCC)

As smolts migrate seaward from the upper Sacramento River they encounter the DCC near Walnut Grove. The DCC can at times draw large volumes of water from the Sacramento River, and some of the smolts follow that current toward the interior delta, where salmon mortality is high.

The objective of this action is to physically block the entrance of the DCC at strategic times during the smolt migration, thereby preventing access to the interior delta. This is a long-standing action that appears to be scientifically justified. However, Burau et al. (2007) estimated that when the DCC gates are open, approximately 45 percent of the Sacramento River flow measured at Freeport is redirected into the delta interior through the DCC and Georgiana Slough. The salmon action (Action Suite IV.1), which under certain triggers requires prolonged closure of the DCC gates from October 1 through June 15, must also consider the effects on delta smelt. The Smelt Working Group (notes from June 4, 2007 meeting) concluded that there could be a small beneficial effect on delta smelt from having the DCC gates open from late May until mid-June.

Although this action does not appear to constitute an important conflict between the needs of smelt and salmon, it illustrates the potential for conflict among the two opinions and the need for closer integration of the actions within the delta that have consequences for more than one of the listed species. This is an example where a systematic analysis of the implications for both species of actions would seem to be a scientific requirement.

Managing OMR Flows for Salmonids

This RPA action (IV.2.3, Old and Middle River Flow Management) also seeks to limit smolt excursion into part of the delta associated with high smolt mortality, but it does so by manipulating current direction and intensity within the Old and Middle River (OMR) drainages. The objective is to reduce current velocity toward the SWP and CVP facilities, thereby exposing fewer smolts to pump entrainment and being drawn into other unfavorable environments.

To accomplish the objective, the action calls for, reducing exports from January 1 through June 15, as necessary, to limit negative OMR flows to -2,500 to -5,000 cfs, depending on the presence of salmonids. The reverse flow will be managed within this range to reduce flows toward the pumps during periods of increased salmonid presence. The flow range was established through correlations of OMR flow and salmon entrainment indices at the pumps, and from entrainment proportions derived using the particle-tracking model (PTM). While the flow management strategy is conceptually sound, the threshold levels needed to protect fish is not definitively established. The response of loss at the pumps to OMR flow (e.g. figure 6-65 from NMFS, 2009) does not suggest a significant change in the vicinity of the flow triggers, but it does suggest that the loss rate increases exponentially above the triggers. The PTM suggests a gradual linear response in the vicinity of the trigger. However, no analysis was presented for the entrainment rate above the trigger (Figure 6-68 from NMFS, 2009), and it is not clear whether the salvage *rates* as well as salvage numbers were modeled. Therefore, the committee is unable to evaluate the validity of the exponential increase in loss rate above the trigger. Uncertainty in the effect of the flow triggers needs to be reduced, and more flexible triggers that might require less water should be evaluated.

The committee concludes that the strategy of limiting net tidal flows toward the pump facilities is sound, but the support for the specific flows targets is less certain. In the near-term telemetry-based smolt migration and survival studies (e.g, Perry and Skalski, 2008) should be used to improve our understanding of smolt responses to OMR flow levels. Reliance on salvage indices or the PTM results alone is not sufficient.

Additionally, there is little direct evidence to support the position that this action alone will benefit the San Joaquin salmon, unless it is combined with an increase in San Joaquin River flows. Furthermore, we understand this and other flow management actions are coordinated with the delta smelt actions. But we found no quantitative analysis that integrates across the actions to systematically evaluate their aggregate effects on both salmonids and smelt. Understanding those interactions will benefit from the development and use of multiple single-species models, including movement models.

Managing Exports and Flows in the San Joaquin River

The objective of this action (IV.2.1) is to reduce the vulnerability of emigrating Central Valley steelhead within the lower San Joaquin River to entrainment into the channels of the south delta and at the pumps by increasing the inflow-to-export ratio. It seeks to enhance the likelihood of salmonids' successfully exiting the delta at Chipps Island by creating more suitable hydraulic conditions in the mainstem of the San Joaquin River for emigrating fish, including greater net downstream flows.

The action has two components: reducing exports, and augmenting San Joaquin River flows at Vernalis. The rationale that increasing San Joaquin inflows to the delta will benefit smolt survival through this region of the delta is based on data from coded-wire tags on smolts. This statistical evidence provides only a coarse assessment of the action, but it indicates that increasing San Joaquin River flows can explain observed increases in escapement. Historical data indicate that high San Joaquin River flows in the spring result in higher survival of outmigrating Chinook salmon smolts and greater adult returns 2.5 years later (Kjelson et al., 1981; Kjelson and Brandes, 1989), and that when the ratio between spring flows and exports increase, Chinook salmon production increases (CDFG, 2005; SJRGA, 2007). In its biological opinion, NMFS therefore concludes that San Joaquin River Basin and Calaveras River steelhead would likewise benefit under higher spring flows in the San Joaquin River in much the same way as fall-run Chinook do. NMFS recognizes this assumption is critical, and thus the biological opinion calls for implementation of a six-year smolt-survival study (acoustic tags) (Action IV.2.2), using hatchery steelhead and fall Chinook.

The controversy lies in the effectiveness of the component of this action that reduces water exports from the delta. The effectiveness of reducing exports to improve steelhead smolt survival is less certain, in part because within the VAMP (Vernalis Adaptive Management Plan) increased flows and reduced exports are combined, and in part because steelhead smolts are larger and stronger swimmers than Chinook salmon smolts. Furthermore, it is not clear in the biological opinion how managing exports for this purpose would be integrated with export management for other actions. The choice of a 4:1 ratio of net flows to exports appears to be the result of coordinated discussions among the interested parties. Given the weak influence of exports in all survival relationships (Newman, 2008), continued negotiation offers opportunities to reduce water use in this specific action without great risk to steelhead. Further analysis of VAMP data also offers an opportunity to help clarify the issue.

The committee concludes that the rationale for increasing San Joaquin River flows has a stronger foundation than the prescribed action of concurrently managing inflows and exports. We further conclude that the implementation of the six-year steelhead smolt survival study (action IV.2.2) could provide useful insight as to the actual effectiveness of the proposed flow management actions as a long-term solution.

Increase Passage through Yolo Bypass

This action would reduce migratory delays and loss of adult and juvenile salmon and green sturgeon at structures in the Yolo Bypass. For sturgeon there is substantial evidence that improved upstream passage at Yolo will be beneficial. For salmon, the purpose is to route salmon away from the interior delta and through a habitat that is favorable for growth. This action is scientifically justified and prudent, but its implications for the routing of flows through the system as a whole were not transparently evaluated. For example, moving water through the Yolo Bypass results in less water coming through the Sacramento River. Were the effects of less flow in the Sacramento River considered in the design of the action? Similarly, how were the possible negative consequences of increased flooding of the Yolo Bypass on mercury cycling considered? This exemplifies a general tendency throughout the discussion of the actions to focus on the biologically beneficial aspects but to not fully present how any conflicting consequences or potential for such consequences were considered.

Floodplain Habitat

The floodplain habitat actions (Actions I.6.1-4) involve increasing the inundation of private and public lands within the Sacramento River basin to increase the amount and quality of rearing habitat for juvenile salmon. This action suite appears scientifically justified on the basis of a number of studies (e.g., Moyle et al., 2007; Sommer et al., 2001; Whitener and Kennedy, 1999). Given the strong basis, the committee recommends early implementation of these actions providing the implications for releases and routing of flows on other actions, and any potential negative consequences, e.g., mobilization of mercury, are adequately considered. In addition, the committee suggests detailed studies of the outcome of these actions to provide important data for improved life cycle models for these species.

INTEGRATION OF RPAs

The RPAs lack a quantitative analytical framework that ties them together within species, between smelt and salmonid species, and across the watershed. This type of systematic, formalized analysis is necessary to provide an objective determination of the net effect of the actions on the listed species and on water users.

An additional overall, systematic, coordinated analysis of the effect of all actions taken together and a process for implementing the optimized, combined set of actions would help to establish the credibility of the effort overall. Instances of coordination certainly exist. For example, the analysis done by NMFS for the Action IV.2.1 (Appendix 5), is an example of coordination, where the water needs for the 4-to-1 flow-to-export ratio for steelhead were determined and used to refine the action. But coordination is not integration. The lack of a systematic, well framed overall analysis is a serious deficiency. The interagency effort to transparently reach consensus on implications of the combined RPAs for their effects on all the species and on water quality and quantity within the delta and on water operations and deliveries should use scientific principles and methods in a collaborative and integrative manner. Full documentation of decisions is an essential part of such an effort, as is inclusion of the environmental water needs of specific actions and for the entire RPA.

It is clear that integrative tools that, for example, combine the effect over life stages into a population-level response would greatly help the development and evaluation of the combined actions. This was acknowledged by the FWS and NMFS, as well by many of the other presenters during the two days of public session of the committee meeting. There has been significant investment in operations and hydrodynamic models for the system, which have been invaluable for understanding and managing the system. An investment in ecological models that complement the operations and hydrodynamics models is sorely needed. This issue has been raised repeatedly in peer reviews, but still has not been incorporated in the NMFS and FWS analyses. Without a quantitative integration tool, the expected effects of individual actions on the listed species will remain a matter of judgment based on the interpretation of many disparate studies. The NMFS and FWS had to therefore determine the cumulative effects of the multiple actions in each RPA in a qualitative manner. This leads to arguments and disputes that are extremely difficult to resolve and that can undermine the credibility of the biological opinions. Commitment to a long-term effort to develop a quantitative tool (or tools) should be part of the RPA, with the explicit goal of formalizing and focusing the sources of disagreement and allowing for the clear testing of alternative arguments.

Transparent consideration of the implications of water requirements also would seem well advised because some of the actions have significant water requirements. DWR and NMFS used CalSim-II and Calite to simulate a collection of actions to determine water needs associated with the NMFS RPA, and concluded that they would amount to 5-7 percent of total water allocations (NMFS, 2009). (Because the actions involving negative OMR flows were similar in timing and magnitude in both the NMFS and the FWS RPAs, all OMR flow management was included in this estimate.) Those, and complementary efforts, should be extended to as many of the actions in combination as feasible, recognizing that the adaptive nature of many aspects of the RPAs, along with variations in environmental conditions and in water demands, limit the degree of certainty associated with such estimates. Credible documentation of the water needed to implement each action and the combined actions, would enable an even clearer and more logical formulation of how the suite of actions might be coordinated to simultaneously benefit the species and ensure water efficiency.

OTHER POSSIBLE RPAs

The committee's charge included the task that the committee should identify, if possible, additional potential RPAs that would provide the potential to provide equal or greater protection to the fishes than the current RPAs while costing less in terms of water availability for other uses. The committee considered RPAs that had been considered and rejected by the agencies or that were recommended to the committee for its consideration (Hamilton, 2010). They included using bubble-curtain technology instead of hard barriers to direct migration of salmon and steelhead smolts, use of weirs to protect wild steelhead from interbreeding and competition, use of weirs to reduce spring-run Chinook from inbreeding and competition with fall-run Chinook, habitat restoration and food-web enhancement, restoration of a more-natural hydrograph, reducing mortality caused by nonnative predators, reducing contaminants, reducing other sources of 'take," implementation of actions to reduce adverse effects of hatcheries, and ferrying San Joaquin River steelhead smolts through the delta.

Some of these are already included to some degree in the RPAs (e.g., reduction of adverse hatchery effects, habitat restoration), and some might not be within the agencies' authorities as RPA actions under the ESA (e.g., contaminant reduction and reduction of other sources of "take"). The committee did not attempt to evaluate whether these suggestions represent good actions to help reduce risks to the listed species in a general attempt at restoration, as that will be addressed in the committee's second report. The committee concludes that none of the above suggested alternative RPAs has received sufficient documentation or evaluation to be confident at present that any of them would have the potential to provide equal or greater protection for the listed species while requiring less disruption of delta water diversions.

Several long-term actions described above have the potential to increase protections for the species while requiring the use of less water for that purpose, because they will result in a better understanding of the system. That better understanding should allow for a better matching of water for species needs, thus potentially reducing the amount of water used in less-effective actions. However, no short-term measure was identified that would provide equal protection to the fishes while reducing restrictions on water diversions.

RESOLVING INCOMPATIBILITIES BETWEEN THE RPAs

The committee noted in its discussion of the Delta Cross Channel action for salmon that it has a small potential for conflict with the requirements for smelt, although the action itself includes a consideration of the effects on smelt. In addition, the agencies have coordinated, and in some cases changed, their actions to avoid or reduce such conflicts, including actions concerning the installation of a "non-physical" barrier at the Head of Old River and the possibility of constructing a barrier across Georgiana Slough (NMFS and FWS, 2010). However, as the committee has noted elsewhere, coordination is not integration, and while it commends the agencies for working together to avoid incompatibilities between the RPAs, it concludes that this coordination is not sufficient to achieve the best results or full evaluation of incompatibilities. To achieve those goals requires an integrated analysis, because without such an analysis it is difficult or impossible to properly evaluate potential conflicts among RPA actions. More important, such an analysis would help to produce more-effective actions. The lack of an integrated analysis also prevented the committee from a fuller evaluation of potential incompatibilities between the RPAs.

EXPECTATIONS AND PROXIMATE MEASURES

The committee heard several times at the public sessions that the RPA actions for delta smelt are not working as there has been no response in the standard annual abundance indices during the last three years when action-related restrictions have been imposed. Such comments are appropriate, but only if realistic expectations are used to judge effectiveness. In this case, it is unrealistic to expect immediate and proportional responses to actions in annual indices of delta smelt, especially within the first few years of implementation. There are several reasons for this. First, fish abundances are influenced by many factors not affected by the actions. This is true in all estuarine and marine systems, and is simply inherent in fish population dynamics. For example, in the case of the species here, three drought years coincided with the implementation of the actions. Other factors have also varied that would further mask any response in the annual indices.

Second, delta smelt populations are very small. The ability of the annual indices to show changes in response to actions is compromised due to the inherent lack of precision in sampling and constructing indices of abundance when populations are very small. Unlike salmon and steelhead, the adults of which can be counted with great precision as they migrate upstream, delta smelt are more difficult to count as well as being rare. While this is frustrating, little change in the annual indices over a few years neither invalidates the utility of the actions nor do they demonstrate that the actions are effective. Finally, there were no prior quantified estimates of response to calibrate expectations. Expectations would be better established if the RPA proposals more explicitly quantified the nature and the expected timescale of responses in the target species, and detailed exactly what would be done to assess the validity of those predictions.

RPA RECOMMENDATIONS

The committee concluded that the uncertainties and disagreements surrounding some of the RPA actions could be reduced by some additional activities. In general, the committee recommends that, within the limits the agencies face with respect to human and financial resources, a more-integrated approach to analyzing adverse effects of water operations and potential actions to reduce those effects would be helpful. The approach would include a broader examination of the life cycles of each fish species and where possible, integrating analyses across species. Although there is much general evidence that the profound reduction and altered timing of the delta water supply has been part of the reason for the degradation of these species' habitats, the marginal benefits of beginning to reverse the damage will be difficult to recognize for some time and there is much uncertainty about how to design attempts at the reversal. At this time, the best that can be done is to design a strategy of pumping limitations that uses the best available monitoring data and the best methods of statistical analysis to design an exploratory approach that could include enhanced field measurements to manage the pumping limitations adaptively while minimizing impacts on water users. Such an approach would include a more explicit and transparent consideration of water requirements, despite the variability in environmental conditions and water demand; and population models to evaluate the combined effects of the individual actions.

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Appendixes

Appendix A

Committee on Sustainable Water and Environmental Management in the California Bay-Delta

STATEMENT OF TASK

At the request of Congress and the Departments of the Interior and Commerce, a committee of independent experts will be formed to review the scientific basis of actions that have been and could be taken to simultaneously achieve both an environmentally sustainable Bay-Delta and a reliable water supply. In order to balance the need to inform near-term decisions with the need for an integrated view of water and environmental management challenges over the longer-term, the committee will undertake two main projects over a term of two years resulting in two reports.

First, by approximately March 15, 2010, the committee will issue a report focusing on scientific questions, assumptions, and conclusions underlying water-management alternatives in the U.S. Fish and Wildlife Service's (FWS) Biological Opinion on Coordinated Operations of the Central Valley Project and State Water Project (Dec. 15, 2008) and the National Marine Fisheries Service's (NMFS) Biological Opinion on the Long-Term Central Valley Project and State Water Project Operations Criteria and Plan (June 4, 2009). This review will consider the following questions:

- Are there any "reasonable and prudent alternatives" (RPAs), including but not limited to alternatives considered but not adopted by FWS (e.g., potential entrainment index and the delta smelt behavioral model) and NMFS (e.g., bubble-curtain technology and engineering solutions to reduce diversion of emigrating juvenile salmonids to the interior and southern Delta instead of towards the sea), that, based on the best available scientific data and analysis, (1) would have lesser impacts to other water uses as compared to those adopted in the biological opinions, and (2) would provide equal or greater protection for the relevant fish species and their designated critical habitat given the uncertainties involved?

- Are there provisions in the FWS and NMFS biological opinions to resolve potential incompatibilities between the opinions with regard to actions that would benefit one listed species while causing negative impacts on another, including, but not limited to, prescriptions that: (1) provide spring flows in the Delta in dry years primarily to meet water quality and outflow objectives pursuant to Water Board Decision-1641 and conserve upstream storage for summertime cold water pool management for anadromous fish species; and (2) provide fall flows during wet years in the Delta to benefit Delta smelt, while also conserving carryover storage to benefit next year's winter-run cohort of salmon in the event that the next year is dry?
- To the extent that time permits, the committee would consider the effects of other stressors (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Bay-Delta. Details of this task are the first item discussed as part of the committee's second report, below, and to the degree that they cannot be addressed in the first report they will be addressed in the second.

Second, in approximately November 2011, the committee will issue a second report on how to most effectively incorporate science and adaptive management concepts into holistic programs for management and restoration of the Bay-Delta. This advice, to the extent possible, should be coordinated in a way that best informs the Bay-Delta Conservation Plan development process. The review will include tasks such as the following:

- Identify the factors that may be contributing to the decline of federally listed species, and as appropriate, other significant at-risk species in the Delta. To the extent practicable, rank the factors contributing to the decline of salmon, steelhead, delta smelt, and green sturgeon in order of their likely impact on the survival and recovery of the species, for the purpose of informing future conservation actions. This task would specifically seek to identify the effects of stressors other than those considered in the biological opinions and their RPAs (e.g., pesticides, ammonia discharges, invasive species) on federally listed and other at-risk species in the Delta, and their effects on baseline conditions. The committee would consider the extent to which addressing stressors other than water exports might result in lesser restrictions on water supply. The committee's review should include existing scientific information, such as that in the NMFS Southwest Fisheries Science Center's paper on decline of Central Valley fall-run Chinook salmon, and products developed through the Pelagic Organism Decline studies (including the National Center for Ecosystem Analysis and Synthesis reviews and analyses that are presently under way).

- Identify future water-supply and delivery options that reflect proper consideration of climate change and compatibility with objectives of maintaining a sustainable Bay-Delta ecosystem. To the extent that water flows through the Delta system contribute to ecosystem structure and functioning, explore flow options that would contribute to sustaining and restoring desired, attainable ecosystem attributes, while providing for urban, industrial, and agricultural uses of tributary, mainstem, and Delta waters, including for drinking water.
- Identify gaps in available scientific information and uncertainties that constrain an ability to identify the factors described above. This part of the activity should take into account the Draft Central Valley Salmon and Steelhead recovery plans (NOAA 2009b), particularly the scientific basis for identification of threats to the species, proposed recovery standards, and the actions identified to achieve recovery.
- Advise, based on scientific information and experience elsewhere, what degree of restoration of the Delta system is likely to be attainable, given adequate resources. Identify metrics that can be used by resource managers to measure progress toward restoration goals.

The specific details of the tasks to be addressed in this second report will likely be refined after consultation among the departments of the Interior and Commerce, Congress, and the National Research Council, considering stakeholder input, and with the goal of building on, rather than duplicating, efforts already being adequately undertaken by others.

Appendix B
Water Science and Technology Board

CLAIRE WELTY, *Chair*, University of Maryland, Baltimore County
YU-PING CHIN, Ohio State University, Columbus
OTTO C. DOERING, Purdue University, West Lafayette, Indiana
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JAMES M. HUGHES, Emory University, Atlanta, Georgia
KIMBERLY L. JONES, Howard University, Washington, D.C.
MICHAEL J. MCGUIRE, Michael J. McGuire, Inc., Santa Monica, California
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Appendix C
Ocean Studies Board

DONALD F. BOESCH (Chair), University of Maryland Center for Environmental Science, Cambridge
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Appendix D
Speakers at Committee's Meeting
January 24-29, 2010
University of California, Davis

Ara Azhderian, San Luis and Delta Mendota Water Authority
Barbara Barrigan-Parilla, Restore the Delta
Brett Baker, Delta Resident
Letty Belin, U.S. Department of the Interior
Cheryl Bly-Chester, UC Berkeley
Dan Castleberry, U.S. Fish and Wildlife Service
Jim Costa, U.S. House of Representatives, California-District 20
DeeDee D'Adamo, Office of U.S. Representative Dennis Cardoza, California-District 18
Cliff Dahm, CALFED (Delta Science Program)
Stan Dean, Sacramento Regional County Sanitation District, Director of Policy
Rick Deriso, Inter-American Tropical Tuna Commission
Diana Engle, Larry Walker Associates
Fred Feyrer, Bureau of Reclamation
David Fullerton, Metropolitan Water District of Southern California
Greg Gartrell, Contra Costa Water District
Zeke Grader, Pacific Coast Federation of Fishermen's Association
Cay Goude, U.S. Fish and Wildlife Service
Scott Hamilton, Coalition for a Sustainable Delta
Ann Hayden, Environmental Defense Fund
Bruce Herbold, U.S. Environmental Protection Agency
John Herrick, South Delta Water Agency
Jerry Johns, California Department of Water Resources
Harold Johnson, Pacific Legal Institute
Linda Katehi, University of California, Davis
Jason Larroba, Tehama-Colusa Canal Authority
Tom Lindemuth, Delta Science Center, Big Break
Steve Lindley, National Marine Fisheries Service
Craig Manson, Council for Endangered Species Act Reliability

BJ Miller, Consultant
Ron Milligan, Bureau of Reclamation
Jeffrey Mount, University of California, Davis
Peter B. Moyle, University of California, Davis
Steve Murawski, National Oceanic and Atmospheric Administration
Eligio Nava, Central Valley Hispanic Chamber
Dante John Nemellini, Central Delta Water Agency
Matt Nobriga, California Department of Fish and Game
Doug Obegi, Natural Resources Defense Council
Tim O'Laughlin, O'Laughlin & Paris
Bruce Oppenheim, National Marine Fisheries Service
Richard Pool, Salmon fishing industry
Maria Rea , National Marine Fisheries Service
Rhonda Reed, National Marine Fisheries Service
Mark Renz, Association of California Water Agencies
Spreck Rosekrans, Environmental Defense Fund
Melanie Rowland, NOAA-General Counsel
Patricia Schuffon, Pacific Advocate Program
Jeff Stuart, National Marine Fisheries Service
Nicky Suard, Delta Land and Business owners
Christina Swanson, The Bay Institute
Robert Thornton, Nossaman
Mike Urkov, Tehama-Colusa Canal Authority
Jay Wells, North American Power Sweeping Association
Carl Wilcox, California Department of Fish and Game
Susan William, Pt. Lobos Marine Preserve
Mary Winfree, PoE/USANG
Phil Wyman, Former Central Valley Senator/Assemblyman
Paula Yang, Hmong Sisterhood
Garwin Yip, National Marine Fisheries Service

Appendix E
Biographical Sketches for Members of the Committee on Sustainable Water and Environmental Management in the California Bay-Delta

ROBERT J. HUGGETT, ***Chair***, is an independent consultant and professor emeritus and former chair of the Department of Environmental Sciences, Virginia Institute of Marine Sciences at the College of William and Mary, where he was on the faculty for over 20 years. He also served as Professor of Zoology and Vice President for Research and Graduate Studies at Michigan State University from 1997 to 2004. Dr. Huggett is an expert in aquatic biogeochemistry and ecosystem management whose research involved the fate and effects of hazardous substances in aquatic systems. From 1994 to 1997, he was the Assistant Administrator for Research and Development for the U.S. Environmental Protection Agency, where his responsibilities included planning and directing the agency's research program. During his time at the EPA, he served as Vice Chair of the Committee on Environment and Natural Resources and Chair of the Subcommittee on toxic substances and solid wastes, both of the White House Office of Science and Technology Policy. Dr. Huggett founded the EPA Star Competitive Research Grants program and the EPA Star Graduate Fellowship program. He has served on the National Research Council's (NRC) Board on Environmental Studies and Toxicology, the Water Science and Technology Board, and numerous study committees on wide ranging topics. Dr. Huggett earned an M.S. in Marine Chemistry from the Scripps Institution of Oceanography at the University of California at San Diego and completed his Ph.D. in Marine Science at the College of William and Mary.

JAMES J. ANDERSON is a research professor the School of Aquatic and Fisheries Sciences at the University of Washington, where he has been teaching since 1983, and Co-Director of Columbia Basin Research. Prior to joining the faculty at the University of Washington, he did research work at the University of Kyoto in Japan, the National Institute of Oceanography in Indonesia, and

Institute of Oceanographic Sciences in Wormley, UK. Dr. Anderson's research focuses on models of ecological and biological processes from a mechanistic perspective, specifically: (1) migration of organisms, (2) decision processes, and (3) mortality processes. For three decades he has studied the effects of hydrosystems and water resource allocations on salmon and other fish species. He has developed computer models of the migration of juvenile and adult salmon through hydrosystems and heads the DART website, an internet database serving real-time environmental and fisheries data on the Columbia River. His other research interests include mathematical studies in ecosystems, biodemography, toxicology and animal behavior. He has served on a number of regional and national panels and has testified numerous times before Congress on the impacts of hydrosystems on fisheries resources. He received his B.S. and Ph.D. in oceanography from the University of Washington.

MICHAEL E. CAMPANA is Professor of Geosciences at Oregon State University, former Director of its Institute for Water and Watersheds, and Emeritus Professor of Earth and Planetary Sciences at the University of New Mexico. Prior to joining OSU in 2006 he held the Albert J. and Mary Jane Black Chair of Hydrogeology and directed the Water Resources Program at the University of New Mexico and was a research hydrologist at the Desert Research Institute and taught in the University of Nevada-Reno's Hydrologic Sciences Program. He has supervised 70 graduate students. His research and interests include hydrophilanthropy, water resources management and policy, communications, transboundary water resources, hydrogeology, and environmental fluid mechanics, and he has published on a variety of topics. Dr. Campana was a Fulbright Scholar to Belize and a Visiting Scientist at Research Institute for Groundwater (Egypt) and the IAEA in Vienna. Central America and the South Caucasus are the current foci of his international work. He has served on six NRC-NAS committees. Dr. Campana is founder, president, and treasurer of the Ann Campana Judge Foundation (www.acjfoundation.org), a 501(c)(3) charitable foundation that funds and undertakes projects related to water, sanitation, and hygiene (WASH) in Central America. He operates the WaterWired blog and Twitter. He earned a BS in geology from the College of William and Mary and MS and PhD degrees in hydrology from the University of Arizona.

THOMAS DUNNE is a professor in the Donald Bren School of Environmental Science and Management at the University of California at Santa Barbara. He is a hydrologist and a geomorphologist, with research interests that include alluvial processes; field and theoretical studies of drainage basin and hill-slope evolution; sediment transport and floodplain sedimentation; debris flows and sediment budgets of drainage basins. He served as a member of the WSTB Committee on Water Resources Research and Committee on Opportunities in the Hydrologic Sciences and was elected to the National Academy of Sciences in 1988. He has acted as a scientific advisor to the United Nations, the governments of Brazil, Taiwan, Kenya, Spain, the Philippines, Washington, Oregon, several U.S. federal agencies, and The Environmental Defense Fund. He is a recipient of the American Geophysical Union Horton Award. Dr. Dunne holds a B.A. from Cambridge University and a Ph.D. in geography from the Johns Hopkins University.

ALBERT E. GIORGI is president and senior fisheries scientist at BioAnalysts, Inc in Redmond, WA. He has been conducting research on Pacific Northwest salmonid resources since 1982. Prior to 1982, he was a research scientist with NOAA in Seattle, WA. He specializes in fish passage migratory behavior, juvenile salmon survival studies, biological effects of hydroelectric facilities and operation. His research includes the use of radio telemetry, acoustic tags, and PIT-tag technologies. In addition to his research, he acts as a technical analyst and advisor to public agencies and private parties. He regularly teams with structural and hydraulic engineers in the design and evaluation of fishways and fish bypass systems. He served on the NRC Committee on Water Resources Management, Instream Flows, and Salmon Survival in the Columbia River. He received his B.A. and M.A. in biology from Humboldt State University and his Ph.D. in fisheries from the University of Washington.

PATRICIA M. GLIBERT is a professor at the University of Maryland Center for Environmental Science, Horn Point Laboratory, where she has been on the faculty since 1986. Prior to UMD-HPL, she was a postdoctoral scholar and an assistant scientist at the Woods Hole Oceanographic Institution. Her research areas are in transformations and fate of inorganic and organic nitrogen in marine and estuarine systems; ecology of phytoplankton in coastal and oceanic environments; stable isotope techniques; eutrophication and its effects; growth and physiology of marine cyanobacteria and harmful algal bloom species; "top-down" control of nitrogen cycling; primary productivity and its regulation by environmental factors; and impacts of harmful algae on oysters. Her current projects are in the Chesapeake and coastal bays of Maryland, Florida Bay, and the Arabian Sea. She received her B.S. in biology from Skidmore College; M.S. in earth science from the University of New Hampshire; and her Ph.D. in organismal and evolutionary biology from Harvard University.

CHRISTINE A. KLEIN is the Chesterfield Smith Professor of Law at the University of Florida Levin College of Law, where she has been teaching since 2003. She offers courses on natural resources law, environmental law, water law, and property. Previously, she was a member of the faculty of Michigan State University College of Law, where she served as Environmental Law Program Director. From 1989 to 1993, she was an assistant attorney general in the Office of Colorado Attorney General, Natural Resources Section, where she specialized in water rights litigation. She has published widely on a variety of water law and natural resources law topics. She holds a B.A. from Middlebury College, Vermont; a J.D. from the University of Colorado School of Law; and an LL.M. from Columbia University School of Law, New York.

SAMUEL N. LUOMA is a a research professor at the John Muir Institute of the Environment, University of California, Davis and an emeritus Senior Research Hydrologist in the Water Resources Division of the U.S. Geological Survey, where he worked for 34 years. He also holds an appointment as a Scientific Associate at The Natural History Museum, London. Dr. Luoma's research centers on processes the control the fate, bioavailability and effects of contaminants, particularly in the San Francisco Bay-Delta. He served as the first lead on the CALFED Bay-delta program and is the Editor-in-Chief of San Francisco Estuary & Watershed Science. He has helped refine approaches to determine the toxicity of marine and estuarine sediments and developed models that are used in development of water quality standards. His most recent research interests are in environmental implications of nanotechnology and better connecting water science to water policy. He has served multiple times on the EPA's Science Advisory Board Subcommittee on Sediment Quality Criteria and on other NRC committees. Dr. Luoma received his B.S. and M.S. in Zoology from Montana State University, Bozeman, and his Ph.D. in Marine Biology from the University of Hawaii, Honolulu.

MICHAEL J. MCGUIRE is president and founder of Michael J. McGuire, Inc., in Santa Monica, California. He has provided consulting services over the past 18 years to public water utilities and industries in the areas of Safe Drinking Water Act compliance, source water quality protection and water treatment optimization. Prior to his consulting assignments, he was director of water quality and assistant general manager of the Metropolitan Water District of Southern California. His research interests include control of trace contaminants in drinking water; compliance with the Safe Drinking Water Act and all related regulations; occurrence, chemistry, and control of disinfection by-products; and identification and control of tastes and odors in water supplies. He is currently a member of the Water Science and Technology Board of the National Research Council and was selected as a member of the National Academy of Engineering in 2009. Dr. McGuire received his B.S. in civil engineering from the University of Pennsylvania and M.S. and Ph.D. in environmental engineering from Drexel University in Philadelphia.

THOMAS MILLER is professor of fisheries at the Chesapeake Biological Laboratory, University of Maryland Center for Environmental Science, where he has been teaching since 1994. Prior to UMCES-CBL, he was a postdoctoral fellow at McGill University, Montreal, Canada, and research specialist with the Center for Great Lakes Studies, University of Wisconsin, Milwaukee. His research focuses on population dynamics of aquatic animals, particularly in understanding recruitment, feeding and bio-physical interactions and early life history of fish and crustaceans. He has been involved in the development of a Chesapeake Bay fishery ecosystem plan, which includes detailed background information on fisheries, foodwebs, habitats and monitoring required to develop multispecies stock assessments. Most recently, he has developed an interest in the sublethal effects of contamination on Chesapeake Bay living resources using population dynamic approaches. He received his B.Sc. (hons) in human and environmental biology from the University of York, UK; his M.S. in ecology and Ph.D. in zoology and oceanography from North Carolina State University.

JAYANTHA OBEYSEKERA directs the Hydrologic & Environmental Systems Modeling Department at the South Florida Water Management District, where he is a lead member of a modeling team dealing with development and applications of computer simulation models for Kissimmee River restoration and the restoration of the Everglades Ecosystem. Prior to joining the South Florida Water Management District, he taught courses in hydrology and water resources at Colorado State University, Fort Collins; George Washington University, Washington, D.C.; and at Florida Atlantic University, Boca Raton, Florida. Dr. Obeysekera has published numerous research articles in refereed journals in the field of water resources. Dr. Obeysekera has over 20 years of experience practicing water resources engineering with an emphasis on both stochastic and deterministic modeling. He has taught short courses on modeling in the Dominican Republic, Colombia, Spain, Sri Lanka, and the U.S. He was a member of the Surface Runoff Committee of the American Geophysical Union and is currently serving as a member of a Federal Task Group on Hydrologic Modeling. He served as member of NRC's Committee on Further Studies of Endangered and Threatened Fishes in the Klamath River. Dr. Obeysekera has a B.S. degree in civil engineering from University of Sri Lanka; M.E. in hydrology from University of Roorkee, India; and Ph.D. in civil engineering with specialization in water resources from Colorado State University.

MAX J. PFEFFER is International Professor of Development Sociology and Chair of the Department at Cornell University. His teaching concentrates on environmental sociology and sociological theory. His research spans several areas including farm labor, rural labor markets, international migration, land use, and environmental planning. The empirical work covers a variety of rural and urban communities, including rural/urban fringe areas. Research sites include rural New York and Central America. He has been awarded competitive grants from the National Institutes of Health, the National Science Foundation, the U.S. Environmental Protection Agency, the U.S. Department of Agriculture's National Research Initiative and its Fund for Rural America, and the Social Science Research Council. Dr. Pfeffer has published a wide range of scholarly articles and has written or co-edited four books. He recently published (with John Schelhas) *Saving Forests, Protecting People? Environmental Conservation in Central America.* He also previously served as the Associate Director of both the Cornell University Agricultural Experiment Station and the Cornell University Center for the Environment. Dr. Pfeffer has served on other NRC committees studying aspects of watershed management. He received his Ph.D. degree in sociology from the University of Wisconsin, Madison.

DENISE J. REED is a University Research Professor at the University of New Orleans and is currently Interim Director of the Ponchartrain Institute for Environmental sciences. Her research interests include coastal marsh response to sea-level rise and how this is affected by human activities. She has worked on coastal issues on the Atlantic, Pacific, and Gulf coasts of the United States, as well as other parts of the world, and has published the results in numerous papers and reports. She is involved in ecosystem restoration planning both in Louisiana and in California. Dr. Reed has served on numerous boards and panels concerning the effects of human alterations on coastal environments and the role of science in guiding ecosystem restoration, including the Chief of Engineers Advisory Board, a number of NRC committees, and the Ecosystem Sciences and Management Working Group of the NOAA Science Advisory Board. She received her B.A. and Ph.D. degrees in geography from the University of Cambridge, United Kingdom.

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DESIREE D. TULLOS is assistant professor in the Department of Biological and Ecological Engineering, Oregon State University, Corvallis. Dr. Tullos consulted with Blue Land Water Infrastructure and with Barge, Waggoner, Sumner, and Cannon before joining the faculty at Oregon State University. Her research areas include ecohydraulics, river morphology and restoration, bioassessment, and habitat and hydraulic modeling. She has done work on investigations of biological responses to restoration and engineered applications in riverine ecosystems; development and evaluation of targeted and appropriate bioindicators for the assessment of engineered designs in riverine systems; assessing effects of urban and agricultural activities and management practices on aquatic ecosystem stability in developing countries. She received her B.S. in civil engineering from the University of Tennessee, Knoxville, and her MC.E. in civil engineering and Ph.D. in biological engineering from North Carolina State University, Raleigh.

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OF SOUTHERN CALIFORNIA

UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES, SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA PARTIALLY CONSOLIDATED WITH: 1:09-cv-480 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	**DECLARATION OF DR. RICHARD B. DERISO**
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	Date: March 23, 2010 Time: 8:30 a.m. Ctrm: 3 Judge: Hon. Oliver W. Wanger
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	

I, RICHARD B. DERISO, declare:

1. The facts and statements set forth in this declaration are true of my own knowledge and if called as a witness, I can testify competently thereto. Any opinions expressed in this declaration are based upon my knowledge, experience, training and education, as set forth in section I.

2. My declaration is set forth in the following manner:

I. INTRODUCTION

3. In July of this year, I prepared a preliminary declaration that set forth a general explanation of the statistical analysis contained in the 2008 Delta Smelt Biological Opinion ("BiOp") prepared by the United States Fish and Wildlife Service ("FWS"). In that declaration, I focused on three areas of analysis performed by FWS—(1) the relationship between Old and Middle River ("OMR") flows and salvage, (2) the effect of Fall X2 on population survival, and (3) the establishment of incidental take levels. In each of these areas, FWS employed statistics, data analysis, and/or statistical modeling—tools that require technical training to understand. The equations, the statistical, mathematical and fishery population dynamic principles, and the modeling exercises involved in the BiOp are highly complicated. Someone without the proper background and training would be unable to thoroughly review what FWS did in a meaningful way.

4. It is my understanding that the Court has authorized the submittal of this declaration so that I may address and explain in detail the issues I identified in my prior declaration. Since my prior declaration, I have been able to complete my review of the BiOp, as well as the relevant publications relied on by FWS and cited in the BiOp. This declaration sets

forth my comprehensive explanation of the statistical modeling and analysis that FWS performed, including its clear, fundamental errors, focusing again on OMR flows, Fall X2, and the incidental take levels. Below, and in the accompanying appendix, I explain what FWS purported to do, and the mistakes they made in reaching their conclusions. I have also provided the information and equations that I used in conducting my review in an appendix so that my statements and explanations can be critically reviewed by others.

II. BACKGROUND AND EXPERIENCE

5. I am the Chief Scientist of the Tuna-Billfish Program at the Inter-American Tropical Tuna Commission ("IATTC"), and I have held this position since 1989. *See* Summary Professional Vitae, attached hereto as Exhibit A. I supervise a scientific staff of approximately 20 scientists and our primary responsibilities are: (1) to collect statistics on the fisheries that operate in the eastern Pacific Ocean, such as tuna and tuna-like species, and (2) to conduct stock assessments annually on the principal tropical tuna species as well as periodically other species such as turtles, sharks, and billfish species. My work involves advising the Commission on the current status of the populations and making conservation recommendations that can permit stocks to be maintained at a level of abundance that will support maximum sustainable yields.

6. IATTC has a long history of successful management of the tuna stocks in the eastern Pacific Ocean. The largest fishery historically has been yellowfin tuna. Yellowfin tuna is currently at a level of abundance above that which would support maximum sustainable yield.

7. I have a Ph.D. in Biomathematics (Quantitative Ecology) from the University of Washington, a Master's of Science in Mathematics from the University of Florida, and a Bachelor's of Science in Industrial Engineering from Auburn University. I have been teaching courses in fish population dynamics, quantitative ecology, and related areas for over twenty years. I was an Associate Adjunct Professor at the Scripps Institution of Oceanography, University of California, San Diego, from 1990 to 2006 and an Affiliate Associate Professor of Fisheries at the University of Washington from 1987 to 2006. Among the graduate courses I have taught are "Theoretical Models of Exploited Animal Populations" at the University of Washington; "Decision Analysis for Exploited Populations" at the University of Washington; and

"Quantitative Theory of Populations and Communities" at Scripps Institution of Oceanography. I have additional professional experience through a current membership on the Scientific and Statistical Committee of the Western Pacific Regional Fisheries Management Council and a past membership on the Ocean Studies Board which governs the U.S. National Research Council, where I served as co-chairman of the Committee on Fish Stock Assessment Methods. I was also formerly a Population Dynamicist for the International Pacific Halibut Commission. I have been a consultant to several agencies and institutions, both public and private.

8. I have authored or co-authored over 50 peer reviewed publications and technical reports, including Deriso, R., Maunder, M., and Pearson, W, *Incorporating covariates into fisheries stock assessment models with application to Pacific herring*, Ecol. App. 18(5): 1270-1286 (2008); Deriso, R., Maunder, M., and Skalski, J., *Variance estimation in integrated assessment models and its importance for hypothesis testing*, Can. J. Fish. Aquat. Sci. 64: 187-197 (2007); and Quinn, T. and Deriso, R., *Quantitative Fish Dynamics*, Oxford University Press (1999). *See* List of Publications, attached hereto as Exhibit B.

9. I have been retained to evaluate the effects of entrainment on fish populations in many circumstances throughout the United States. I have consulted on the environmental review of once-through cooling systems of the Indian Point nuclear power plants on the Hudson and Delaware Rivers, focusing on impingement and entrainment of fish, with a particular emphasis on their impacts to population. For this analysis, I was retained by ESSA Technologies Ltd. through a contract with the New York State Department of Environmental Conservation. This analysis included modeling, and reviewing models of, the impacts of entrainment and impingement on fish populations. I am a member of the Estuary Enhancement Program Advisory Committee that reviews the mitigation measures for losses of fish through impingement and entrainment at the Salem Nuclear Power Plant on the Delaware River in New Jersey. I have evaluated both the mortality and related impacts of hydroelectric dam operations on Chinook salmon populations on the Columbia and Snake Rivers.

10. I am familiar with, understand, and am able to explain to the Court the concepts and techniques used in the 2008 Delta Smelt Biological Opinion to evaluate the impacts of the

Central Valley Project and the State Water Project operations on the delta smelt population. My testimony and opinions are offered in the context of explaining the standard practices and statistical methods that are used in fish population dynamics to evaluate impacts to fish populations, and the practices and statistical methods employed by the FWS in the BiOp.

III. GENERALLY ACCEPTED PRINCIPLES OF FISH POPULATION DYNAMICS THAT APPLY TO AN ANALYSIS OF IMPACTS TO FISH SPECIES

11. In the BiOp, FWS sought to evaluate the effects of the Central Valley Project and State Water Project on the threatened delta smelt. When looking at potential impacts of a project to fish species, the standard of practice is for qualified professionals to employ certain well-established principles of fish population dynamics.

A. Principle 1: Quantitative Analysis Should Be Conducted

12. The fundamental approach to assessing fish population dynamics is through quantitative statistical analysis (mathematical models) of population dynamics. "Quantitative analysis" involves the use of actual measured data and the testing of relationships between that data. The nature and degree of project impacts on a species must be determined using quantitative methods where quantitative data is available. Similarly, measures designed to benefit the species and avoid harm must be based on a quantitative approach. Only in this way can impacts and benefits be measured for proper evaluation of their effect on the species.

13. By contrast, a qualitative approach may be appropriate where no quantitative data or measurements are available. Qualitative analysis consists of a more subjective evaluation of the degrees of importance of particular factors and circumstances for which quantitative data and measurements are not appropriate or do not exist.

B. Principle 2: Impacts to the Total Population Should Be Evaluated

14. Population dynamics also involve a qualified scientist conducting an evaluation of project impacts to a threatened fish by focusing on impacts to the total population. Measuring effects on a single fish, or a limited group of fish, does not lead to reliable conclusions about population level effects. Such population level conclusions are essential when evaluating a project's impacts on the species as a whole and its ability to survive and recover.

15. Population level effects are properly evaluated using rates and proportions. This means that a given impact or variable cannot be taken as significant on its own without accounting for the *relative* impact on the total population. The population growth rate is an appropriate and reliable measure of population increases and decreases from year to year.

C. Principle 3: Models Should Be Reliable and Biologically Plausible

16. The standard of practice for a fish population dynamicist requires that any statistical models that are utilized must be reliable and biologically plausible. Such statistical models are based on mathematical formulas that assign numeric values to biotic and abiotic variables to explain the relationships among them. To be biologically plausible means that the mathematical formulas used must reflect the reality that the "variables" are reflective of the biology of the living organisms that are being assessed. For example, living organisms have a limited life span and limited reproductive capabilities that must be taken into account in any model used to evaluate their behavior and vulnerabilities. Thus, the models that are properly used are designed to attribute a quantitative value to those influential biological factors so that the model enables quantitative measurement of their interrelationships. Such models are designed to reflect biological realities and to evaluate the relationship between living stock and recruits.

D. Principle 4: Data Should Be Used Consistently

17. In performing a quantitative fish population analysis, generally accepted scientific standards require that the study be internally consistent in its use of data. Data that is rejected in one aspect of the analysis should not be relied upon elsewhere in the same study.

18. With these general principles in mind, I turn to the subject of this action, the 2008 Delta Smelt Biological Opinion for the Operations Criteria and Plan for the State Water Project and the Central Valley Project.

IV. THE BIOP'S EVALUATION OF PROJECT EFFECTS AND THE BIOP'S RPAS ARE BASED ON A "QUANTITATIVE" ANALYSIS

19. The core analyses and conclusions in the BiOp are contained in the sections entitled "Effects of the Proposed Action" (BiOp at 202-239 [Administrative Record ("AR") at 000217-000254]), "Reasonable and Prudent Alternative" ("RPA") (BiOp at 279-285, 324-81 [AR

at 000294-000300, 000339-000396]), and "Incidental Take Statement" ("ITS") (BiOp at 285-295 [AR at 000300-000310]). These sections define the effects of the water projects on the delta smelt and the restrictions which FWS imposed to avoid jeopardy.

20. In the section of the BiOp entitled "Effects Analysis Methods," FWS explains that the effects of the project pumps on entrainment (OMR flows and salvage, and incidental take levels) and the fall habitat suitability and its effect on population (Fall X2) "are quantitatively analyzed."

> The effects analyses range from qualitative descriptions and conceptual models of project effects to quantitative analyses. The effects of Banks and Jones pumping on adult delta smelt entrainment, larval-juvenile delta smelt entrainment, and fall habitat suitability and its predicted effect on the summer townet survey abundance index are quantitatively analyzed. The remainder of proposed action elements and effects are not analyzed quantitatively because data are not available to do so or it is the opinion of the FWS that they have minor effects on delta smelt.

BiOp at 208-209 (AR at 000223-000224). This representation is consistent with my review of the BiOp—FWS conducted a quantitative statistical analysis in order to (1) evaluate project effects on the smelt population and (2) develop RPAs designed to mitigate and avoid any such effects to the extent necessary to avoid jeopardy to the species and adverse modification of its critical habitat. As I would expect of most any scientific exercise, FWS relied on and used data when it was available, unless FWS concluded that the issue was too "minor."

21. Because the BiOp concludes that the projects jeopardize the species and adversely modify its critical habitat, it includes RPAs that restrict project operations in an attempt to avoid jeopardy and adverse modification. The RPAs address categories of effects to which FWS applied quantitative analyses: adult entrainment and larval/juvenile entrainment as related to OMR flows, and fall habitat. These are outlined in more detail below.

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22. **Actions 1 and 2 (Winter OMR Flows)**.[1] Actions 1 and 2 are designed to avoid jeopardy to adults from entrainment. These Actions restrict Old and Middle River ("OMR") flows to reduce adult salvage in the winter. Action 1 is triggered first and lasts for 14 days, followed immediately by Action 2, which is triggered if certain criteria are present and lasts until spawning begins or a certain water temperature is reached. Both of these Actions prescribe a similar range of OMR flows, but at different times of the year. The quantitative analysis presented in Attachment B to support the prescribed OMR flow levels in Actions 1 and 2 is set forth in the BiOp at 345-349 and is represented in two graphs labeled Figure B-13 and Figure B-14, which appear to share the same data. *See* BiOp at 348, 350 (AR at 000363, 000365). Figure B-13 depicts the BiOp's analysis of the relationship between winter OMR flows and adult salvage, concluding that as flows become more negative, salvage increases. Based on this relationship, Actions 1 and 2 set less negative flow levels to reduce salvage.

23. **Action 3 (Spring OMR Flows)**. Action 3 is designed to avoid jeopardy to larvae and juveniles from entrainment. This Action restricts OMR flows to reduce larval/juvenile salvage in the spring. FWS did not apply statistical modeling to evaluate whether or not reductions in OMR flows or X2 would reduce impacts to juveniles, because there is no actual data on larval and juvenile salvage for fish smaller than 20 millimeters. Instead, FWS relied on the assumption that larval and juvenile movement can be predicted using a particle tracking model. A particle tracking model is a theoretical simulation of the flow of neutrally buoyant particles through a water system, where particles are used as surrogates for actual fish. Similar to Actions 1 and 2, Action 3 sets less negative flow levels to reduce salvage.

24. **Action 4 (Fall X2)**. Action 4 is designed to protect fall habitat for adults. This Action prescribes Delta outflows to push X2 more seaward during the fall. The BiOp relies primarily on the quantitative analysis represented by the summary statistics for the stock-recruit

[1] The RPAs are divided into four "Components," which are supported by supplemental information in Attachment B to the BiOp. Attachment B breaks down the RPA Components into five "Actions," such that Component 1 is represented by Actions 1 and 2, Component 2 is supported by Action 3, Component 3 is supported by Action 4, and Component 4 is supported by Action 5. Because most of the technical analysis is contained in Attachment B, and for ease of reference, I will refer to the RPAs in terms of the Actions rather than the Components.

model set forth in Figure E-22 to establish that the location of Fall X2 has a significant effect on delta smelt abundance. *See* BiOp at 268 (AR at 000283). Based on this purported relationship, Action 4 sets Delta outflow levels to control the location of X2.

25. **<u>Incidental Take Statement</u>**. The BiOp also includes an Incidental Take Statement, which prescribes the acceptable level of take of larval/juvenile and adult delta smelt using quantitative methods. For each of larvae/juveniles and adults, FWS took the average salvage rate from certain prior years which it deemed to be representative of future conditions under the RPAs. The average salvage rate from the prior representative years was set as the maximum take level under the RPAs. *See* BiOp at 385-390 (AR at 000400-000405).

26. To summarize, FWS used quantitative methods to evaluate the effects of water project operations (OMR flows) on the species, on its fall habitat (as represented by Fall X2), and to establish incidental take levels. I will next explain the clear, fundamental errors I have identified in that quantitative analysis.

V. THE QUANTITATIVE ANALYSIS BY FWS DOES NOT FOLLOW STANDARD FISH POPULATION ASSESSMENT METHODS

A. Actions 1 & 2 (Winter OMR Flows): Use of Raw Salvage Numbers Instead of the Salvage Rate

27. Actions 1 and 2 prescribe OMR flow levels based on the BiOp's calculation of the relationship between OMR flows and adult salvage. This relationship is depicted in Figure B-13 and compares OMR flow levels to raw salvage numbers. The salvage numbers used are the total number of fish counted at the salvage facilities.

28. Raw salvage numbers do not represent the proportion of the total population that is lost to salvage, which is the salvage rate. For example, a raw salvage total of 100 adults has vastly different significance depending on whether the total population is 200 (salvage rate of 50 percent) or 10,000 (salvage rate of 1 percent). Thus, Figure B-13 does not show what effect OMR flows have on the total delta smelt population.

29. Use of raw salvage numbers, rather than the salvage rate, could be appropriate if the total delta smelt population was known and a model that incorporates every life stage of the

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species (a life-cycle model)[2] was being used. Salvage of delta smelt is a source of loss of individuals—it is analogous to using catch as a mortality loss to the population. If the total delta smelt population was known, then the salvage numbers themselves could be incorporated directly into a life-cycle model and would make it possible to determine the population effects of salvage. A simple version of such a model is explained in Hilborn, R. & Walters, C., *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*, Chapman & Hall (1992) at 298:

> The changes in a population's biomass from one time to the next can be simply written as
>
> next biomass = last biomass + recruitment + growth – catch – natural mortality.

Salvage would take the role of catch in a similar life-cycle model for delta smelt.

30. Here, however, the total population of delta smelt is unknown, although there have been recent attempts to provide such estimates. Because actual abundance is not known, raw salvage numbers cannot be used to show population level effects.

31. In the absence of actual adult abundance numbers, adult abundance is estimated by the Fall Midwater Trawl Survey ("FMWT"), which collects samples around the Delta. An index of the FMWT is used to track the relative increase or decrease in adult abundance from year to year. The survey counts the number of smelt captured in a net of known dimensions and multiplies it by the volume of water actually sampled. That number is then applied to the entire estimated volume of water where the smelt is believed to reside. From this data, an index is derived.

32. The FMWT index is scientifically reasonable and widely relied upon by scientists studying the delta smelt, though not without its technical flaws. It is a numerical scale used to compare variables derived from a series of observed facts with one another or with some reference number to reveal relative changes as a function of time. Because actual abundance is not known, raw salvage numbers cannot be used to show population level effects.

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[2] A life-cycle model is a well-accepted and reliable method of evaluating population dynamics from generation to generation (adults to adults), rather than focusing solely on one age group or the change from adults to juveniles.

33. For adult delta smelt, the scientifically accepted and reliable method is to use the cumulative salvage index to evaluate whether a relationship exists between OMR flows and adult salvage. The cumulative salvage index is equal to the raw number salvaged divided by the prior year FMWT index. *See* BiOp at 338 (AR at 000353). In this way, the cumulative salvage index represents an index of the proportion of abundance that is lost to salvage each year. In the absence of abundance figures, the prior year FMWT index stands as a usable denominator for a ratio that would reveal any population level effects from entrainment.

B. Actions 1, 2 & 3 (Winter and Spring OMR Flows): Failure to Evaluate the Smelt's Population Growth Over Time

34. The BiOp's failure to evaluate population level effects using the correct variable (salvage rate) is consistent with its more general failure to use the well-accepted, reliable statistical models typically used to evaluate population level effects. The BiOp did not employ life-cycle modeling**,** which, among other things, is used to estimate a population's growth.

35. Life-cycle modeling is a well-accepted and reliable method of evaluating population dynamics from generation to generation (adults to adults). It typically consists of the simple models known as biomass dynamic models and stock production models, or the more complex models such as age-structured models. *See* Quinn & Deriso (1999) at ch. 2, 6-8; Hilborn & Walters (1992) at 297.

36. In fisheries science, often the total number of fish in a population is unknown. It is standard practice that, given the data available, population level effects can be determined using surrogate methods such as the population growth rate and the salvage rate.

37. Similar to Actions 1 and 2, the BiOp omits any analysis of the effect of spring OMR flows (Action 3) on the delta smelt population growth rate. A standard life-cycle model could be applied to determine whether spring OMR flows, which would potentially affect larvae and juveniles, are affecting the change in total population from year to year. This kind of quantitative analysis would make it possible to reliably calculate population level effects for delta smelt.

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C. Action 4 (Fall X2): Use of a Linear Additive Model Instead of a Multiplicative Model

38. FWS's quantitative Fall X2 analysis for Action 4 of the BiOp is based on a stock-recruitment model. A stock-recruitment model is a model used to evaluate population level effects that quantitatively characterizes the relationship between the parental "stock" and the progeny it produces ("recruits"). In the BiOp, the parental stock is measured through the FMWT and the progeny is measured at the juvenile life stage through the Summer Townet Survey ("TNS").

39. There are many different stock-recruitment models. In selecting a model, one necessary criterion is that the model must be biologically plausible. This means that the mathematical formulas reflect biological reality and limitations, as described above.

40. FWS employed a linear additive stock-recruitment model when evaluating Action 4. A linear additive model adds several factors together to achieve a sum, without use of logarithms. A simple example is A + B = C. This type of model is not appropriate for stock and recruitment relationships, for two main reasons.

41. First, adding and subtracting factors can generate a positive sum, even if one of the factors is zero. This seems mathematically accurate, but it does not work in a situation where the factors are living organisms with certain non-mathematical properties. For instance, in an equation where various factors are added to adult abundance to determine the effect on their juvenile offspring, one can achieve a positive sum (number of juveniles) even if the factor representing the number of adults is zero. In terms of biological reality, zero adults cannot produce offspring. Thus, simply adding the factors does not reflect the manner in which populations grow.

42. Second, a linear additive model treats factors as having a fixed effect on the population, rather than a proportional effect. That is, by adding a factor, it will always increase or decrease the sum by the same absolute amount. While mathematically accurate, this does not work when the factors being added are habitat components that have a changing proportional effect on the sum (population abundance), not a fixed effect. When the total population is

smaller, a smaller number of individuals exist that can potentially be affected by a given factor. This is accounted for by using proportions and rates.

43. In contrast, multiplicative stock-recruitment models produce biologically accurate results and they are appropriate for fish population dynamics. Simply put, a multiplicative model reads as A x B = C. Two multiplicative models available to FWS are the Beverton-Holt and Ricker models. These models are typically used because they are well-accepted by the scientific peer community and are reliable.[3]

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[3] *See, e.g.*, Jorgensen, S. & Fath, B. (eds.), *Encyclopedia of Ecology*, Academic Press (2008); Knowler, D., Estimation of a Stock-Recruitment Relationship for Black Sea Anchovy (Engraulis encrasicolus) Under the Influence of Nutrient Enrichment and the Invasive Comb-Jelly, Mnemiopsis leidyi, 84:3 Fisheries Research 275-281 (May 2007); Owen-Smith, N., Introduction to Modeling Wildlife and Resource Conservation, Blackwell Publ'g (2007); Brauer, F. & Castillo-Chavez, C., Mathematical Models in Biology and Epidemiology, Springer-Verlag New York, Inc. (2006); Kritzer, J. & Sale, P. (eds.), Marine Metapopulations, Elsevier Academic Press (2006); Mangel, M., The Theoretical Biologist's Toolbox: Quantitative Methods for Ecology and Evolutionary Biology, Cambridge Univ. Press (2006); Ferrier, R., et al. (eds.), Evolutionary Conservation Biology, Cambridge Studies in Adaptive Dynamics, Cambridge Univ. Press (2004); Hoff, M., Biotic and Abiotic Factors Related to Rainbow Smelt Recruitment in the Wisconsin Waters of Lake Superior, 1978-1997, 30 Journal of Great Lakes Research, Supp. 1 Exploring Superior, 414-422 (2004); Walters, C. & Martell, S., Fisheries Ecology and Management, Princeton Univ. Press (2004); Hart, P. & Reynolds, R. (eds.), Handbook of Fish Biology and Fisheries, 1 Fish Biology, Blackwell Publ'g (2002); Haddon, M., Modeling and Quantitative Methods in Fisheries, Chapman & Hall (2001); Jennings, S., et al., Marine Fisheries Ecology, Blackwell Publ'g (2001); Lorda, E. et al., Application of a Population Dynamics Model to the Probabilistic Assessment of Cooling Water Intake Effects of Millstone Nuclear Power Station (Waterford, CT) on a Nearby Winter Flounder Spawning Stock, 3 Envtl. Science & Policy, Supp. 1, 471-482 (Sept. 2000); McCallum, H., Population Parameters: Estimation for Ecological Models, Blackwell Publ'g (2000); Guenette, S. & Pitcher, T., An Age-Structured Model Showing the Benefits of Marine Reserves in Controlling Overexploitation, 39:3 Fisheries Research 295-303 (Jan. 1999); Quinn & Deriso (1999); Ricklefs, R. & Miller, G., Ecology, 4th ed., W.H. Freeman (1999); Hilborn & Walters (1992); Rothschild, B., Dynamics of Marine Fish Populations, Harvard Univ. Press (1986); Walters, C., Adaptive Management of Renewable Resources, MacMillan Publ'g Co. (1986); Mangel, M., Decision and Control in Uncertain Resource Systems, Academic Press (1985); Pauly, D., Fish Population Dynamics in Tropical Waters: A Manual for Use With Programmable Calculators, 8 ICLARM Studies & Reviews (1984); Fournier, D. & Archibald, C., A General Theory for Analyzing Catch at Age Data, 39 Canadian Journal of Fisheries & Aquatic Sciences 1195-1207 (1982); Pitcher, T. & Hart, P., Fisheries Ecology, Kluwer Academic Publ'g (1982); Walters, C. & Ludwig, D., Effects of Measurement Errors on the Assessment of Stock-Recruitment Relationships, 38 Canadian Journal of Fisheries & Aquatic Sciences 704-710 (1981); Clark, C., Mathematical Bioeconomics: The Optimal Management of Renewable Resources, Wiley (1976); Ricker, W., Handbook of Computation for Biological Statistics of Fish Populations, Bulletin 119 of the Canada Fisheries Res. Bd. (1958), issued again as Ricker, W., Computation and Interpretation of Biological Statistics of Fish Populations, Bulletin 191 of the Canada Fisheries Res. Bd. (1975); Weatherley, A., Growth and Ecology of Fish Populations, Academic Press (1972); Beverton, R. & Holt, S., On the Dynamics of Exploited Fish Populations, 14 Fishery Investigations Series II, Ministry of Agriculture, Fisheries & Food (1957).

44. For measuring population level effects, multiplicative or rate-based models such as Ricker and Beverton-Holt should be used to achieve scientifically accepted, reliable results. Additive models should not, because they generate inaccurate and unreliable results. These are the two most widely-used models in actual practice because they were designed to be biologically accurate and reflect the relationship between stock and recruits. A feature of a multiplicative model is that when there are zero adults on one side of the equation, there are zero young on the other side; i.e., zero adults yields zero offspring. This follows because any number multiplied by zero will always equal zero. As stated in Ricker (1975) at 281, the model is designed "so that when there is no adult stock there is no reproduction . . . ." The same result can be expected using other types of multiplicative models.

D. ITS: Use of Rejected Data Points Instead of Representative Data Points

45. The BiOp sets the adult incidental take limit based on the average salvage rate from the years 2006, 2007, and 2008, which FWS determined to be representative of future conditions under the RPAs. BiOp at 385-86 (AR at 000400-000401). According to the list of salvage levels contained in the ITS, salvage in 2007 was extremely low compared to other years and to 2006 and 2008 in particular. *See* BiOp at 386 (AR at 000401) (Table C-1). In another section of the BiOp, FWS itself had considered the salvage level in 2007 as unusable for purposes of analyzing salvage and OMR flows due to that year's low average water turbidity, a presence/absence indicator. *See* BiOp at 348 (AR at 000363) (Figure B-13, Note). Thus, FWS recognized that the unusual conditions in 2007 made it an unrepresentative year that would skew its analysis of salvage impacts. Use of an unrepresentative data point that was rejected elsewhere in the same study runs counter to basic principles of quantitative fish assessment. FWS does not attempt to justify why the data point would be used in one instance and not another, so one possible explanation is that it is simply a material error in the analysis.

46. To calculate the incidental take limit for larvae and juveniles, FWS largely followed the same methodology that it used for adults. BiOp at 389 (AR at 000404). The take limit is set based on the average monthly juvenile salvage index from four years – 2005, 2006,

2007, and 2008. According to data listed in the BiOp, the salvage in 2006 was extremely low compared to other years. *See* BiOp at 392 (AR at 000407) (Table C-4). I examined this year carefully and discovered through my review of OMR flow data obtained from a Freedom of Information Act ("FOIA") request to FWS[4], that in 2006, average OMR flow was strongly positive in April through June. When analyzing the effects of OMR flows on salvage in the Effects Analysis section of the BiOp, FWS explained that positive OMR flow yields zero or very low salvage. BiOp at 163 (AR at 000178). Thus, FWS's use of 2006 as a "representative" year for larval/juvenile salvage is internally inconsistent with its explanation elsewhere that positive OMR flow (which is what occurred in spring 2006) yields little or no salvage. The year 2006 was therefore not representative and should have been omitted, as it was elsewhere by FWS for other purposes.

VI. THE BIOP'S APPLICATION OF STATISTICAL MODELS AND INPUT VARIABLES IS INCONSISTENT WITH STANDARD PRINCIPLES OF FISHERIES POPULATION DYNAMICS

47. To decipher the models and methods that FWS used, I reviewed and interpreted the limited graphs and tables provided in the BiOp, along with similar information and studies in the administrative record.

48. I compared FWS's models against the standard models employed by the scientific community, and particularly those models that are commonly used in fish population modeling. My review and comparison revealed that the BiOp does not use the well-accepted models in more

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[4] My review of the BiOp and the administrative record revealed that FWS had not provided all of the underlying data that FWS relied on in performing its work on the BiOp. In my experience, a full scientific analysis is not possible without making the underlying data available so that the work may be checked and evaluated by others. This omission hinders the ability to conduct a standard peer review of the FWS analysis without estimating data point values from the graphs or searching for data in other sections. FWS's failure to include the data underlying its basic analyses and determinations is an inexplicable defect given the conclusions FWS reaches. After I identified the missing categories of data, the Metropolitan Water District of Southern California requested that data through a FOIA request. On October 29, 2009, more than ten weeks after the request was made, FWS provided a disc containing portions of the data underlying the BiOp. Included on that disc were daily OMR flow data. I used those data to calculate several average OMR flows, including monthly average flows, as noted in this declaration.

than one place, but rather relies on models that are not biologically sound and lead to erroneous results.

49. I evaluated the same data presented in the BiOp and input it into the standard models to determine whether the end result would be different. The results are fundamentally different from the results reached in the BiOp.

50. Based on the material I reviewed, the fundamental errors I have identified call into question the jeopardy and adverse modification conclusions in the BiOp and reveal that FWS had no reliable scientific basis for imposing the RPAs adopted.

A. FWS's Analysis of the Relationship Between Old and Middle River Flows and Adult Salvage Is Flawed

51. The BiOp's analysis of the effects of the projects on adult delta smelt and its conclusion that winter flow restrictions are necessary are based on a statistical model of the alleged relationship between OMR flows and adult salvage. The modeling and analysis are contained in the Effects of the Proposed Action section of the BiOp, pages 202-279 (AR at 000217-000294), and RPA Actions 1 and 2 in Attachment B to the BiOp, pages 329-356 (AR at 000344-000371). Actions 1 and 2 rely on Figure B-13 on page 348 (AR at 000363) and on various studies, including Kimmerer, W., *Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta* (AR at 018854), and the work of Pete Smith, which is cited by Kimmerer.

(1) Improper Use of Total Adult Salvage Numbers Instead of Cumulative Salvage Index

52. FWS uses total adult salvage numbers to demonstrate an alleged relationship between OMR flows and adult salvage. *See* BiOp at 163-65; 347-50 (AR at 000178-000180; 000362-000365). The alleged relationship is derived from the graph in Figure B-13 which compares the number of adults salvaged each year to the corresponding OMR flow rate for that year. BiOp at 164, 348 (AR at 000179; 000363).

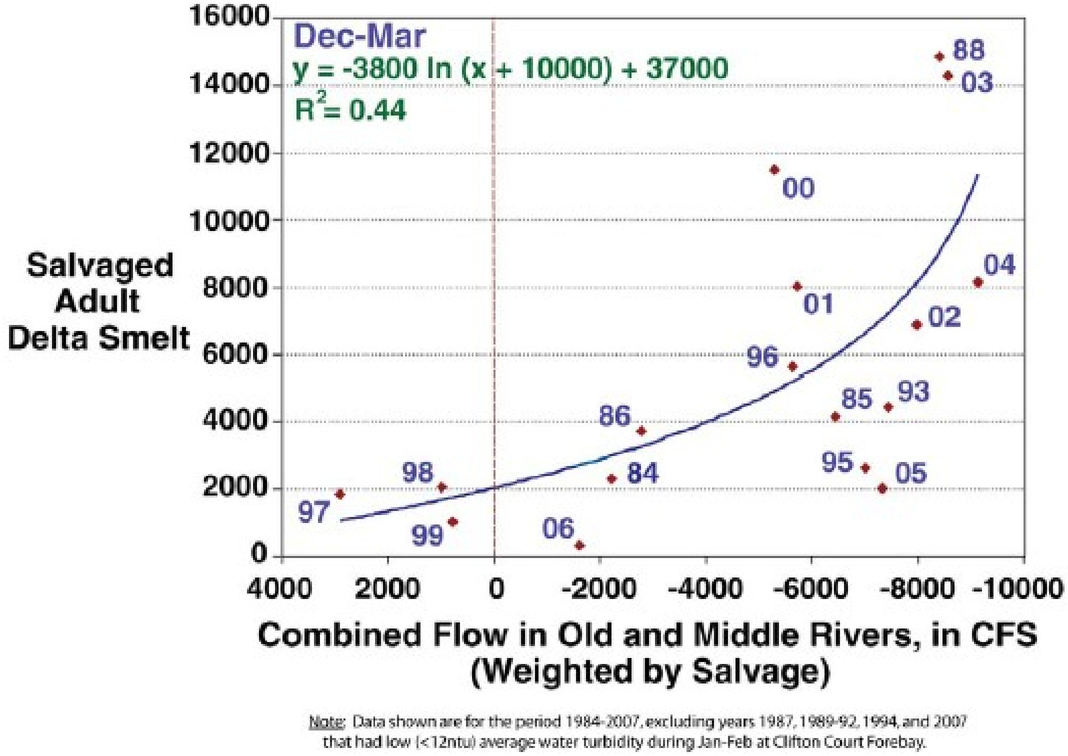

Figure B-13. OMR-Salvage relationship for adult delta smelt. (source, P. Smith). Data from this figure were the raw data used in the piecewise polynomial regression analysis.

53. FWS relied on this graph to conclude that OMR flows correlate to total salvage numbers—suggesting that as negative OMR flows increase, more adults are salvaged.

54. This conclusion by FWS is scientifically flawed because raw salvage numbers do not have a directly proportional effect on population and do not take into account the overall size of the population as determined by representative survey data. Nonetheless, FWS relied on Figure B-13 and Figure B-14 (which appear to share the same data) to set OMR flow levels in RPA Actions 1 and 2. In other words, FWS set OMR flow levels in Actions 1 and 2 without determining population level effects.

55. The scientifically appropriate approach would have been for FWS to use the cumulative salvage index to evaluate whether a relationship exists between OMR flows and adult salvage. FWS had already developed that index for other purposes. *See* BiOp at 386 (AR at 000401) (using the cumulative salvage index in another context, to calculate the incidental take). The cumulative salvage index represents an index of the salvage rate, taking into account data on the size of the population. This has long been recognized as appropriate for analysis of delta

smelt by those scientists actively studying the smelt. *See, e.g.*, Bennett, W., *Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California*, San Francisco Estuary & Watershed Science, Cal. Bay-Delta Auth. Science Program & John Muir Inst. of the Env't (2005) at 37 ("As first step [sic], assessing the potential impacts of the water project operations on delta smelt requires estimating the proportion lost relative to population abundance."). The cumulative salvage index is proportional to the fraction of adult fish that are lost due to water diversion.

56. The concept of dividing fish loss by abundance is well-accepted and reliable and is applied in other, similar applications, such as part of the procedure for estimating the impact of entrainment and impingement of fishes by water withdrawals of once-through cooling systems for nuclear power plants on the Hudson River.

> This approach is based on conditional mortality rates, or the fraction of an initial population that would be killed by some agent during the year if no other sources of mortality operated. Conditional entrainment mortality rates are used as estimates of the direct impact of power plants on individual year classes . . . . (2) Conditional mortality rates can be entered directly into life-cycle models for assessing potential long-term impacts on fish populations.

Barnthouse, L., et al. (eds.), *Science, Law, and Hudson River Power Plants: a Case Study in Environmental Impact Assessment*, Am. Fisheries Soc'y Monograph 4, Am. Fisheries Soc'y (1988) at 122.

57. Another example is biological reference points ("BRP") which can be used as targets for optimal fishing: "A BRP can be expressed as a fishing mortality rate (F) and/or as a level of stock biomass (B)." Comm. on Fish Stock Assessment Methods, Nat'l Research Council, *Improving Fish Stock Assessment Methods*, Nat'l Academy Press (1998) at 45. The fishing mortality rate (F) depends mathematically on the ratio of catch divided by biomass and it is similar to a cumulative salvage index in that both represent a ratio of losses to abundance.

58. Since total population data does not exist, the cumulative salvage index uses a survey index which gives a relative increase or decrease in annual survey numbers to monitor population levels. Use of the cumulative salvage index to evaluate the effects of OMR flows is

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scientifically accepted, reliable, and superior to using the raw salvage numbers themselves (as used in Figure B-13), for the following reasons:

59. The total number of adults salvaged does not indicate population level effects. *See* BiOp at 338 (AR at 000353) ("the total number salvaged at the facilities does not necessarily indicate a negative impact upon the overall delta smelt population"). Stated differently, to make sense of total adult salvage numbers, total adult abundance must be taken into account. For example, a salvage of 100 adults has vastly different significance depending on whether the total population is 200 or 50,000.

60. In contrast, the cumulative salvage index is an index of the *proportion* of adults salvaged from the total population, using the FMWT to relate salvage to population levels. The cumulative salvage index is equal to the number salvaged divided by the prior year FMWT index. *See* BiOp at 338 (AR at 000353).

61. Use of the cumulative salvage index, rather than total salvage numbers, was recommended by the Peer Review. *See Independent Peer Review of USFWS's Draft Effects Analysis for the Operations Criteria and Plan's Biological Opinion, 2008* at 6 (AR at 008818) ("The Panel suggests that the use of predicted salvage of adult smelt should be normalized for population size. . . . Expressing salvage as a normalized index may help remove some of the confounding of the temporal trends during the baseline period.").

(2) Use of the Cumulative Salvage Index Shows That There Is No Statistically Significant Relationship Between OMR Flows and Adult Salvage for Flows Less Negative Than -6100 Cubic Feet per Second at the Very Least

62. To assess FWS's methods, I plotted a graph of the relationship between the cumulative salvage index (salvage rate) and the OMR flows for each year that was analyzed in the BiOp. In developing this graph, I used the cumulative salvage index data provided in the BiOp. *See, e.g.*, BiOp at 386 (AR at 000401). Because Figure B-13 uses salvage weighted OMR flows, which are not listed anywhere in the BiOp, I visually estimated a magnified version of the OMR flow curve in Figure B-13 and interpolated the data points for each year.

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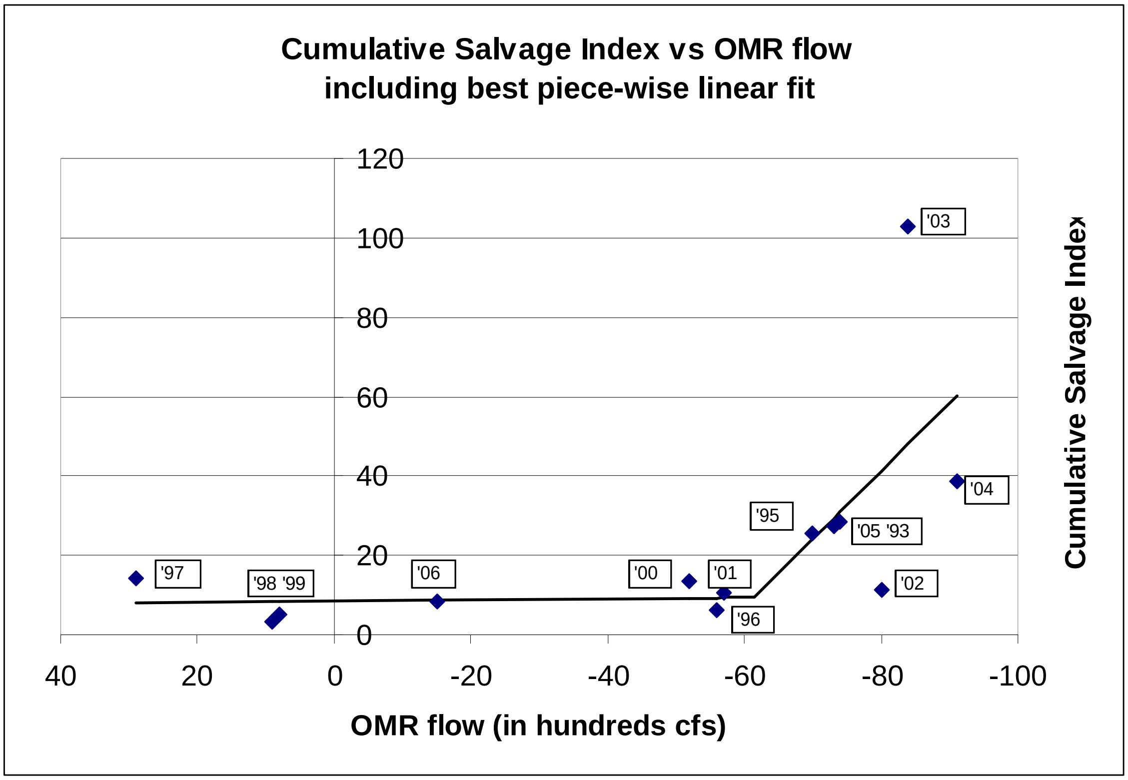

The Cumulative Salvage Index (Table B-2 & C-1) and corresponding Dec-Mar salvage weighted OMR (Figure B-13); note the salvage weighted OMR flows were visually estimated from Figure B-13. Years span 1993-2006 but exclude 1994 because that was also excluded in Figure B-13. A piece-wise linear model (the line on the figure) is also shown whose coefficients were obtained by the statistical procedure of maximum likelihood estimation.

63. The graph of salvage rate versus OMR flow shows that salvage rate remains flat as OMR flows increase until OMR flows reach -6100 to -7000 cubic feet per second ("cfs"). At -7000 cfs, salvage rate begins to increase as negative OMR flows increase. The graph demonstrates that OMR flows do not correlate to the salvage rate at flows less negative than -6100 cfs at the very least. I have determined that, based on the data available and using the appropriate reliable analytic method, there is no scientific basis for FWS's imposition of OMR flow restrictions at flows less negative than -6100 cfs (and potentially -7000 cfs). For additional technical detail, see Appendix 1 at Point 1.

64. As shown in the x-axis label on Figure B-13 (see ¶ 52 above), FWS used "Combined Flow in Old and Middle Rivers, in CFS (Weighted by Salvage)" to evaluate the relationship between OMR flows and salvage. "Weighted by Salvage" is not defined in the

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BiOp; however, a logical definition is that the salvage weighted average OMR flow is an average over several time periods, such as weeks, and the influence that a given week's OMR flow has on the overall average is set proportional to the salvage in that week.

65. FWS's October 29, 2009 FOIA response included daily OMR flow data (as opposed to the weighted average flows used in Figure B-13). I constructed December through March average OMR estimates based on the daily OMR flows provided by FWS. I modeled the relationship between the straight average OMR flows and the cumulative salvage index and confirmed that the results are consistent with those reached using the Figure B-13 weighted average flows. Using the straight average, the flows were not significant until a much more negative flow level (approximately -7943 cfs). The results are shown in Appendix 1 at Point 1.

B. The BiOp Fails to Evaluate Population Level Effects Using the Population Growth Rate – Interpreting the Data in This Way Shows That Salvage and OMR Flows Do Not Have a Statistically Significant Effect on the Population Growth Rate

66. Given the data in FWS's possession, and given its goal of evaluating the projects' effect on the total population, the appropriate analysis is to use that data to evaluate the effect on the population from year to year. This includes interpretation of the data to determine the effect of salvage (or more generally, population removals) on the population growth rate by application of a life-cycle model, as is standard practice in fisheries stock assessment. This approach is confirmed by the authors of widely read and accepted texts, which discuss the reliable methods of undertaking these analyses. *See, e.g.*, Quinn & Deriso (1999) at ch. 2; Hilborn & Walters (1992) at ch. 8. The population growth rate represents the relative increase or decrease in adults from one year to the next, which is a full life-cycle approach. Owen-Smith (2007) at 28. This approach is critical for evaluating the species' potential for recovery in that it measures the population's ability to rebound from year to year. *See, e.g.*, Bennett (2005) at 41 ("Population modeling may be the best way to evaluate the potential impacts of water export operations relative to other sources of mortality.").

67. Interpreting the data to evaluate the effect of salvage on the population growth rate is necessary because the survival of the species at one life stage cannot necessarily be the basis

for population level conclusions. To evaluate the effects of salvage, one must look beyond a single phase of life (i.e., FMWT only) or even adults to juveniles (i.e., FMWT to TNS). A complete analysis requires an evaluation of trends from one year's FMWT to the next year's FMWT because mortality in one life stage may be offset by mortality in another life stage or it may be affected by density dependence (described below in ¶ 68). As noted by Bennett (2005) at 44, when discussing simulation results of a hypothetical population model for delta smelt, "These results show how export mortality could be easily offset or masked by very small changes in mortality at other life stages." A generation-to-generation analysis eliminates or reduces the risk that population level conclusions will be drawn based on mortality effects in one life stage or the apparent change in mortality effects due to offsets in another life stage.

68. Delta smelt appear to exhibit reduced population growth when population abundance is high due to density dependence. Density dependence can occur through many mechanisms, as described by Ricker (1975) at 280: "Although cannibalism of young by adults is possible in many species, it is likely that the effect of parental stock density upon recruitment is usually exerted *via* the density of the eggs or larvae they produce, survival of the latter being affected by density-dependent competition for food or space, compensatory predation, etc." Thus, density dependent effects must be taken into account when evaluating the population growth rate. Density dependence terms are present in all major stock production, biomass dynamic, and stock-recruitment models, including the Ricker model. *See* Quinn & Deriso (1999) at chs. 2, 3.

69. Standard practice dictates that population level conclusions should not be based solely on raw salvage numbers. Rather, a fish population dynamicist should evaluate population level effects using the cumulative salvage index (salvage rate), and also evaluate the effect of the cumulative salvage index on the population growth rate, just as is typically done with harvest rates. As noted by Bennett (2005) at 37, "In several respects, losses to the water export facilities are analogous to harvest in a fishery, with the main exception that 'harvest' in this case includes all life stages (except eggs)." Harvest rates are routinely evaluated for their population level effects, and their consequence to population growth levels over time, in fisheries stock

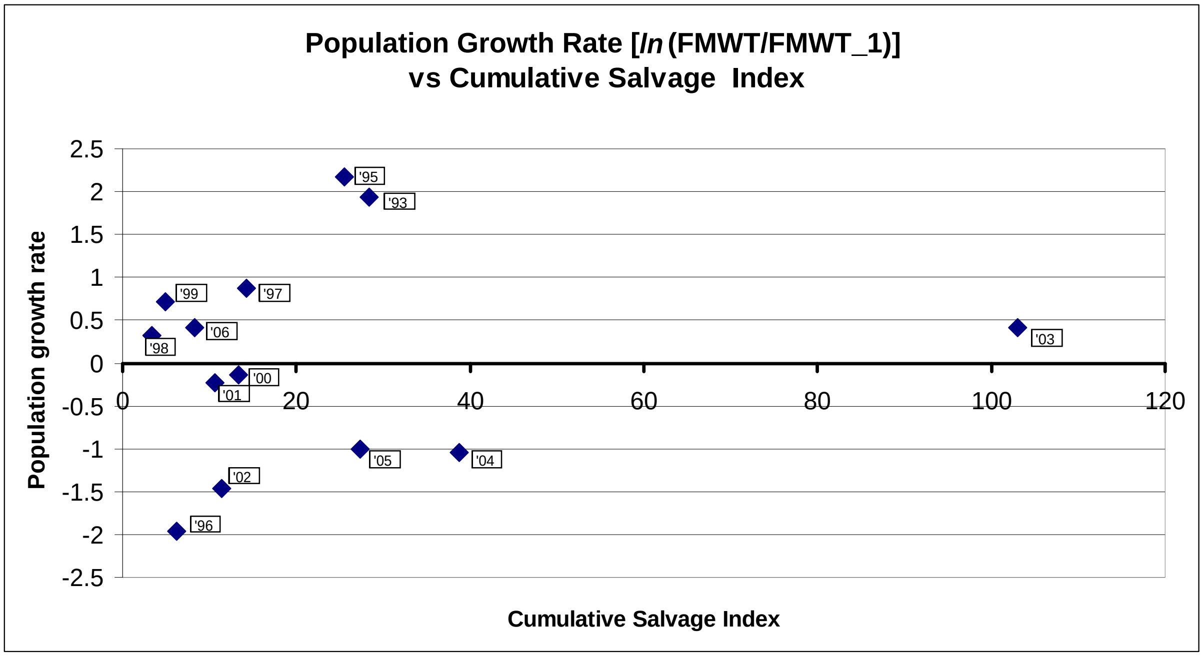
evaluations. *See, e.g.*, Quinn & Deriso (1999) at ch. 2; Hilborn & Walters (1992) at ch. 8. Only by looking at population level effects can it be determined whether salvage is impacting the delta smelt population and its ability to recover in a statistically significant way.

70. Through my review of the modeling and analysis in the BiOp, I determined that FWS did not apply a life-cycle approach in the BiOp. FWS did not attempt to evaluate the effect of the projects on the population growth rate. The BiOp completely omits any analysis or conclusions about project effects on the overall life cycle of the delta smelt and its ability to recover from year to year. However, the data to perform such an analysis is all available, and evaluating population growth rate effects is an elementary exercise. When I looked at the data for such effects, I readily recognized that there is no statistically significant relationship between salvage and the population growth rate.

(1) Adults – Salvage

71. Applying standard principles to calculate population level effects, and using the correct variable to determine those effects (the salvage rate), I modeled the relationship between the cumulative salvage index and the population growth rate. The life-cycle model used for this analysis is a standard Ricker stock-recruitment model in which consecutive year FMWT estimates take the role of stock and recruitment, respectively. I used the cumulative salvage index data taken from the BiOp itself. *See* BiOp at 386 (AR at 000401).

72. The output of this standard model shows that there is no statistically significant relationship between salvage and the population growth rate. This demonstration is based upon using 0.05 as the significance level—the standard benchmark in applied statistics for determining a significance level. *See, e.g.*, Sigler, S., *Fisher and the 5% Level*, 21:4 Chance, Springer New York (Dec. 2008). Statistical significance is found when the p-value is less than 0.05. The p-value is the probability that the result obtained in a statistical test is due to chance rather than a true relationship between variables. In the analysis that I performed, the p-value was 0.76, which is greater than the benchmark and thus not statistically significant. *See* Appendix 1 at Point 2 for additional technical detail. The population growth rate and cumulative salvage index are depicted in the graph below as a visual aid.

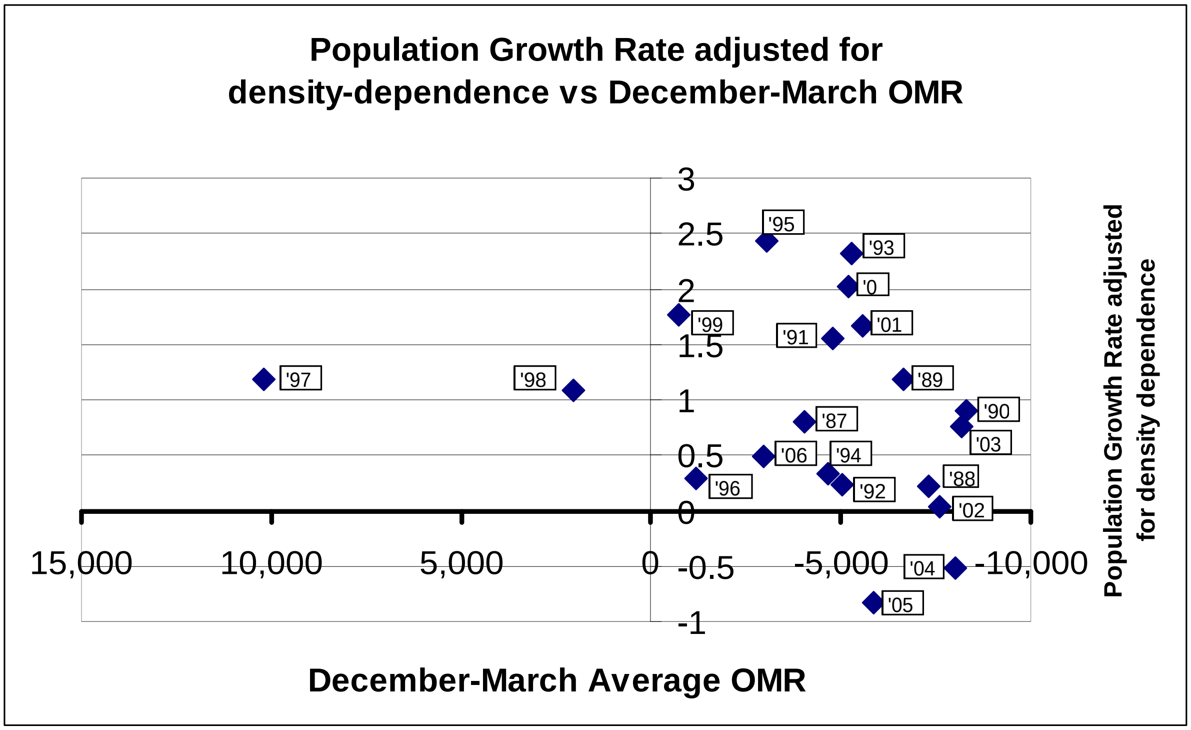


73. If the cumulative salvage index had a strong negative effect on population growth, the above graph would have been expected to show a pronounced negative slope. Instead, the graph shows no trend in population growth rate as the salvage rate increases. If the population has a growth rate of zero, then the population is neither increasing nor declining. A positive growth rate means the population is increasing on an annual basis, and a negative growth rate means the population is declining on an annual basis. Here, the population growth rate did not trend in a negative direction as the cumulative salvage index increased, so there is no statistical basis to conclude that cumulative salvage has a negative population level effect within the range of cumulative salvage index levels historically observed.

(2) Adults – OMR Flows

74. I conducted a second analysis to evaluate the relationship between December-March average OMR flows and the population growth rate. I calculated the average flows using the daily OMR flow data from the October 29, 2009 FOIA request. Using a standard Ricker stock-recruitment model and the standard 0.05 significance level, I found that the relationship between March-December OMR flows and the population growth rate is not statistically significant. The p-value is 0.321, which is above the significance level of 0.05. The modeling

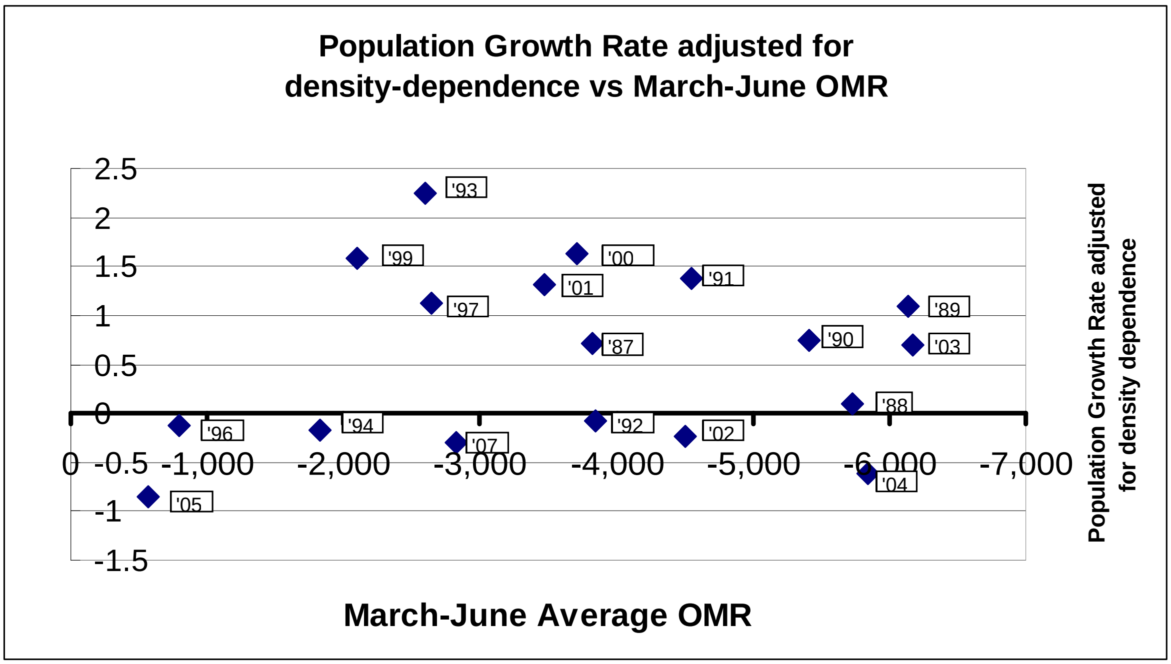
results are shown below as a visual aid. Thus, here too, there is no statistical basis to conclude that the OMR flows cause a negative population level effect within the range of December-March average OMR flows historically observed. For additional technical detail, see Appendix 1 at Point 3.



(3) Juveniles

75. The BiOp includes entrainment estimates for larval-juvenile delta smelt based on the work of Kimmerer (2008), who in turn bases those estimates on a method in which the assumption is made that entrainment is proportional to the southward OMR flow. I tested whether or not average southward OMR flow during the larval/juvenile salvage months of March through June could explain a statistically significant amount of the variation in population growth. I used the Ricker model again as a life-cycle model. March-June average OMR flow for years during the time span 1987 through 2007 in which the average flow was negative (that excluded years 1995, 1998, and 2006) was entered as a candidate explanatory variable and regression analysis was used to test whether or not the candidate variable was statistically significant. A starting year of 1987 was used because that is the starting year used in the BiOp, as data from that year forward "represents current delta smelt population dynamics." *See* BiOp at

236 (AR at 000251). Results show that March-June average OMR does not have a statistically significant impact on smelt population growth rate (the p-value is 0.703, which is above the significance level of 0.05). For additional technical detail, see Appendix 1 at Point 4. Even if entrainment of larval/juvenile smelt is related to spring OMR flow, that entrainment does not have a statistically significant impact on population growth. The result can be seen visually in the graph below which shows that variation in population growth rate (adjusted for density dependence) is not explained by the average March-June OMR flow.



76. March-June OMR does not negatively impact population growth, as can be seen visually in the graph above, where even at the most negative observed average OMR flows, the population growth rate was positive (irrespective of whether a density dependent adjustment is made). For additional technical detail, see Appendix 1 at Point 4. This result implies that there is no scientific justification for proposed RPA Action 3.

C. The Model Used in FWS's Analysis to Compare the Effect of Fall X2 on Population Survival Is Biologically Implausible and Potentially Misleading – It Is Simply Inappropriate for Fish Population Dynamics Modeling

77. FWS used statistical modeling to demonstrate an alleged relationship between Fall X2 and delta smelt abundance. The modeling and analysis are contained in the Effects of the

Proposed Action section of the BiOp, pages 233-238 and 265-274 (AR at 000248-000253 and 000280-000289), and in RPA Action 4 in Attachment B to the BiOp, pages 369-376 (AR at 000384-000391). FWS relied on various studies, particularly the work of Feyrer et al. in a 2007 article, *Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA* (AR at 018266) and a draft 2008 manuscript, *Modeling the Effects of Water Management Actions on Suitable Habitat and Abundance of a Critically Imperiled Estuarine Fish (Delta Smelt* Hypomesus transpacificus) (AR at 018278); a 2005 article by Bennett, *Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California* (AR at 017004); a 2008 report by Baxter et al., *Pelagic Organism Decline Progress Report: 2007 Synthesis of Results* (AR at 016922); and a 2008 article by Nobriga et al., *Long-Term Trends in Summertime Habitat Suitability for Delta Smelt,* Hypomesus transpacificus (AR at 019940).

(1) FWS Used a Linear Additive Model

78. FWS used a linear additive model to demonstrate an alleged relationship between Fall X2 and delta smelt abundance. The model finds that juvenile abundance, as measured by the TNS, is equal to the sum of a constant number plus the previous year's FMWT index (times a constant number), less X2 (times a constant number). *See* BiOp at 268 (AR at 000283) (Figure E-22). Essentially, this calculation finds that A = B + C - D.

79. FWS followed the linear additive model developed by Feyrer et al. (2007), which claims that Fall X2 has a population level effect. This model runs counter to well-accepted, basic modeling principles for this type of calculation. When analyzing the effect of Fall X2, FWS also cites to a 2005 article by Bennett. *See* BiOp at 236 (AR at 000251). However, Bennett applies a well-established stock-recruit model, namely, the Beverton-Holt model, and an alternative linear multiplicative model. *See* Bennett (2005) at 28-29.

80. The linear additive model produces the result that zero adults in one year could still yield some young in the following year, a result that is biologically implausible. Using the simple translation A (juveniles measured in TNS) = B (constant) + C (adults measured in FMWT) – D (Fall X2), one can see that, if C were set at zero (no adult spawners), B – D could still

produce a positive number for A (juveniles). This model thus has the biologically impossible property of generating juveniles from zero adults.

81. A linear additive model also treats the environmental factor X2 as an additive factor, which has the implausible property of reducing the absolute numbers of juveniles by the same quantity for a given value of X2 irrespective of the total population. For example, if X2 is set at a certain value such that when X2 is added, 1,000 juveniles are lost, that model would produce the result that 1,000 juveniles are always lost irrespective of the total number of juveniles present or the total number of juveniles that actually respond to X2.

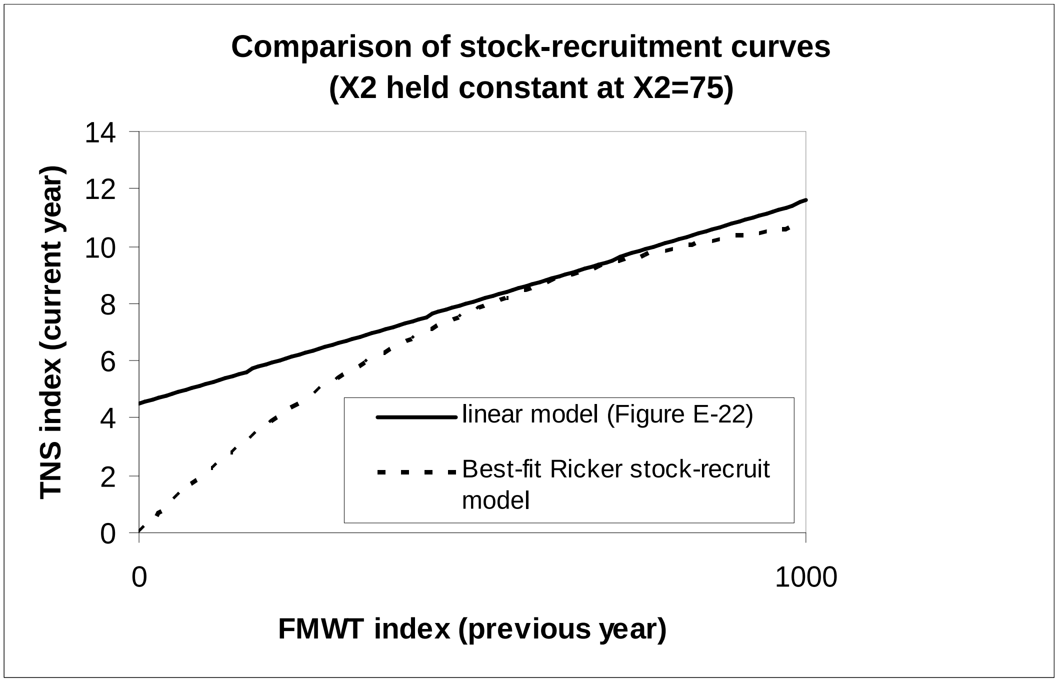
82. For reasons such as these, a linear additive model is inappropriate for stock-recruitment modeling, because the results are biologically impossible.

(2) FWS Should Have Used a Multiplicative Stock-Recruit Model

83. FWS inappropriately used a linear additive model to conduct the analysis that FWS performed with respect to the effect of Fall X2 on population survival. It is well established by those scientists qualified to conduct the type of analysis undertaken by FWS that a multiplicative stock-recruitment should be used. A multiplicative stock-recruit model better reflects actual biological realities when modeling fish populations because it describes survival of a year-class of fish. An example is the Leslie Matrix population model (equation 7.2 in Quinn & Deriso (1999) at 269). Survival processes are inherently multiplicative because the fraction of individuals that survive to a given age is given by the product of daily survivals through each day since the day of birth (*see, e.g.*, cumulative survival in Quinn & Deriso (1999) at 292). A commonly used, well known multiplicative stock-recruit model is the Ricker model. A qualified scientist in this field would be familiar with this model and would have no difficulty using it to perform the analysis that FWS did.

84. Any reliable, scientifically accepted stock-recruit model, such as the Ricker model or the Beverton-Holt model, is not a linear additive model. Such multiplicative stock-recruit models produce the biologically appropriate result that zero adults yields zero young. Thus, regardless of the presence of other factors, if there are zero adult spawners, there will be zero juveniles the following year. A graphical depiction of the difference between a multiplicative

model, such as the Ricker model, and a linear additive model is helpful to illustrate how a multiplicative model better reflects biological reality.



85. A multiplicative model, as opposed to an additive model, yields the sensible result that varying an environmental factor such as X2 will elicit a proportional response in population abundance. This is appropriate for a factor that affects survival because survival is, by definition, a fraction (what proportion of the population survives). In contrast, the linear additive model produces an absolute response irrespective of the size of the population. Multiplicative models are appropriate when describing the survival of a given cohort of fish. Additive terms may be appropriate components in certain types of cohort models when tracking the absolute abundance of a cohort over time—i.e., in situations that involve calculating the total raw population numbers over time, an exercise that has not been done for the delta smelt. *See* Quinn & Deriso (1999) at 323.

86. The BiOp itself questions the use of a linear additive model to evaluate the effect of Fall X2, stating that "some type of transformation of the data would help to define a better fitting model," but declines to correct the situation (such as through the use of a multiplicative model). BiOp at 236 (AR at 000251).

87. The Peer Review also criticized the linear additive model, finding that "[t]he [Effects Analysis] points out that the residuals from this analysis are not normally distributed and that some transformation might be required. We suspect that a few of the data points may have high influence on the outcome. These results together suggest that the model may be inappropriate for the data being used." *Independent Peer Review of USFWS's Draft Effects Analysis for the Operations Criteria and Plan's Biological Opinion, 2008* at 7 (AR at 008819).

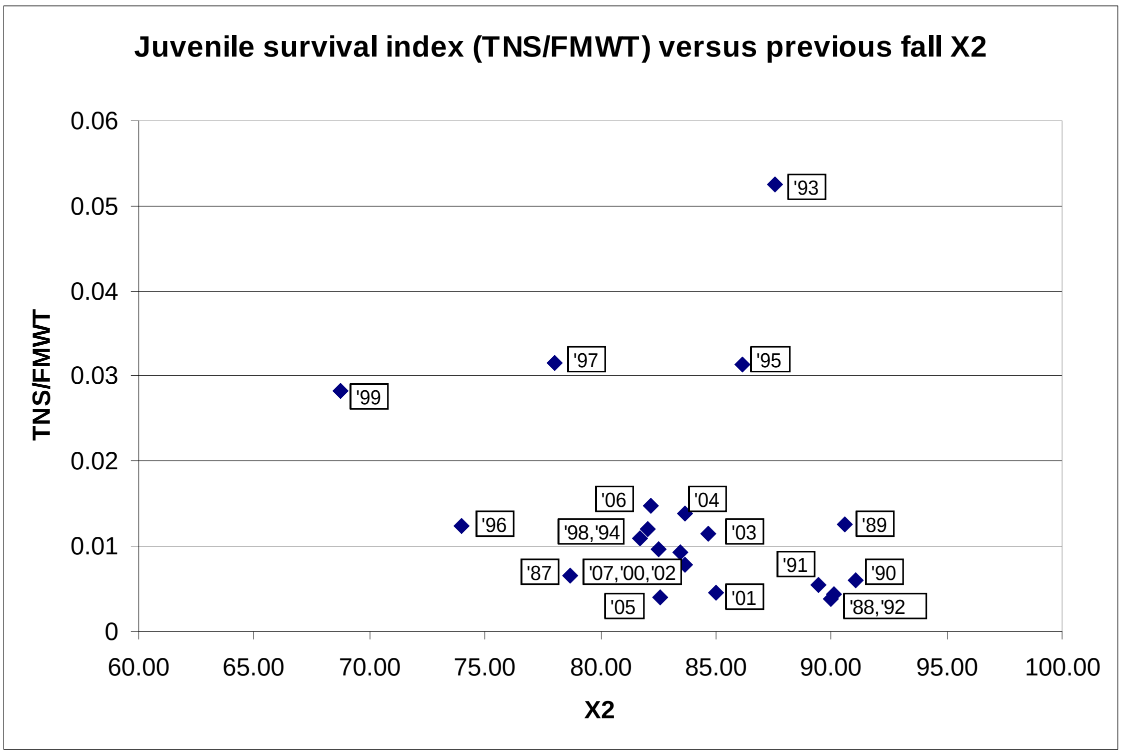
88. During my review of FWS's analysis, I plotted a stock-recruit curve of the relationship between FMWT (previous year) and TNS (current year) using the standard Ricker stock-recruitment model that was obtained by fitting the model to data. See details in Appendix 1 at Point 5. A visual comparison of the linear additive model that FWS used in the BiOp against the Ricker model is shown above. As shown on the comparison, when FMWT is set at zero in the linear model that FWS used, TNS is above zero. In contrast, when FMWT is set at zero in the standard Ricker model, TNS is also zero.

89. In order to evaluate whether there is a relationship between Fall X2 and abundance, I used the publicly available FMWT and TNS data and publicly available Fall X2 data in a standard Ricker stock-recruit model.[5] After employing the Ricker stock-recruit model, I was able to determine that there is no statistically significant relationship between Fall X2, stock abundance, and recruit abundance. The p-value for Fall X2 is 0.059, which is greater than the benchmark significance level of 0.05. See Appendix 1 at Point 5 for additional technical detail. The contrary conclusion that FWS reached is due to its improper use of a biologically implausible linear additive model.

90. I determined that the density dependent term in the Ricker model was not statistically significant. As a result, I used a reduced survival model that omitted the density

[5] FMWT data is available at: http://www.delta.dfg.ca.gov/data/mwt/charts.asp. The BiOp cites to http://www.delta.dfg.ca.gov as a source for FMWT data at page 143 (AR at 000158). TNS data is available at: http://www.delta.dfg.ca.gov/data/projects/?ProjectID=TOWNET. The BiOp cites to this website as a source for TNS data at page 300 (AR at 000315). Fall X2 data is available at: http://www.iep.ca.gov/dayflow/output/index. The BiOp relied on CALSIM modeling to calculate X2 values, and cites to http://www.iep.ca.gov/dayflow for "historical hydrologic data provided in the DAYFLOW database" which was used in the CALSIM modeling. *See* BiOp at 204, 235 (AR at 000219, 000250).

dependent term. The result shows that Fall X2 term is not statistically significant, since the p-value of 0.094 is greater than the 0.05 significance level. The graph below is included as a visual aid to show that there is no relationship between an index of juvenile survival ("TNS/FMWT_1") and Fall X2. If there had been a strong negative effect of Fall X2 on juvenile survival, the graph would have been expected to show a pronounced negative slope. Instead, the graph shows no trend in juvenile survival as X2 increases. For additional technical detail, *see* Appendix 1 at Point 5.



(3) Use of a Scientifically Appropriate Multiplicative Model Shows That Fall X2 Has No Statistically Significant Effect on the Population Growth Rate

91. In my review of the BiOp, I determined that FWS did not evaluate the effect of Fall X2 on the population growth rate. Use of the population growth rate would enable FWS to evaluate effects on the full life-cycle of the delta smelt.

92. Instead of carrying forward the linear additive model, as did FWS, the proper scientific method is to model the relationship between Fall X2 and the population growth rate

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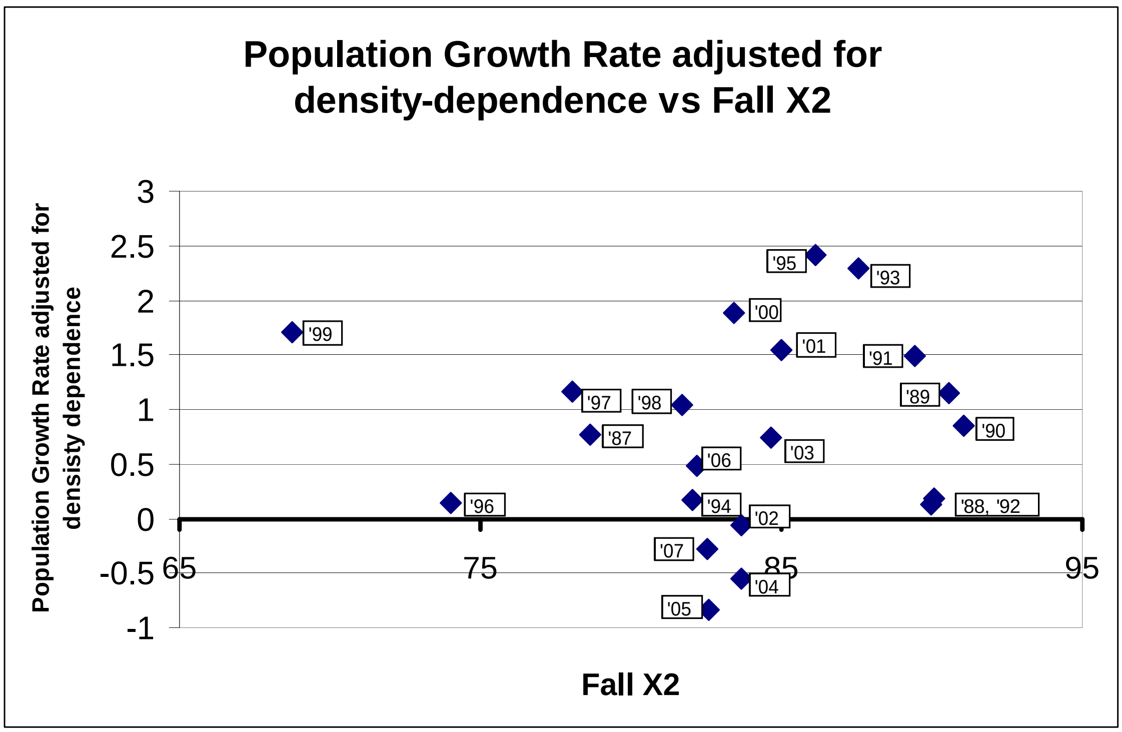
using a multiplicative model. As explained above, a multiplicative model is the scientific standard for fish population dynamics.

93. I used a Ricker model, which is a multiplicative model, to calculate the population growth rate and to evaluate the relationship between Fall X2 and the population growth rate with the regression method described in Appendix 1 at Point 6. I adjusted for density dependence in the modeling. In this application, I determined that the density dependent term in the Ricker model was statistically significant. Thus, the population growth rate had to be adjusted to account for these effects so that the potential effect of Fall X2 could be isolated. For additional technical detail, see Appendix 1 at Point 6. This relationship, adjusted for density dependence, is depicted below.



94. My application of a multiplicative Ricker life-cycle model demonstrates that Fall X2 does not have a statistically significant effect on the population growth rate. As Fall X2 increases, the population growth rate varies randomly. Taken together with the modeling I performed above (comparing Fall X2 to abundance, see ¶ 89) and statistical analysis of the regression estimates, this means that Fall X2 does not have a statistically significant effect on population abundance in a given water year (adults to juveniles), or on the full life-cycle of the

delta smelt (adults to adults). Since FWS's imposition of Fall X2 restrictions in RPA Action 4 is based upon its erroneous use of the wrong model—which, in turn, has led to the incorrect result that Fall X2 has population effects on the delta smelt—it is scientifically unjustified.

D. FWS's Incidental Take Analysis Is Improperly Influenced by Unrepresentative Data Points That Even FWS Rejected for Other Purposes

(1) FWS's Adult Incidental Take Analysis Is Improperly Influenced by an Unrepresentative Data Point

95. FWS's adult incidental take analysis can be found in Attachment C to the BiOp, pages 382-396 (AR at 000397-000411). In developing the incidental take limit for adult entrainment, FWS relied on a series of statistical analyses and calculations in the BiOp and in Kimmerer (2008).

96. The incidental take limit is set at 7.25 times the prior year's FMWT index of adult abundance. BiOp at 386 (AR at 000401). The 7.25 figure represents the average salvage rate from only three years—2006, 2007, and 2008. *See* BiOp at 385-86 (AR at 000400-000401). The BiOp uses the average salvage rate for these three years as a predictor of take levels during each year that the RPAs will be in effect. Although salvage data is analyzed dating back to 1993, the BiOp claims that "these years [2006 through 2008] within the historic dataset best approximate expected salvage under the RPA Component 1," which restricts OMR flows. *Id.*

97. The BiOp lists the annual salvage numbers and salvage rates for the years 1993-2008, and shows that the salvage in 1994 and 2007 were extremely low compared to the other years and to 2006 and 2008 in particular. *See* BiOp at 386 (AR at 000401) (Table C-1). The cumulative salvage index is just 0.88 for 2007, compared to 8.3 for 2006 and 12.6 for 2008. *Id.*

98. In my review, I searched for additional information regarding the conditions that might have contributed to these salvage levels. In another section of the BiOp, I discovered that FWS had considered the salvage level in 2007 as ***unusable*** for purposes of analyzing salvage and OMR flows due to that year's low average water turbidity. *See* BiOp at 348 (AR at 000363) (Figure B-13, Note). The low turbidity explains why salvage in 2007 was extremely low, as turbidity is a strong indicator of presence or absence of delta smelt near the project facilities.

Lower turbidity means fewer fish will be present and, accordingly, fewer fish are capable of being entrained. Thus, FWS recognized that the unusual conditions in 2007 made it an unrepresentative year that would skew its analysis. For FWS to then go ahead and use that salvage level in the incidental take equation is scientifically unjustified.

99. Without the year 2007 factored into the equation, the take coefficient increases from 7.25 to 10.45, which lies within the range of historical estimates based on the figure shown in ¶ 62 above for flows less negative than -7000 cfs. This figure represents the average of the salvage indices in 2006 and 2008, and would significantly increase the permissible take level. FWS's calculation should be corrected to remove the outlier year of 2007.

(2) FWS's Larval/Juvenile Incidental Take Analysis Is Improperly Influenced by an Unrepresentative Data Point

100. FWS's larval/juvenile incidental take analysis can be found in Attachment C to the BiOp, pages 382-396 (AR at 000397-000411). To calculate the incidental take limit for larval/juvenile entrainment, FWS largely followed the same methodology that it used for adults. BiOp at 389 (AR at 000404).

101. The incidental take limit is set at 1.5 times the Concern Level for larvae and juveniles. The Concern Level is equivalent to the average monthly juvenile salvage index from 2005-2008 times the current water year FMWT of adult abundance. BiOp at 390 (AR at 000405). Combining these two formulae, the incidental take limit can be calculated by multiplying 1.5 times the average monthly juvenile salvage index times the FMWT. Only four years are considered – 2005, 2006, 2007, and 2008.

102. The BiOp lists the annual salvage numbers and salvage rates for the years 1995-2008, and shows that the salvage in 2006 was extremely low compared to all other years, with the exception of 1995 and 1998 (see discussion below). *See* BiOp at 392 (AR at 000407) (Table C-4). The juvenile salvage index is just 0.4, compared to 23.4 for 2005, 65.1 for 2007, and 60.9 for 2008. *Id.*

103. In my review of the BiOp, I searched for additional information that might explain the conditions that were present in these years and how they contributed to salvage levels. I was

provided with daily OMR flow data through a FOIA request to FWS. I discovered that in 2006, average OMR flow was strongly positive for the months April through June, the first three (of four) months during which the monthly juvenile salvage index is calculated. OMR flow was negative in July 2006, but typically, very few fish are salvaged in July. *See, e.g.,* BiOp at 391 (AR at 000406) (Figure C-3) (showing that cumulative salvage reaches a plateau in July).

104. When analyzing the effects of OMR flows on salvage in the Effects Analysis section of the BiOp, FWS explained that "net OMR flow generally works very well as a binary switch: negative OMR flow is associated with some degree of entrainment, while positive OMR flow is usually associated with no, or very low, entrainment." BiOp at 163 (AR at 000178). The juvenile salvage index is reported in the BiOp for the years 1995-2008. BiOp at 392 (AR at 000407). During that time, there were three years when salvage was nearly zero – 1995, 1998, and 2006. These are the only three years when OMR flow was positive. *See* BiOp at 254 (AR at 000269) (Figure E-8). Thus, FWS's statement that positive OMR flow yields zero or very low salvage is supported by historical measurements of juvenile salvage and OMR flow. It also undermines FWS's decision to include one of those years – 2006 – in the incidental take equation.

105. Without the year 2006 factored into the equation, the average juvenile salvage index increases, which necessarily increases the Concern Level (monthly juvenile salvage index times FMWT) and the incidental take level (1.5 times Concern Level). The incidental take level increases by approximately 32-33 percent in May, June, and July, and decreases by approximately 14 percent in April (when salvage is low). Overall, in the months with the highest salvage, removal of the unrepresentative year 2006 significantly increases the take level. FWS's calculation should be corrected to remove the year 2006, which had positive OMR flow.

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I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this declaration was executed on November 13, 2009 at St. Thomas, U.S. Virgin Islands.

RICHARD B. DERISO, Ph.D.

Appendix

Exhibit A

Exhibit A

Summary Professional Vitae

Richard B. Deriso

Inter-American Tropical Tuna Commission
Scripps Institution of Oceanography
La Jolla, CA 92093-0203

Formal Education

University of Washington
Ph.D. in Biomathematics (Quantitative Ecology) 1978

University of Florida
M.S. in Mathematics 1975

Auburn University
B.S. in Industrial Engineering 1972

Academic Honors

Tau Beta Pi, Pi Alpha Mu (scholastic honor societies)
1981 W. F. Thompson Award from American Institute of Fishery Research Biologists for publication (Deriso, 1980 CJAFS).

Major Research Interests

Fisheries Population Dynamics, Quantitative Ecology, applied mathematics, statistics.

Recent Professional Experience

Chief Scientist of the Tuna-Billfish Program, Inter-American Tropical Tuna Commission, 1988 - present.

Associate Adjunct Professor, Scripps Institution of Oceanography, UCSD, 1990 - 2006.

Ocean Studies Board member, U.S. National Research Council. 2002- 2004.

Affiliate Associate Professor of Fisheries, University of Washington, 1987 - 2006; 1982-1986, Assistant Professor.

Scientific and Statistical Committee member, Western Pacific Regional Fisheries Management Council, 1993 - present.

Population Dynamicist, International Pacific Halibut Commission, Seattle, WA, 1980 - 1988.

Visiting Research Assistant Professor, Marine Sciences, University of North Carolina at Chapel Hill, 1979 - 1980.

Consultant to several agencies and institutions, including US Minerals Management Service, ExxonMobil, Essa Technologies Ltd., Australian Fisheries Management Agency, Great Lakes Fishery Commission, Ontario Ministry of Natural Resources, University of Alaska at Juneau, Applied Biomathematics Inc., Living Marine Resources Inc., Marine Stewardship Council, National Marine Fisheries Service, North Carolina Sea Grant Program, US Environmental Protection Agency, New York State Department of Environmental Conservation, and Public Service Electric and Gas Company of New Jersey.

Other Professional Activities

Over 30 seminars given at various universities, agencies, and conferences.

Taught several graduate courses, including
FISH 557 course (Theoretical Models of Exploited Animal Populations, University of Washington) , QSCI 598 (Decision analysis for exploited populations, University of Washington), SIO 276 (Quantitative theory of populations and communities, Scripps Institution of Oceanography, with G. Sugihara).

Served on several committees and working groups, including groups with ICES, FAO, NAS, OSB, and NRC. Past co-chairman, NRC Committee on Fish Stock Assessment Methods.

Publications And Reports

Over 50 publications and reports, including

Deriso, R.B., Maunder, M.N., Pearson, W.H. 2008. Incorporating covariates into fisheries stock assessment models with application to Pacific herring. Ecol. App. 18(5): 1270-1286.

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Exhibit B

Exhibit B

Publications

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Attorneys for Plaintiff
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UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES, SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA PARTIALLY CONSOLIDATED WITH: 1:09-cv-480 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	**DECLARATION OF DR. RICHARD B. DERISO**
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	Date: March 23, 2010 Time: 8:30 a.m. Ctrm: 3 Judge: Hon. Oliver W. Wanger
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	

I, RICHARD B. DERISO, declare:

1. The facts and statements set forth in this declaration are true of my own knowledge and if called as a witness, I can testify competently thereto. Any opinions expressed in this declaration are based upon my knowledge, experience, training and education, as set forth in section I.

2. My declaration is set forth in the following manner:

I. INTRODUCTION

3. In July of this year, I prepared a preliminary declaration that set forth a general explanation of the statistical analysis contained in the 2008 Delta Smelt Biological Opinion ("BiOp") prepared by the United States Fish and Wildlife Service ("FWS"). In that declaration, I focused on three areas of analysis performed by FWS—(1) the relationship between Old and Middle River ("OMR") flows and salvage, (2) the effect of Fall X2 on population survival, and (3) the establishment of incidental take levels. In each of these areas, FWS employed statistics, data analysis, and/or statistical modeling—tools that require technical training to understand. The equations, the statistical, mathematical and fishery population dynamic principles, and the modeling exercises involved in the BiOp are highly complicated. Someone without the proper background and training would be unable to thoroughly review what FWS did in a meaningful way.

4. It is my understanding that the Court has authorized the submittal of this declaration so that I may address and explain in detail the issues I identified in my prior declaration. Since my prior declaration, I have been able to complete my review of the BiOp, as well as the relevant publications relied on by FWS and cited in the BiOp. This declaration sets

forth my comprehensive explanation of the statistical modeling and analysis that FWS performed, including its clear, fundamental errors, focusing again on OMR flows, Fall X2, and the incidental take levels. Below, and in the accompanying appendix, I explain what FWS purported to do, and the mistakes they made in reaching their conclusions. I have also provided the information and equations that I used in conducting my review in an appendix so that my statements and explanations can be critically reviewed by others.

II. BACKGROUND AND EXPERIENCE

5. I am the Chief Scientist of the Tuna-Billfish Program at the Inter-American Tropical Tuna Commission ("IATTC"), and I have held this position since 1989. *See* Summary Professional Vitae, attached hereto as Exhibit A. I supervise a scientific staff of approximately 20 scientists and our primary responsibilities are: (1) to collect statistics on the fisheries that operate in the eastern Pacific Ocean, such as tuna and tuna-like species, and (2) to conduct stock assessments annually on the principal tropical tuna species as well as periodically other species such as turtles, sharks, and billfish species. My work involves advising the Commission on the current status of the populations and making conservation recommendations that can permit stocks to be maintained at a level of abundance that will support maximum sustainable yields.

6. IATTC has a long history of successful management of the tuna stocks in the eastern Pacific Ocean. The largest fishery historically has been yellowfin tuna. Yellowfin tuna is currently at a level of abundance above that which would support maximum sustainable yield.

7. I have a Ph.D. in Biomathematics (Quantitative Ecology) from the University of Washington, a Master's of Science in Mathematics from the University of Florida, and a Bachelor's of Science in Industrial Engineering from Auburn University. I have been teaching courses in fish population dynamics, quantitative ecology, and related areas for over twenty years. I was an Associate Adjunct Professor at the Scripps Institution of Oceanography, University of California, San Diego, from 1990 to 2006 and an Affiliate Associate Professor of Fisheries at the University of Washington from 1987 to 2006. Among the graduate courses I have taught are "Theoretical Models of Exploited Animal Populations" at the University of Washington; "Decision Analysis for Exploited Populations" at the University of Washington; and

"Quantitative Theory of Populations and Communities" at Scripps Institution of Oceanography. I have additional professional experience through a current membership on the Scientific and Statistical Committee of the Western Pacific Regional Fisheries Management Council and a past membership on the Ocean Studies Board which governs the U.S. National Research Council, where I served as co-chairman of the Committee on Fish Stock Assessment Methods. I was also formerly a Population Dynamicist for the International Pacific Halibut Commission. I have been a consultant to several agencies and institutions, both public and private.

8. I have authored or co-authored over 50 peer reviewed publications and technical reports, including Deriso, R., Maunder, M., and Pearson, W, *Incorporating covariates into fisheries stock assessment models with application to Pacific herring*, Ecol. App. 18(5): 1270-1286 (2008); Deriso, R., Maunder, M., and Skalski, J., *Variance estimation in integrated assessment models and its importance for hypothesis testing*, Can. J. Fish. Aquat. Sci. 64: 187-197 (2007); and Quinn, T. and Deriso, R., *Quantitative Fish Dynamics*, Oxford University Press (1999). *See* List of Publications, attached hereto as Exhibit B.

9. I have been retained to evaluate the effects of entrainment on fish populations in many circumstances throughout the United States. I have consulted on the environmental review of once-through cooling systems of the Indian Point nuclear power plants on the Hudson and Delaware Rivers, focusing on impingement and entrainment of fish, with a particular emphasis on their impacts to population. For this analysis, I was retained by ESSA Technologies Ltd. through a contract with the New York State Department of Environmental Conservation. This analysis included modeling, and reviewing models of, the impacts of entrainment and impingement on fish populations. I am a member of the Estuary Enhancement Program Advisory Committee that reviews the mitigation measures for losses of fish through impingement and entrainment at the Salem Nuclear Power Plant on the Delaware River in New Jersey. I have evaluated both the mortality and related impacts of hydroelectric dam operations on Chinook salmon populations on the Columbia and Snake Rivers.

10. I am familiar with, understand, and am able to explain to the Court the concepts and techniques used in the 2008 Delta Smelt Biological Opinion to evaluate the impacts of the

Central Valley Project and the State Water Project operations on the delta smelt population. My testimony and opinions are offered in the context of explaining the standard practices and statistical methods that are used in fish population dynamics to evaluate impacts to fish populations, and the practices and statistical methods employed by the FWS in the BiOp.

III. GENERALLY ACCEPTED PRINCIPLES OF FISH POPULATION DYNAMICS THAT APPLY TO AN ANALYSIS OF IMPACTS TO FISH SPECIES

11. In the BiOp, FWS sought to evaluate the effects of the Central Valley Project and State Water Project on the threatened delta smelt. When looking at potential impacts of a project to fish species, the standard of practice is for qualified professionals to employ certain well-established principles of fish population dynamics.

A. Principle 1: Quantitative Analysis Should Be Conducted

12. The fundamental approach to assessing fish population dynamics is through quantitative statistical analysis (mathematical models) of population dynamics. "Quantitative analysis" involves the use of actual measured data and the testing of relationships between that data. The nature and degree of project impacts on a species must be determined using quantitative methods where quantitative data is available. Similarly, measures designed to benefit the species and avoid harm must be based on a quantitative approach. Only in this way can impacts and benefits be measured for proper evaluation of their effect on the species.

13. By contrast, a qualitative approach may be appropriate where no quantitative data or measurements are available. Qualitative analysis consists of a more subjective evaluation of the degrees of importance of particular factors and circumstances for which quantitative data and measurements are not appropriate or do not exist.

B. Principle 2: Impacts to the Total Population Should Be Evaluated

14. Population dynamics also involve a qualified scientist conducting an evaluation of project impacts to a threatened fish by focusing on impacts to the total population. Measuring effects on a single fish, or a limited group of fish, does not lead to reliable conclusions about population level effects. Such population level conclusions are essential when evaluating a project's impacts on the species as a whole and its ability to survive and recover.

15. Population level effects are properly evaluated using rates and proportions. This means that a given impact or variable cannot be taken as significant on its own without accounting for the *relative* impact on the total population. The population growth rate is an appropriate and reliable measure of population increases and decreases from year to year.

C. Principle 3: Models Should Be Reliable and Biologically Plausible

16. The standard of practice for a fish population dynamicist requires that any statistical models that are utilized must be reliable and biologically plausible. Such statistical models are based on mathematical formulas that assign numeric values to biotic and abiotic variables to explain the relationships among them. To be biologically plausible means that the mathematical formulas used must reflect the reality that the "variables" are reflective of the biology of the living organisms that are being assessed. For example, living organisms have a limited life span and limited reproductive capabilities that must be taken into account in any model used to evaluate their behavior and vulnerabilities. Thus, the models that are properly used are designed to attribute a quantitative value to those influential biological factors so that the model enables quantitative measurement of their interrelationships. Such models are designed to reflect biological realities and to evaluate the relationship between living stock and recruits.

D. Principle 4: Data Should Be Used Consistently

17. In performing a quantitative fish population analysis, generally accepted scientific standards require that the study be internally consistent in its use of data. Data that is rejected in one aspect of the analysis should not be relied upon elsewhere in the same study.

18. With these general principles in mind, I turn to the subject of this action, the 2008 Delta Smelt Biological Opinion for the Operations Criteria and Plan for the State Water Project and the Central Valley Project.

IV. THE BIOP'S EVALUATION OF PROJECT EFFECTS AND THE BIOP'S RPAS ARE BASED ON A "QUANTITATIVE" ANALYSIS

19. The core analyses and conclusions in the BiOp are contained in the sections entitled "Effects of the Proposed Action" (BiOp at 202-239 [Administrative Record ("AR") at 000217-000254]), "Reasonable and Prudent Alternative" ("RPA") (BiOp at 279-285, 324-81 [AR

at 000294-000300, 000339-000396]), and "Incidental Take Statement" ("ITS") (BiOp at 285-295 [AR at 000300-000310]). These sections define the effects of the water projects on the delta smelt and the restrictions which FWS imposed to avoid jeopardy.

20. In the section of the BiOp entitled "Effects Analysis Methods," FWS explains that the effects of the project pumps on entrainment (OMR flows and salvage, and incidental take levels) and the fall habitat suitability and its effect on population (Fall X2) "are quantitatively analyzed."

> The effects analyses range from qualitative descriptions and conceptual models of project effects to quantitative analyses. The effects of Banks and Jones pumping on adult delta smelt entrainment, larval-juvenile delta smelt entrainment, and fall habitat suitability and its predicted effect on the summer townet survey abundance index are quantitatively analyzed. The remainder of proposed action elements and effects are not analyzed quantitatively because data are not available to do so or it is the opinion of the FWS that they have minor effects on delta smelt.

BiOp at 208-209 (AR at 000223-000224). This representation is consistent with my review of the BiOp—FWS conducted a quantitative statistical analysis in order to (1) evaluate project effects on the smelt population and (2) develop RPAs designed to mitigate and avoid any such effects to the extent necessary to avoid jeopardy to the species and adverse modification of its critical habitat. As I would expect of most any scientific exercise, FWS relied on and used data when it was available, unless FWS concluded that the issue was too "minor."

21. Because the BiOp concludes that the projects jeopardize the species and adversely modify its critical habitat, it includes RPAs that restrict project operations in an attempt to avoid jeopardy and adverse modification. The RPAs address categories of effects to which FWS applied quantitative analyses: adult entrainment and larval/juvenile entrainment as related to OMR flows, and fall habitat. These are outlined in more detail below.

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22. **Actions 1 and 2 (Winter OMR Flows)**.[1] Actions 1 and 2 are designed to avoid jeopardy to adults from entrainment. These Actions restrict Old and Middle River ("OMR") flows to reduce adult salvage in the winter. Action 1 is triggered first and lasts for 14 days, followed immediately by Action 2, which is triggered if certain criteria are present and lasts until spawning begins or a certain water temperature is reached. Both of these Actions prescribe a similar range of OMR flows, but at different times of the year. The quantitative analysis presented in Attachment B to support the prescribed OMR flow levels in Actions 1 and 2 is set forth in the BiOp at 345-349 and is represented in two graphs labeled Figure B-13 and Figure B-14, which appear to share the same data. *See* BiOp at 348, 350 (AR at 000363, 000365). Figure B-13 depicts the BiOp's analysis of the relationship between winter OMR flows and adult salvage, concluding that as flows become more negative, salvage increases. Based on this relationship, Actions 1 and 2 set less negative flow levels to reduce salvage.

23. **Action 3 (Spring OMR Flows)**. Action 3 is designed to avoid jeopardy to larvae and juveniles from entrainment. This Action restricts OMR flows to reduce larval/juvenile salvage in the spring. FWS did not apply statistical modeling to evaluate whether or not reductions in OMR flows or X2 would reduce impacts to juveniles, because there is no actual data on larval and juvenile salvage for fish smaller than 20 millimeters. Instead, FWS relied on the assumption that larval and juvenile movement can be predicted using a particle tracking model. A particle tracking model is a theoretical simulation of the flow of neutrally buoyant particles through a water system, where particles are used as surrogates for actual fish. Similar to Actions 1 and 2, Action 3 sets less negative flow levels to reduce salvage.

24. **Action 4 (Fall X2)**. Action 4 is designed to protect fall habitat for adults. This Action prescribes Delta outflows to push X2 more seaward during the fall. The BiOp relies primarily on the quantitative analysis represented by the summary statistics for the stock-recruit

[1] The RPAs are divided into four "Components," which are supported by supplemental information in Attachment B to the BiOp. Attachment B breaks down the RPA Components into five "Actions," such that Component 1 is represented by Actions 1 and 2, Component 2 is supported by Action 3, Component 3 is supported by Action 4, and Component 4 is supported by Action 5. Because most of the technical analysis is contained in Attachment B, and for ease of reference, I will refer to the RPAs in terms of the Actions rather than the Components.

model set forth in Figure E-22 to establish that the location of Fall X2 has a significant effect on delta smelt abundance. *See* BiOp at 268 (AR at 000283). Based on this purported relationship, Action 4 sets Delta outflow levels to control the location of X2.

25. **Incidental Take Statement**. The BiOp also includes an Incidental Take Statement, which prescribes the acceptable level of take of larval/juvenile and adult delta smelt using quantitative methods. For each of larvae/juveniles and adults, FWS took the average salvage rate from certain prior years which it deemed to be representative of future conditions under the RPAs. The average salvage rate from the prior representative years was set as the maximum take level under the RPAs. *See* BiOp at 385-390 (AR at 000400-000405).

26. To summarize, FWS used quantitative methods to evaluate the effects of water project operations (OMR flows) on the species, on its fall habitat (as represented by Fall X2), and to establish incidental take levels. I will next explain the clear, fundamental errors I have identified in that quantitative analysis.

V. THE QUANTITATIVE ANALYSIS BY FWS DOES NOT FOLLOW STANDARD FISH POPULATION ASSESSMENT METHODS

A. Actions 1 & 2 (Winter OMR Flows): Use of Raw Salvage Numbers Instead of the Salvage Rate

27. Actions 1 and 2 prescribe OMR flow levels based on the BiOp's calculation of the relationship between OMR flows and adult salvage. This relationship is depicted in Figure B-13 and compares OMR flow levels to raw salvage numbers. The salvage numbers used are the total number of fish counted at the salvage facilities.

28. Raw salvage numbers do not represent the proportion of the total population that is lost to salvage, which is the salvage rate. For example, a raw salvage total of 100 adults has vastly different significance depending on whether the total population is 200 (salvage rate of 50 percent) or 10,000 (salvage rate of 1 percent). Thus, Figure B-13 does not show what effect OMR flows have on the total delta smelt population.

29. Use of raw salvage numbers, rather than the salvage rate, could be appropriate if the total delta smelt population was known and a model that incorporates every life stage of the

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species (a life-cycle model)[2] was being used. Salvage of delta smelt is a source of loss of individuals—it is analogous to using catch as a mortality loss to the population. If the total delta smelt population was known, then the salvage numbers themselves could be incorporated directly into a life-cycle model and would make it possible to determine the population effects of salvage. A simple version of such a model is explained in Hilborn, R. & Walters, C., *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*, Chapman & Hall (1992) at 298:

> The changes in a population's biomass from one time to the next can be simply written as
>
> next biomass = last biomass + recruitment + growth – catch – natural mortality.

Salvage would take the role of catch in a similar life-cycle model for delta smelt.

30. Here, however, the total population of delta smelt is unknown, although there have been recent attempts to provide such estimates. Because actual abundance is not known, raw salvage numbers cannot be used to show population level effects.

31. In the absence of actual adult abundance numbers, adult abundance is estimated by the Fall Midwater Trawl Survey ("FMWT"), which collects samples around the Delta. An index of the FMWT is used to track the relative increase or decrease in adult abundance from year to year. The survey counts the number of smelt captured in a net of known dimensions and multiplies it by the volume of water actually sampled. That number is then applied to the entire estimated volume of water where the smelt is believed to reside. From this data, an index is derived.

32. The FMWT index is scientifically reasonable and widely relied upon by scientists studying the delta smelt, though not without its technical flaws. It is a numerical scale used to compare variables derived from a series of observed facts with one another or with some reference number to reveal relative changes as a function of time. Because actual abundance is not known, raw salvage numbers cannot be used to show population level effects.

[2] A life-cycle model is a well-accepted and reliable method of evaluating population dynamics from generation to generation (adults to adults), rather than focusing solely on one age group or the change from adults to juveniles.

33. For adult delta smelt, the scientifically accepted and reliable method is to use the cumulative salvage index to evaluate whether a relationship exists between OMR flows and adult salvage. The cumulative salvage index is equal to the raw number salvaged divided by the prior year FMWT index. *See* BiOp at 338 (AR at 000353). In this way, the cumulative salvage index represents an index of the proportion of abundance that is lost to salvage each year. In the absence of abundance figures, the prior year FMWT index stands as a usable denominator for a ratio that would reveal any population level effects from entrainment.

B. Actions 1, 2 & 3 (Winter and Spring OMR Flows): Failure to Evaluate the Smelt's Population Growth Over Time

34. The BiOp's failure to evaluate population level effects using the correct variable (salvage rate) is consistent with its more general failure to use the well-accepted, reliable statistical models typically used to evaluate population level effects. The BiOp did not employ life-cycle modeling**,** which, among other things, is used to estimate a population's growth.

35. Life-cycle modeling is a well-accepted and reliable method of evaluating population dynamics from generation to generation (adults to adults). It typically consists of the simple models known as biomass dynamic models and stock production models, or the more complex models such as age-structured models. *See* Quinn & Deriso (1999) at ch. 2, 6-8; Hilborn & Walters (1992) at 297.

36. In fisheries science, often the total number of fish in a population is unknown. It is standard practice that, given the data available, population level effects can be determined using surrogate methods such as the population growth rate and the salvage rate.

37. Similar to Actions 1 and 2, the BiOp omits any analysis of the effect of spring OMR flows (Action 3) on the delta smelt population growth rate. A standard life-cycle model could be applied to determine whether spring OMR flows, which would potentially affect larvae and juveniles, are affecting the change in total population from year to year. This kind of quantitative analysis would make it possible to reliably calculate population level effects for delta smelt.

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C. Action 4 (Fall X2): Use of a Linear Additive Model Instead of a Multiplicative Model

38. FWS's quantitative Fall X2 analysis for Action 4 of the BiOp is based on a stock-recruitment model. A stock-recruitment model is a model used to evaluate population level effects that quantitatively characterizes the relationship between the parental "stock" and the progeny it produces ("recruits"). In the BiOp, the parental stock is measured through the FMWT and the progeny is measured at the juvenile life stage through the Summer Townet Survey ("TNS").

39. There are many different stock-recruitment models. In selecting a model, one necessary criterion is that the model must be biologically plausible. This means that the mathematical formulas reflect biological reality and limitations, as described above.

40. FWS employed a linear additive stock-recruitment model when evaluating Action 4. A linear additive model adds several factors together to achieve a sum, without use of logarithms. A simple example is A + B = C. This type of model is not appropriate for stock and recruitment relationships, for two main reasons.

41. First, adding and subtracting factors can generate a positive sum, even if one of the factors is zero. This seems mathematically accurate, but it does not work in a situation where the factors are living organisms with certain non-mathematical properties. For instance, in an equation where various factors are added to adult abundance to determine the effect on their juvenile offspring, one can achieve a positive sum (number of juveniles) even if the factor representing the number of adults is zero. In terms of biological reality, zero adults cannot produce offspring. Thus, simply adding the factors does not reflect the manner in which populations grow.

42. Second, a linear additive model treats factors as having a fixed effect on the population, rather than a proportional effect. That is, by adding a factor, it will always increase or decrease the sum by the same absolute amount. While mathematically accurate, this does not work when the factors being added are habitat components that have a changing proportional effect on the sum (population abundance), not a fixed effect. When the total population is

smaller, a smaller number of individuals exist that can potentially be affected by a given factor. This is accounted for by using proportions and rates.

43. In contrast, multiplicative stock-recruitment models produce biologically accurate results and they are appropriate for fish population dynamics. Simply put, a multiplicative model reads as A x B = C. Two multiplicative models available to FWS are the Beverton-Holt and Ricker models. These models are typically used because they are well-accepted by the scientific peer community and are reliable.[3]

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[3] *See, e.g.*, Jorgensen, S. & Fath, B. (eds.), *Encyclopedia of Ecology*, Academic Press (2008); Knowler, D., Estimation of a Stock-Recruitment Relationship for Black Sea Anchovy (Engraulis encrasicolus) Under the Influence of Nutrient Enrichment and the Invasive Comb-Jelly, Mnemiopsis leidyi, 84:3 Fisheries Research 275-281 (May 2007); Owen-Smith, N., Introduction to Modeling Wildlife and Resource Conservation, Blackwell Publ'g (2007); Brauer, F. & Castillo-Chavez, C., Mathematical Models in Biology and Epidemiology, Springer-Verlag New York, Inc. (2006); Kritzer, J. & Sale, P. (eds.), Marine Metapopulations, Elsevier Academic Press (2006); Mangel, M., The Theoretical Biologist's Toolbox: Quantitative Methods for Ecology and Evolutionary Biology, Cambridge Univ. Press (2006); Ferrier, R., et al. (eds.), Evolutionary Conservation Biology, Cambridge Studies in Adaptive Dynamics, Cambridge Univ. Press (2004); Hoff, M., Biotic and Abiotic Factors Related to Rainbow Smelt Recruitment in the Wisconsin Waters of Lake Superior, 1978-1997, 30 Journal of Great Lakes Research, Supp. 1 Exploring Superior, 414-422 (2004); Walters, C. & Martell, S., Fisheries Ecology and Management, Princeton Univ. Press (2004); Hart, P. & Reynolds, R. (eds.), Handbook of Fish Biology and Fisheries, 1 Fish Biology, Blackwell Publ'g (2002); Haddon, M., Modeling and Quantitative Methods in Fisheries, Chapman & Hall (2001); Jennings, S., et al., Marine Fisheries Ecology, Blackwell Publ'g (2001); Lorda, E. et al., Application of a Population Dynamics Model to the Probabilistic Assessment of Cooling Water Intake Effects of Millstone Nuclear Power Station (Waterford, CT) on a Nearby Winter Flounder Spawning Stock, 3 Envtl. Science & Policy, Supp. 1, 471-482 (Sept. 2000); McCallum, H., Population Parameters: Estimation for Ecological Models, Blackwell Publ'g (2000); Guenette, S. & Pitcher, T., An Age-Structured Model Showing the Benefits of Marine Reserves in Controlling Overexploitation, 39:3 Fisheries Research 295-303 (Jan. 1999); Quinn & Deriso (1999); Ricklefs, R. & Miller, G., Ecology, 4th ed., W.H. Freeman (1999); Hilborn & Walters (1992); Rothschild, B., Dynamics of Marine Fish Populations, Harvard Univ. Press (1986); Walters, C., Adaptive Management of Renewable Resources, MacMillan Publ'g Co. (1986); Mangel, M., Decision and Control in Uncertain Resource Systems, Academic Press (1985); Pauly, D., Fish Population Dynamics in Tropical Waters: A Manual for Use With Programmable Calculators, 8 ICLARM Studies & Reviews (1984); Fournier, D. & Archibald, C., A General Theory for Analyzing Catch at Age Data, 39 Canadian Journal of Fisheries & Aquatic Sciences 1195-1207 (1982); Pitcher, T. & Hart, P., Fisheries Ecology, Kluwer Academic Publ'g (1982); Walters, C. & Ludwig, D., Effects of Measurement Errors on the Assessment of Stock-Recruitment Relationships, 38 Canadian Journal of Fisheries & Aquatic Sciences 704-710 (1981); Clark, C., Mathematical Bioeconomics: The Optimal Management of Renewable Resources, Wiley (1976); Ricker, W., Handbook of Computation for Biological Statistics of Fish Populations, Bulletin 119 of the Canada Fisheries Res. Bd. (1958), issued again as Ricker, W., Computation and Interpretation of Biological Statistics of Fish Populations, Bulletin 191 of the Canada Fisheries Res. Bd. (1975); Weatherley, A., Growth and Ecology of Fish Populations, Academic Press (1972); Beverton, R. & Holt, S., On the Dynamics of Exploited Fish Populations, 14 Fishery Investigations Series II, Ministry of Agriculture, Fisheries & Food (1957).

44. For measuring population level effects, multiplicative or rate-based models such as Ricker and Beverton-Holt should be used to achieve scientifically accepted, reliable results. Additive models should not, because they generate inaccurate and unreliable results. These are the two most widely-used models in actual practice because they were designed to be biologically accurate and reflect the relationship between stock and recruits. A feature of a multiplicative model is that when there are zero adults on one side of the equation, there are zero young on the other side; i.e., zero adults yields zero offspring. This follows because any number multiplied by zero will always equal zero. As stated in Ricker (1975) at 281, the model is designed "so that when there is no adult stock there is no reproduction . . . ." The same result can be expected using other types of multiplicative models.

D. ITS: Use of Rejected Data Points Instead of Representative Data Points

45. The BiOp sets the adult incidental take limit based on the average salvage rate from the years 2006, 2007, and 2008, which FWS determined to be representative of future conditions under the RPAs. BiOp at 385-86 (AR at 000400-000401). According to the list of salvage levels contained in the ITS, salvage in 2007 was extremely low compared to other years and to 2006 and 2008 in particular. *See* BiOp at 386 (AR at 000401) (Table C-1). In another section of the BiOp, FWS itself had considered the salvage level in 2007 as unusable for purposes of analyzing salvage and OMR flows due to that year's low average water turbidity, a presence/absence indicator. *See* BiOp at 348 (AR at 000363) (Figure B-13, Note). Thus, FWS recognized that the unusual conditions in 2007 made it an unrepresentative year that would skew its analysis of salvage impacts. Use of an unrepresentative data point that was rejected elsewhere in the same study runs counter to basic principles of quantitative fish assessment. FWS does not attempt to justify why the data point would be used in one instance and not another, so one possible explanation is that it is simply a material error in the analysis.

46. To calculate the incidental take limit for larvae and juveniles, FWS largely followed the same methodology that it used for adults. BiOp at 389 (AR at 000404). The take limit is set based on the average monthly juvenile salvage index from four years – 2005, 2006,

2007, and 2008. According to data listed in the BiOp, the salvage in 2006 was extremely low compared to other years. *See* BiOp at 392 (AR at 000407) (Table C-4). I examined this year carefully and discovered through my review of OMR flow data obtained from a Freedom of Information Act ("FOIA") request to FWS[4], that in 2006, average OMR flow was strongly positive in April through June. When analyzing the effects of OMR flows on salvage in the Effects Analysis section of the BiOp, FWS explained that positive OMR flow yields zero or very low salvage. BiOp at 163 (AR at 000178). Thus, FWS's use of 2006 as a "representative" year for larval/juvenile salvage is internally inconsistent with its explanation elsewhere that positive OMR flow (which is what occurred in spring 2006) yields little or no salvage. The year 2006 was therefore not representative and should have been omitted, as it was elsewhere by FWS for other purposes.

VI. THE BIOP'S APPLICATION OF STATISTICAL MODELS AND INPUT VARIABLES IS INCONSISTENT WITH STANDARD PRINCIPLES OF FISHERIES POPULATION DYNAMICS

47. To decipher the models and methods that FWS used, I reviewed and interpreted the limited graphs and tables provided in the BiOp, along with similar information and studies in the administrative record.

48. I compared FWS's models against the standard models employed by the scientific community, and particularly those models that are commonly used in fish population modeling. My review and comparison revealed that the BiOp does not use the well-accepted models in more

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[4] My review of the BiOp and the administrative record revealed that FWS had not provided all of the underlying data that FWS relied on in performing its work on the BiOp. In my experience, a full scientific analysis is not possible without making the underlying data available so that the work may be checked and evaluated by others. This omission hinders the ability to conduct a standard peer review of the FWS analysis without estimating data point values from the graphs or searching for data in other sections. FWS's failure to include the data underlying its basic analyses and determinations is an inexplicable defect given the conclusions FWS reaches. After I identified the missing categories of data, the Metropolitan Water District of Southern California requested that data through a FOIA request. On October 29, 2009, more than ten weeks after the request was made, FWS provided a disc containing portions of the data underlying the BiOp. Included on that disc were daily OMR flow data. I used those data to calculate several average OMR flows, including monthly average flows, as noted in this declaration.

than one place, but rather relies on models that are not biologically sound and lead to erroneous results.

49. I evaluated the same data presented in the BiOp and input it into the standard models to determine whether the end result would be different. The results are fundamentally different from the results reached in the BiOp.

50. Based on the material I reviewed, the fundamental errors I have identified call into question the jeopardy and adverse modification conclusions in the BiOp and reveal that FWS had no reliable scientific basis for imposing the RPAs adopted.

A. FWS's Analysis of the Relationship Between Old and Middle River Flows and Adult Salvage Is Flawed

51. The BiOp's analysis of the effects of the projects on adult delta smelt and its conclusion that winter flow restrictions are necessary are based on a statistical model of the alleged relationship between OMR flows and adult salvage. The modeling and analysis are contained in the Effects of the Proposed Action section of the BiOp, pages 202-279 (AR at 000217-000294), and RPA Actions 1 and 2 in Attachment B to the BiOp, pages 329-356 (AR at 000344-000371). Actions 1 and 2 rely on Figure B-13 on page 348 (AR at 000363) and on various studies, including Kimmerer, W., *Losses of Sacramento River Chinook Salmon and Delta Smelt to Entrainment in Water Diversions in the Sacramento-San Joaquin Delta* (AR at 018854), and the work of Pete Smith, which is cited by Kimmerer.

(1) Improper Use of Total Adult Salvage Numbers Instead of Cumulative Salvage Index

52. FWS uses total adult salvage numbers to demonstrate an alleged relationship between OMR flows and adult salvage. *See* BiOp at 163-65; 347-50 (AR at 000178-000180; 000362-000365). The alleged relationship is derived from the graph in Figure B-13 which compares the number of adults salvaged each year to the corresponding OMR flow rate for that year. BiOp at 164, 348 (AR at 000179; 000363).

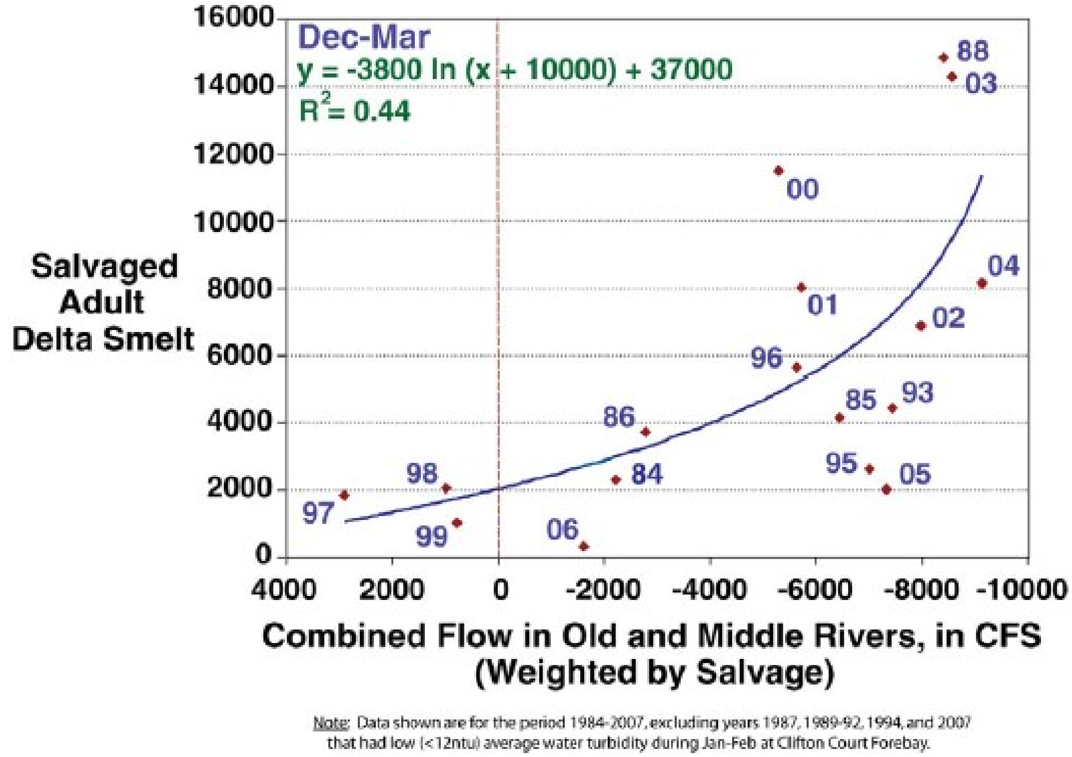

Figure B-13. OMR-Salvage relationship for adult delta smelt. (source, P. Smith). Data from this figure were the raw data used in the piecewise polynomial regression analysis.

53. FWS relied on this graph to conclude that OMR flows correlate to total salvage numbers—suggesting that as negative OMR flows increase, more adults are salvaged.

54. This conclusion by FWS is scientifically flawed because raw salvage numbers do not have a directly proportional effect on population and do not take into account the overall size of the population as determined by representative survey data. Nonetheless, FWS relied on Figure B-13 and Figure B-14 (which appear to share the same data) to set OMR flow levels in RPA Actions 1 and 2. In other words, FWS set OMR flow levels in Actions 1 and 2 without determining population level effects.

55. The scientifically appropriate approach would have been for FWS to use the cumulative salvage index to evaluate whether a relationship exists between OMR flows and adult salvage. FWS had already developed that index for other purposes. *See* BiOp at 386 (AR at 000401) (using the cumulative salvage index in another context, to calculate the incidental take). The cumulative salvage index represents an index of the salvage rate, taking into account data on the size of the population. This has long been recognized as appropriate for analysis of delta

smelt by those scientists actively studying the smelt. *See, e.g.*, Bennett, W., *Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California*, San Francisco Estuary & Watershed Science, Cal. Bay-Delta Auth. Science Program & John Muir Inst. of the Env't (2005) at 37 ("As first step [sic], assessing the potential impacts of the water project operations on delta smelt requires estimating the proportion lost relative to population abundance."). The cumulative salvage index is proportional to the fraction of adult fish that are lost due to water diversion.

56. The concept of dividing fish loss by abundance is well-accepted and reliable and is applied in other, similar applications, such as part of the procedure for estimating the impact of entrainment and impingement of fishes by water withdrawals of once-through cooling systems for nuclear power plants on the Hudson River.

> This approach is based on conditional mortality rates, or the fraction of an initial population that would be killed by some agent during the year if no other sources of mortality operated. Conditional entrainment mortality rates are used as estimates of the direct impact of power plants on individual year classes . . . . (2) Conditional mortality rates can be entered directly into life-cycle models for assessing potential long-term impacts on fish populations.

Barnthouse, L., et al. (eds.), *Science, Law, and Hudson River Power Plants: a Case Study in Environmental Impact Assessment*, Am. Fisheries Soc'y Monograph 4, Am. Fisheries Soc'y (1988) at 122.

57. Another example is biological reference points ("BRP") which can be used as targets for optimal fishing: "A BRP can be expressed as a fishing mortality rate (F) and/or as a level of stock biomass (B)." Comm. on Fish Stock Assessment Methods, Nat'l Research Council, *Improving Fish Stock Assessment Methods*, Nat'l Academy Press (1998) at 45. The fishing mortality rate (F) depends mathematically on the ratio of catch divided by biomass and it is similar to a cumulative salvage index in that both represent a ratio of losses to abundance.

58. Since total population data does not exist, the cumulative salvage index uses a survey index which gives a relative increase or decrease in annual survey numbers to monitor population levels. Use of the cumulative salvage index to evaluate the effects of OMR flows is

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scientifically accepted, reliable, and superior to using the raw salvage numbers themselves (as used in Figure B-13), for the following reasons:

59. The total number of adults salvaged does not indicate population level effects. *See* BiOp at 338 (AR at 000353) ("the total number salvaged at the facilities does not necessarily indicate a negative impact upon the overall delta smelt population"). Stated differently, to make sense of total adult salvage numbers, total adult abundance must be taken into account. For example, a salvage of 100 adults has vastly different significance depending on whether the total population is 200 or 50,000.

60. In contrast, the cumulative salvage index is an index of the *proportion* of adults salvaged from the total population, using the FMWT to relate salvage to population levels. The cumulative salvage index is equal to the number salvaged divided by the prior year FMWT index. *See* BiOp at 338 (AR at 000353).

61. Use of the cumulative salvage index, rather than total salvage numbers, was recommended by the Peer Review. *See Independent Peer Review of USFWS's Draft Effects Analysis for the Operations Criteria and Plan's Biological Opinion, 2008* at 6 (AR at 008818) ("The Panel suggests that the use of predicted salvage of adult smelt should be normalized for population size. . . . Expressing salvage as a normalized index may help remove some of the confounding of the temporal trends during the baseline period.").

(2) Use of the Cumulative Salvage Index Shows That There Is No Statistically Significant Relationship Between OMR Flows and Adult Salvage for Flows Less Negative Than -6100 Cubic Feet per Second at the Very Least

62. To assess FWS's methods, I plotted a graph of the relationship between the cumulative salvage index (salvage rate) and the OMR flows for each year that was analyzed in the BiOp. In developing this graph, I used the cumulative salvage index data provided in the BiOp. *See, e.g.*, BiOp at 386 (AR at 000401). Because Figure B-13 uses salvage weighted OMR flows, which are not listed anywhere in the BiOp, I visually estimated a magnified version of the OMR flow curve in Figure B-13 and interpolated the data points for each year.

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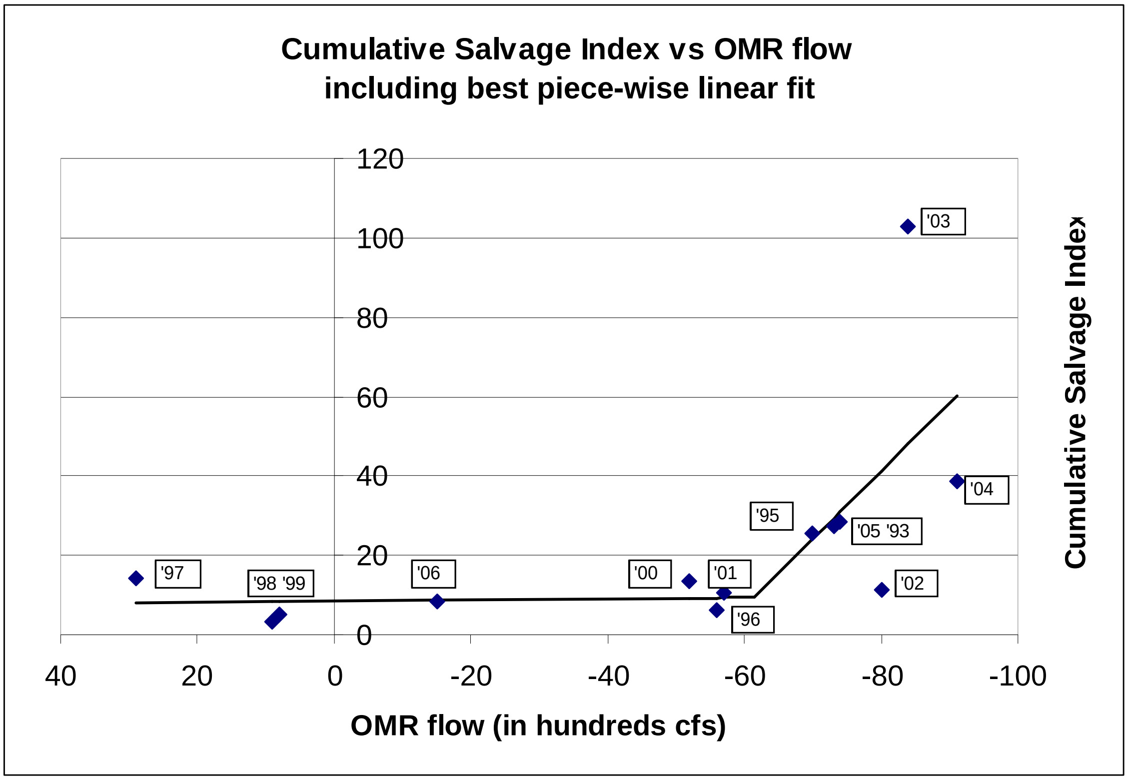

The Cumulative Salvage Index (Table B-2 & C-1) and corresponding Dec-Mar salvage weighted OMR (Figure B-13); note the salvage weighted OMR flows were visually estimated from Figure B-13. Years span 1993-2006 but exclude 1994 because that was also excluded in Figure B-13. A piece-wise linear model (the line on the figure) is also shown whose coefficients were obtained by the statistical procedure of maximum likelihood estimation.

63. The graph of salvage rate versus OMR flow shows that salvage rate remains flat as OMR flows increase until OMR flows reach -6100 to -7000 cubic feet per second ("cfs"). At -7000 cfs, salvage rate begins to increase as negative OMR flows increase. The graph demonstrates that OMR flows do not correlate to the salvage rate at flows less negative than -6100 cfs at the very least. I have determined that, based on the data available and using the appropriate reliable analytic method, there is no scientific basis for FWS's imposition of OMR flow restrictions at flows less negative than -6100 cfs (and potentially -7000 cfs). For additional technical detail, see Appendix 1 at Point 1.

64. As shown in the x-axis label on Figure B-13 (see ¶ 52 above), FWS used "Combined Flow in Old and Middle Rivers, in CFS (Weighted by Salvage)" to evaluate the relationship between OMR flows and salvage. "Weighted by Salvage" is not defined in the

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BiOp; however, a logical definition is that the salvage weighted average OMR flow is an average over several time periods, such as weeks, and the influence that a given week's OMR flow has on the overall average is set proportional to the salvage in that week.

65. FWS's October 29, 2009 FOIA response included daily OMR flow data (as opposed to the weighted average flows used in Figure B-13). I constructed December through March average OMR estimates based on the daily OMR flows provided by FWS. I modeled the relationship between the straight average OMR flows and the cumulative salvage index and confirmed that the results are consistent with those reached using the Figure B-13 weighted average flows. Using the straight average, the flows were not significant until a much more negative flow level (approximately -7943 cfs). The results are shown in Appendix 1 at Point 1.

B. The BiOp Fails to Evaluate Population Level Effects Using the Population Growth Rate – Interpreting the Data in This Way Shows That Salvage and OMR Flows Do Not Have a Statistically Significant Effect on the Population Growth Rate

66. Given the data in FWS's possession, and given its goal of evaluating the projects' effect on the total population, the appropriate analysis is to use that data to evaluate the effect on the population from year to year. This includes interpretation of the data to determine the effect of salvage (or more generally, population removals) on the population growth rate by application of a life-cycle model, as is standard practice in fisheries stock assessment. This approach is confirmed by the authors of widely read and accepted texts, which discuss the reliable methods of undertaking these analyses. *See, e.g.*, Quinn & Deriso (1999) at ch. 2; Hilborn & Walters (1992) at ch. 8. The population growth rate represents the relative increase or decrease in adults from one year to the next, which is a full life-cycle approach. Owen-Smith (2007) at 28. This approach is critical for evaluating the species' potential for recovery in that it measures the population's ability to rebound from year to year. *See, e.g.*, Bennett (2005) at 41 ("Population modeling may be the best way to evaluate the potential impacts of water export operations relative to other sources of mortality.").

67. Interpreting the data to evaluate the effect of salvage on the population growth rate is necessary because the survival of the species at one life stage cannot necessarily be the basis

for population level conclusions. To evaluate the effects of salvage, one must look beyond a single phase of life (i.e., FMWT only) or even adults to juveniles (i.e., FMWT to TNS). A complete analysis requires an evaluation of trends from one year's FMWT to the next year's FMWT because mortality in one life stage may be offset by mortality in another life stage or it may be affected by density dependence (described below in ¶ 68). As noted by Bennett (2005) at 44, when discussing simulation results of a hypothetical population model for delta smelt, "These results show how export mortality could be easily offset or masked by very small changes in mortality at other life stages." A generation-to-generation analysis eliminates or reduces the risk that population level conclusions will be drawn based on mortality effects in one life stage or the apparent change in mortality effects due to offsets in another life stage.

68. Delta smelt appear to exhibit reduced population growth when population abundance is high due to density dependence. Density dependence can occur through many mechanisms, as described by Ricker (1975) at 280: "Although cannibalism of young by adults is possible in many species, it is likely that the effect of parental stock density upon recruitment is usually exerted *via* the density of the eggs or larvae they produce, survival of the latter being affected by density-dependent competition for food or space, compensatory predation, etc." Thus, density dependent effects must be taken into account when evaluating the population growth rate. Density dependence terms are present in all major stock production, biomass dynamic, and stock-recruitment models, including the Ricker model. *See* Quinn & Deriso (1999) at chs. 2, 3.

69. Standard practice dictates that population level conclusions should not be based solely on raw salvage numbers. Rather, a fish population dynamicist should evaluate population level effects using the cumulative salvage index (salvage rate), and also evaluate the effect of the cumulative salvage index on the population growth rate, just as is typically done with harvest rates. As noted by Bennett (2005) at 37, "In several respects, losses to the water export facilities are analogous to harvest in a fishery, with the main exception that 'harvest' in this case includes all life stages (except eggs)." Harvest rates are routinely evaluated for their population level effects, and their consequence to population growth levels over time, in fisheries stock

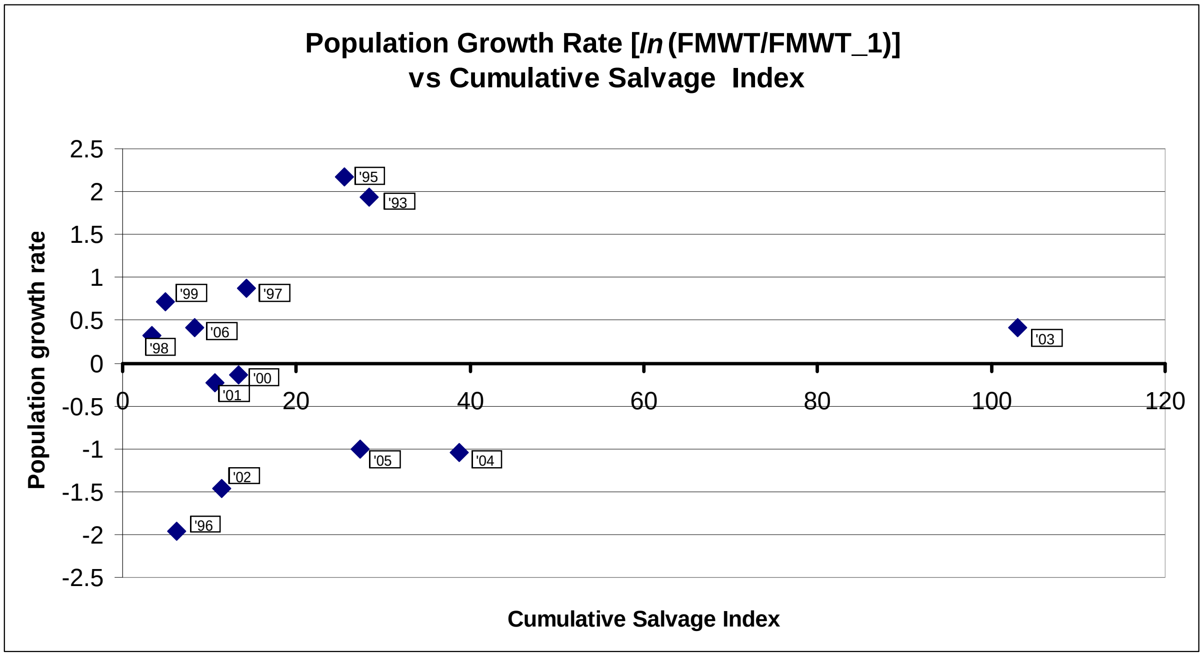
evaluations. *See, e.g.*, Quinn & Deriso (1999) at ch. 2; Hilborn & Walters (1992) at ch. 8. Only by looking at population level effects can it be determined whether salvage is impacting the delta smelt population and its ability to recover in a statistically significant way.

70. Through my review of the modeling and analysis in the BiOp, I determined that FWS did not apply a life-cycle approach in the BiOp. FWS did not attempt to evaluate the effect of the projects on the population growth rate. The BiOp completely omits any analysis or conclusions about project effects on the overall life cycle of the delta smelt and its ability to recover from year to year. However, the data to perform such an analysis is all available, and evaluating population growth rate effects is an elementary exercise. When I looked at the data for such effects, I readily recognized that there is no statistically significant relationship between salvage and the population growth rate.

(1) Adults – Salvage

71. Applying standard principles to calculate population level effects, and using the correct variable to determine those effects (the salvage rate), I modeled the relationship between the cumulative salvage index and the population growth rate. The life-cycle model used for this analysis is a standard Ricker stock-recruitment model in which consecutive year FMWT estimates take the role of stock and recruitment, respectively. I used the cumulative salvage index data taken from the BiOp itself. *See* BiOp at 386 (AR at 000401).

72. The output of this standard model shows that there is no statistically significant relationship between salvage and the population growth rate. This demonstration is based upon using 0.05 as the significance level—the standard benchmark in applied statistics for determining a significance level. *See, e.g.*, Sigler, S., *Fisher and the 5% Level*, 21:4 Chance, Springer New York (Dec. 2008). Statistical significance is found when the p-value is less than 0.05. The p-value is the probability that the result obtained in a statistical test is due to chance rather than a true relationship between variables. In the analysis that I performed, the p-value was 0.76, which is greater than the benchmark and thus not statistically significant. *See* Appendix 1 at Point 2 for additional technical detail. The population growth rate and cumulative salvage index are depicted in the graph below as a visual aid.

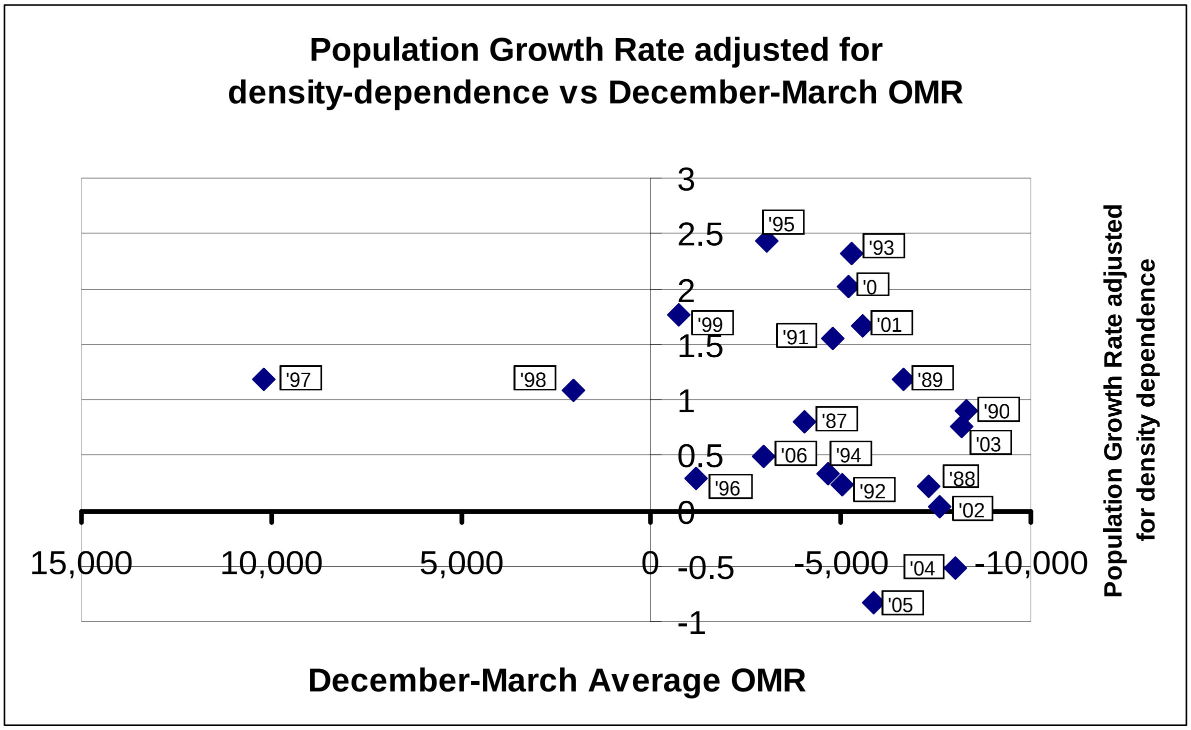


73. If the cumulative salvage index had a strong negative effect on population growth, the above graph would have been expected to show a pronounced negative slope. Instead, the graph shows no trend in population growth rate as the salvage rate increases. If the population has a growth rate of zero, then the population is neither increasing nor declining. A positive growth rate means the population is increasing on an annual basis, and a negative growth rate means the population is declining on an annual basis. Here, the population growth rate did not trend in a negative direction as the cumulative salvage index increased, so there is no statistical basis to conclude that cumulative salvage has a negative population level effect within the range of cumulative salvage index levels historically observed.

(2) Adults – OMR Flows

74. I conducted a second analysis to evaluate the relationship between December-March average OMR flows and the population growth rate. I calculated the average flows using the daily OMR flow data from the October 29, 2009 FOIA request. Using a standard Ricker stock-recruitment model and the standard 0.05 significance level, I found that the relationship between March-December OMR flows and the population growth rate is not statistically significant. The p-value is 0.321, which is above the significance level of 0.05. The modeling

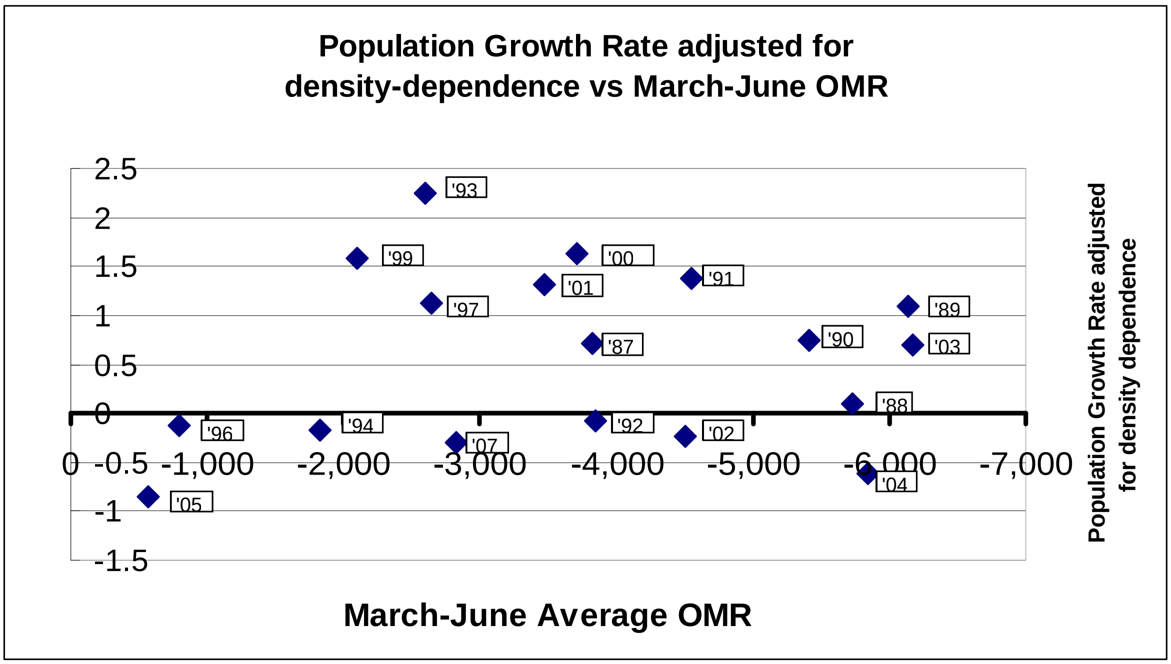
results are shown below as a visual aid. Thus, here too, there is no statistical basis to conclude that the OMR flows cause a negative population level effect within the range of December-March average OMR flows historically observed. For additional technical detail, see Appendix 1 at Point 3.



(3) Juveniles

75. The BiOp includes entrainment estimates for larval-juvenile delta smelt based on the work of Kimmerer (2008), who in turn bases those estimates on a method in which the assumption is made that entrainment is proportional to the southward OMR flow. I tested whether or not average southward OMR flow during the larval/juvenile salvage months of March through June could explain a statistically significant amount of the variation in population growth. I used the Ricker model again as a life-cycle model. March-June average OMR flow for years during the time span 1987 through 2007 in which the average flow was negative (that excluded years 1995, 1998, and 2006) was entered as a candidate explanatory variable and regression analysis was used to test whether or not the candidate variable was statistically significant. A starting year of 1987 was used because that is the starting year used in the BiOp, as data from that year forward "represents current delta smelt population dynamics." *See* BiOp at

236 (AR at 000251). Results show that March-June average OMR does not have a statistically significant impact on smelt population growth rate (the p-value is 0.703, which is above the significance level of 0.05). For additional technical detail, see Appendix 1 at Point 4. Even if entrainment of larval/juvenile smelt is related to spring OMR flow, that entrainment does not have a statistically significant impact on population growth. The result can be seen visually in the graph below which shows that variation in population growth rate (adjusted for density dependence) is not explained by the average March-June OMR flow.



76. March-June OMR does not negatively impact population growth, as can be seen visually in the graph above, where even at the most negative observed average OMR flows, the population growth rate was positive (irrespective of whether a density dependent adjustment is made). For additional technical detail, see Appendix 1 at Point 4. This result implies that there is no scientific justification for proposed RPA Action 3.

C. The Model Used in FWS's Analysis to Compare the Effect of Fall X2 on Population Survival Is Biologically Implausible and Potentially Misleading – It Is Simply Inappropriate for Fish Population Dynamics Modeling

77. FWS used statistical modeling to demonstrate an alleged relationship between Fall X2 and delta smelt abundance. The modeling and analysis are contained in the Effects of the

Proposed Action section of the BiOp, pages 233-238 and 265-274 (AR at 000248-000253 and 000280-000289), and in RPA Action 4 in Attachment B to the BiOp, pages 369-376 (AR at 000384-000391). FWS relied on various studies, particularly the work of Feyrer et al. in a 2007 article, *Multidecadal Trends for Three Declining Fish Species: Habitat Patterns and Mechanisms in the San Francisco Estuary, California, USA* (AR at 018266) and a draft 2008 manuscript, *Modeling the Effects of Water Management Actions on Suitable Habitat and Abundance of a Critically Imperiled Estuarine Fish (Delta Smelt* Hypomesus transpacificus) (AR at 018278); a 2005 article by Bennett, *Critical Assessment of the Delta Smelt Population in the San Francisco Estuary, California* (AR at 017004); a 2008 report by Baxter et al., *Pelagic Organism Decline Progress Report: 2007 Synthesis of Results* (AR at 016922); and a 2008 article by Nobriga et al., *Long-Term Trends in Summertime Habitat Suitability for Delta Smelt,* Hypomesus transpacificus (AR at 019940).

(1) FWS Used a Linear Additive Model

78. FWS used a linear additive model to demonstrate an alleged relationship between Fall X2 and delta smelt abundance. The model finds that juvenile abundance, as measured by the TNS, is equal to the sum of a constant number plus the previous year's FMWT index (times a constant number), less X2 (times a constant number). *See* BiOp at 268 (AR at 000283) (Figure E-22). Essentially, this calculation finds that A = B + C - D.

79. FWS followed the linear additive model developed by Feyrer et al. (2007), which claims that Fall X2 has a population level effect. This model runs counter to well-accepted, basic modeling principles for this type of calculation. When analyzing the effect of Fall X2, FWS also cites to a 2005 article by Bennett. *See* BiOp at 236 (AR at 000251). However, Bennett applies a well-established stock-recruit model, namely, the Beverton-Holt model, and an alternative linear multiplicative model. *See* Bennett (2005) at 28-29.

80. The linear additive model produces the result that zero adults in one year could still yield some young in the following year, a result that is biologically implausible. Using the simple translation A (juveniles measured in TNS) = B (constant) + C (adults measured in FMWT) – D (Fall X2), one can see that, if C were set at zero (no adult spawners), B – D could still

produce a positive number for A (juveniles). This model thus has the biologically impossible property of generating juveniles from zero adults.

81. A linear additive model also treats the environmental factor X2 as an additive factor, which has the implausible property of reducing the absolute numbers of juveniles by the same quantity for a given value of X2 irrespective of the total population. For example, if X2 is set at a certain value such that when X2 is added, 1,000 juveniles are lost, that model would produce the result that 1,000 juveniles are always lost irrespective of the total number of juveniles present or the total number of juveniles that actually respond to X2.

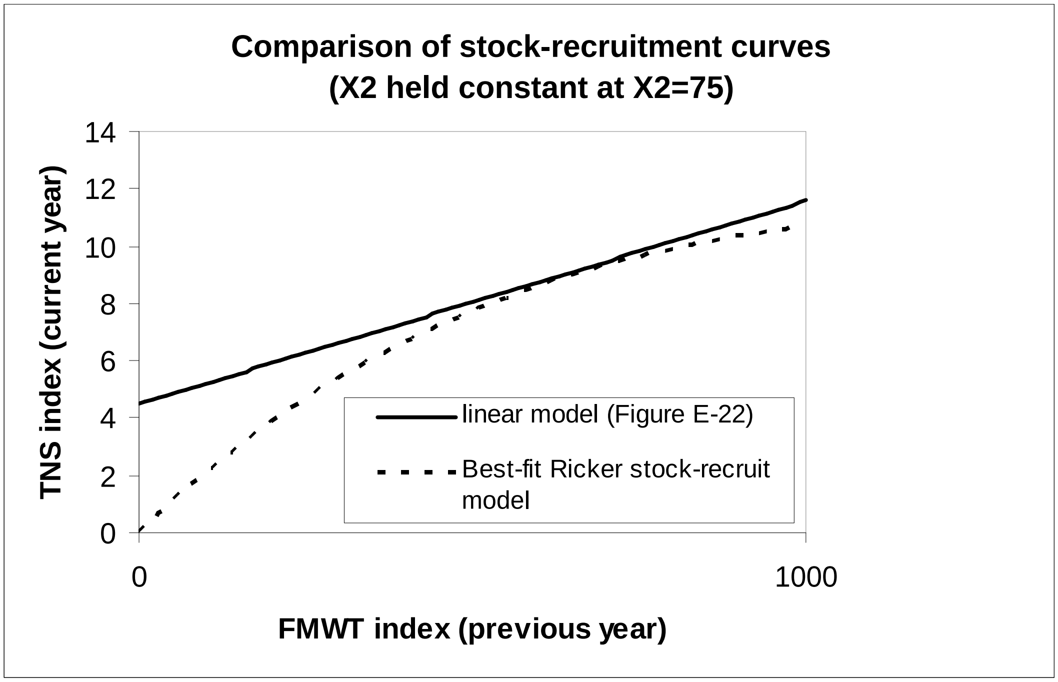
82. For reasons such as these, a linear additive model is inappropriate for stock-recruitment modeling, because the results are biologically impossible.

(2) FWS Should Have Used a Multiplicative Stock-Recruit Model

83. FWS inappropriately used a linear additive model to conduct the analysis that FWS performed with respect to the effect of Fall X2 on population survival. It is well established by those scientists qualified to conduct the type of analysis undertaken by FWS that a multiplicative stock-recruitment should be used. A multiplicative stock-recruit model better reflects actual biological realities when modeling fish populations because it describes survival of a year-class of fish. An example is the Leslie Matrix population model (equation 7.2 in Quinn & Deriso (1999) at 269). Survival processes are inherently multiplicative because the fraction of individuals that survive to a given age is given by the product of daily survivals through each day since the day of birth (*see, e.g.*, cumulative survival in Quinn & Deriso (1999) at 292). A commonly used, well known multiplicative stock-recruit model is the Ricker model. A qualified scientist in this field would be familiar with this model and would have no difficulty using it to perform the analysis that FWS did.

84. Any reliable, scientifically accepted stock-recruit model, such as the Ricker model or the Beverton-Holt model, is not a linear additive model. Such multiplicative stock-recruit models produce the biologically appropriate result that zero adults yields zero young. Thus, regardless of the presence of other factors, if there are zero adult spawners, there will be zero juveniles the following year. A graphical depiction of the difference between a multiplicative

model, such as the Ricker model, and a linear additive model is helpful to illustrate how a multiplicative model better reflects biological reality.



85. A multiplicative model, as opposed to an additive model, yields the sensible result that varying an environmental factor such as X2 will elicit a proportional response in population abundance. This is appropriate for a factor that affects survival because survival is, by definition, a fraction (what proportion of the population survives). In contrast, the linear additive model produces an absolute response irrespective of the size of the population. Multiplicative models are appropriate when describing the survival of a given cohort of fish. Additive terms may be appropriate components in certain types of cohort models when tracking the absolute abundance of a cohort over time—i.e., in situations that involve calculating the total raw population numbers over time, an exercise that has not been done for the delta smelt. *See* Quinn & Deriso (1999) at 323.

86. The BiOp itself questions the use of a linear additive model to evaluate the effect of Fall X2, stating that "some type of transformation of the data would help to define a better fitting model," but declines to correct the situation (such as through the use of a multiplicative model). BiOp at 236 (AR at 000251).

87. The Peer Review also criticized the linear additive model, finding that "[t]he [Effects Analysis] points out that the residuals from this analysis are not normally distributed and that some transformation might be required. We suspect that a few of the data points may have high influence on the outcome. These results together suggest that the model may be inappropriate for the data being used." *Independent Peer Review of USFWS's Draft Effects Analysis for the Operations Criteria and Plan's Biological Opinion, 2008* at 7 (AR at 008819).

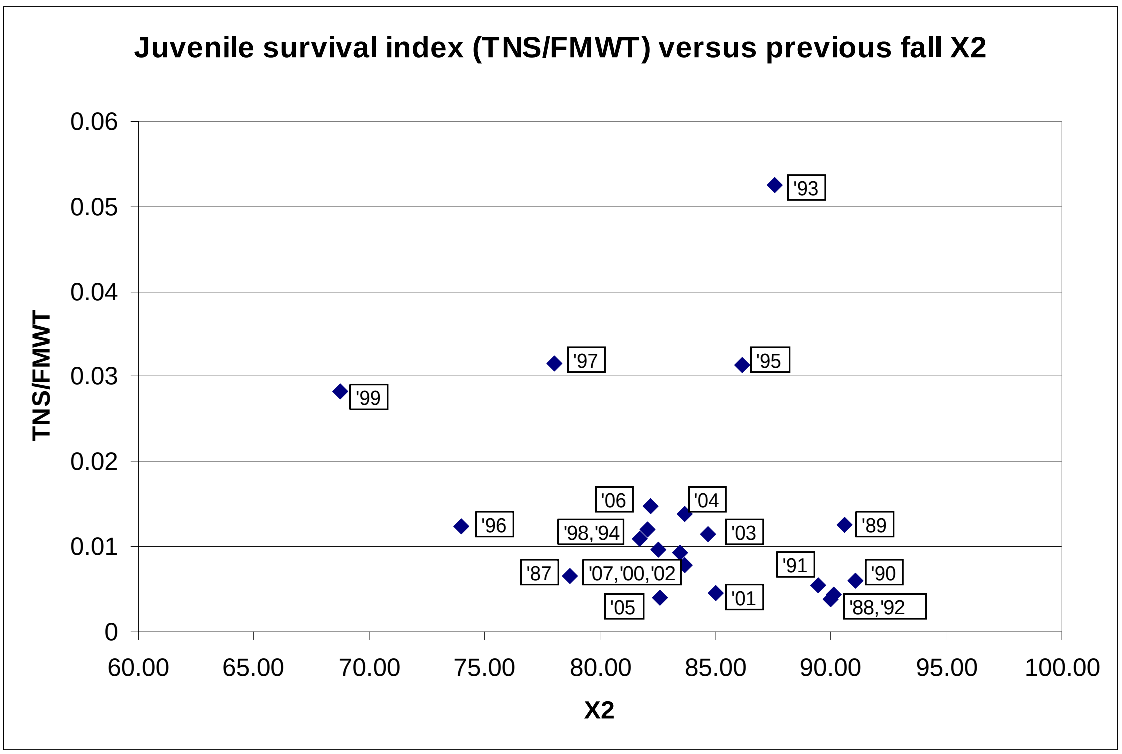
88. During my review of FWS's analysis, I plotted a stock-recruit curve of the relationship between FMWT (previous year) and TNS (current year) using the standard Ricker stock-recruitment model that was obtained by fitting the model to data. See details in Appendix 1 at Point 5. A visual comparison of the linear additive model that FWS used in the BiOp against the Ricker model is shown above. As shown on the comparison, when FMWT is set at zero in the linear model that FWS used, TNS is above zero. In contrast, when FMWT is set at zero in the standard Ricker model, TNS is also zero.

89. In order to evaluate whether there is a relationship between Fall X2 and abundance, I used the publicly available FMWT and TNS data and publicly available Fall X2 data in a standard Ricker stock-recruit model.[5] After employing the Ricker stock-recruit model, I was able to determine that there is no statistically significant relationship between Fall X2, stock abundance, and recruit abundance. The p-value for Fall X2 is 0.059, which is greater than the benchmark significance level of 0.05. See Appendix 1 at Point 5 for additional technical detail. The contrary conclusion that FWS reached is due to its improper use of a biologically implausible linear additive model.

90. I determined that the density dependent term in the Ricker model was not statistically significant. As a result, I used a reduced survival model that omitted the density

[5] FMWT data is available at: http://www.delta.dfg.ca.gov/data/mwt/charts.asp. The BiOp cites to http://www.delta.dfg.ca.gov as a source for FMWT data at page 143 (AR at 000158). TNS data is available at: http://www.delta.dfg.ca.gov/data/projects/?ProjectID=TOWNET. The BiOp cites to this website as a source for TNS data at page 300 (AR at 000315). Fall X2 data is available at: http://www.iep.ca.gov/dayflow/output/index. The BiOp relied on CALSIM modeling to calculate X2 values, and cites to http://www.iep.ca.gov/dayflow for "historical hydrologic data provided in the DAYFLOW database" which was used in the CALSIM modeling. *See* BiOp at 204, 235 (AR at 000219, 000250).

dependent term. The result shows that Fall X2 term is not statistically significant, since the p-value of 0.094 is greater than the 0.05 significance level. The graph below is included as a visual aid to show that there is no relationship between an index of juvenile survival ("TNS/FMWT_1") and Fall X2. If there had been a strong negative effect of Fall X2 on juvenile survival, the graph would have been expected to show a pronounced negative slope. Instead, the graph shows no trend in juvenile survival as X2 increases. For additional technical detail, *see* Appendix 1 at Point 5.



(3) Use of a Scientifically Appropriate Multiplicative Model Shows That Fall X2 Has No Statistically Significant Effect on the Population Growth Rate

91. In my review of the BiOp, I determined that FWS did not evaluate the effect of Fall X2 on the population growth rate. Use of the population growth rate would enable FWS to evaluate effects on the full life-cycle of the delta smelt.

92. Instead of carrying forward the linear additive model, as did FWS, the proper scientific method is to model the relationship between Fall X2 and the population growth rate

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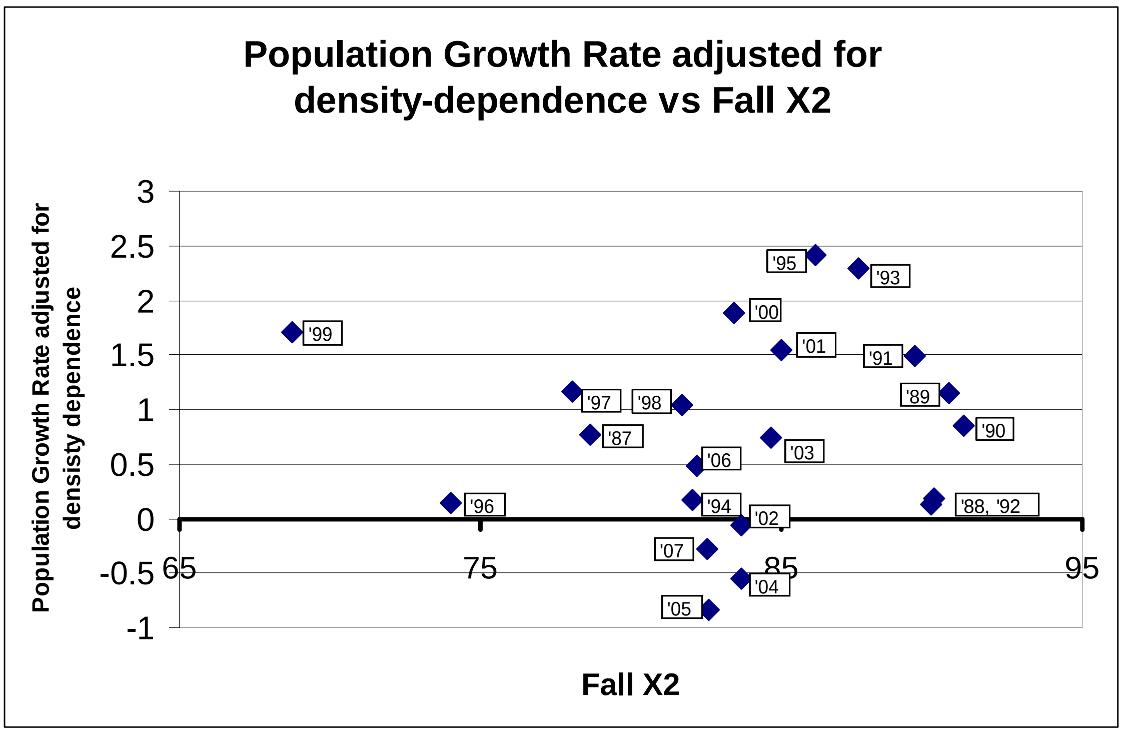
using a multiplicative model. As explained above, a multiplicative model is the scientific standard for fish population dynamics.

93. I used a Ricker model, which is a multiplicative model, to calculate the population growth rate and to evaluate the relationship between Fall X2 and the population growth rate with the regression method described in Appendix 1 at Point 6. I adjusted for density dependence in the modeling. In this application, I determined that the density dependent term in the Ricker model was statistically significant. Thus, the population growth rate had to be adjusted to account for these effects so that the potential effect of Fall X2 could be isolated. For additional technical detail, see Appendix 1 at Point 6. This relationship, adjusted for density dependence, is depicted below.



94. My application of a multiplicative Ricker life-cycle model demonstrates that Fall X2 does not have a statistically significant effect on the population growth rate. As Fall X2 increases, the population growth rate varies randomly. Taken together with the modeling I performed above (comparing Fall X2 to abundance, see ¶ 89) and statistical analysis of the regression estimates, this means that Fall X2 does not have a statistically significant effect on population abundance in a given water year (adults to juveniles), or on the full life-cycle of the

delta smelt (adults to adults). Since FWS's imposition of Fall X2 restrictions in RPA Action 4 is based upon its erroneous use of the wrong model—which, in turn, has led to the incorrect result that Fall X2 has population effects on the delta smelt—it is scientifically unjustified.

D. FWS's Incidental Take Analysis Is Improperly Influenced by Unrepresentative Data Points That Even FWS Rejected for Other Purposes

(1) FWS's Adult Incidental Take Analysis Is Improperly Influenced by an Unrepresentative Data Point

95. FWS's adult incidental take analysis can be found in Attachment C to the BiOp, pages 382-396 (AR at 000397-000411). In developing the incidental take limit for adult entrainment, FWS relied on a series of statistical analyses and calculations in the BiOp and in Kimmerer (2008).

96. The incidental take limit is set at 7.25 times the prior year's FMWT index of adult abundance. BiOp at 386 (AR at 000401). The 7.25 figure represents the average salvage rate from only three years—2006, 2007, and 2008. *See* BiOp at 385-86 (AR at 000400-000401). The BiOp uses the average salvage rate for these three years as a predictor of take levels during each year that the RPAs will be in effect. Although salvage data is analyzed dating back to 1993, the BiOp claims that "these years [2006 through 2008] within the historic dataset best approximate expected salvage under the RPA Component 1," which restricts OMR flows. *Id.*

97. The BiOp lists the annual salvage numbers and salvage rates for the years 1993-2008, and shows that the salvage in 1994 and 2007 were extremely low compared to the other years and to 2006 and 2008 in particular. *See* BiOp at 386 (AR at 000401) (Table C-1). The cumulative salvage index is just 0.88 for 2007, compared to 8.3 for 2006 and 12.6 for 2008. *Id.*

98. In my review, I searched for additional information regarding the conditions that might have contributed to these salvage levels. In another section of the BiOp, I discovered that FWS had considered the salvage level in 2007 as ***unusable*** for purposes of analyzing salvage and OMR flows due to that year's low average water turbidity. *See* BiOp at 348 (AR at 000363) (Figure B-13, Note). The low turbidity explains why salvage in 2007 was extremely low, as turbidity is a strong indicator of presence or absence of delta smelt near the project facilities.

Lower turbidity means fewer fish will be present and, accordingly, fewer fish are capable of being entrained. Thus, FWS recognized that the unusual conditions in 2007 made it an unrepresentative year that would skew its analysis. For FWS to then go ahead and use that salvage level in the incidental take equation is scientifically unjustified.

99. Without the year 2007 factored into the equation, the take coefficient increases from 7.25 to 10.45, which lies within the range of historical estimates based on the figure shown in ¶ 62 above for flows less negative than -7000 cfs. This figure represents the average of the salvage indices in 2006 and 2008, and would significantly increase the permissible take level. FWS's calculation should be corrected to remove the outlier year of 2007.

(2) FWS's Larval/Juvenile Incidental Take Analysis Is Improperly Influenced by an Unrepresentative Data Point

100. FWS's larval/juvenile incidental take analysis can be found in Attachment C to the BiOp, pages 382-396 (AR at 000397-000411). To calculate the incidental take limit for larval/juvenile entrainment, FWS largely followed the same methodology that it used for adults. BiOp at 389 (AR at 000404).

101. The incidental take limit is set at 1.5 times the Concern Level for larvae and juveniles. The Concern Level is equivalent to the average monthly juvenile salvage index from 2005-2008 times the current water year FMWT of adult abundance. BiOp at 390 (AR at 000405). Combining these two formulae, the incidental take limit can be calculated by multiplying 1.5 times the average monthly juvenile salvage index times the FMWT. Only four years are considered – 2005, 2006, 2007, and 2008.

102. The BiOp lists the annual salvage numbers and salvage rates for the years 1995-2008, and shows that the salvage in 2006 was extremely low compared to all other years, with the exception of 1995 and 1998 (see discussion below). *See* BiOp at 392 (AR at 000407) (Table C-4). The juvenile salvage index is just 0.4, compared to 23.4 for 2005, 65.1 for 2007, and 60.9 for 2008. *Id.*

103. In my review of the BiOp, I searched for additional information that might explain the conditions that were present in these years and how they contributed to salvage levels. I was

provided with daily OMR flow data through a FOIA request to FWS. I discovered that in 2006, average OMR flow was strongly positive for the months April through June, the first three (of four) months during which the monthly juvenile salvage index is calculated. OMR flow was negative in July 2006, but typically, very few fish are salvaged in July. *See, e.g.,* BiOp at 391 (AR at 000406) (Figure C-3) (showing that cumulative salvage reaches a plateau in July).

104. When analyzing the effects of OMR flows on salvage in the Effects Analysis section of the BiOp, FWS explained that "net OMR flow generally works very well as a binary switch: negative OMR flow is associated with some degree of entrainment, while positive OMR flow is usually associated with no, or very low, entrainment." BiOp at 163 (AR at 000178). The juvenile salvage index is reported in the BiOp for the years 1995-2008. BiOp at 392 (AR at 000407). During that time, there were three years when salvage was nearly zero – 1995, 1998, and 2006. These are the only three years when OMR flow was positive. *See* BiOp at 254 (AR at 000269) (Figure E-8). Thus, FWS's statement that positive OMR flow yields zero or very low salvage is supported by historical measurements of juvenile salvage and OMR flow. It also undermines FWS's decision to include one of those years – 2006 – in the incidental take equation.

105. Without the year 2006 factored into the equation, the average juvenile salvage index increases, which necessarily increases the Concern Level (monthly juvenile salvage index times FMWT) and the incidental take level (1.5 times Concern Level). The incidental take level increases by approximately 32-33 percent in May, June, and July, and decreases by approximately 14 percent in April (when salvage is low). Overall, in the months with the highest salvage, removal of the unrepresentative year 2006 significantly increases the take level. FWS's calculation should be corrected to remove the year 2006, which had positive OMR flow.

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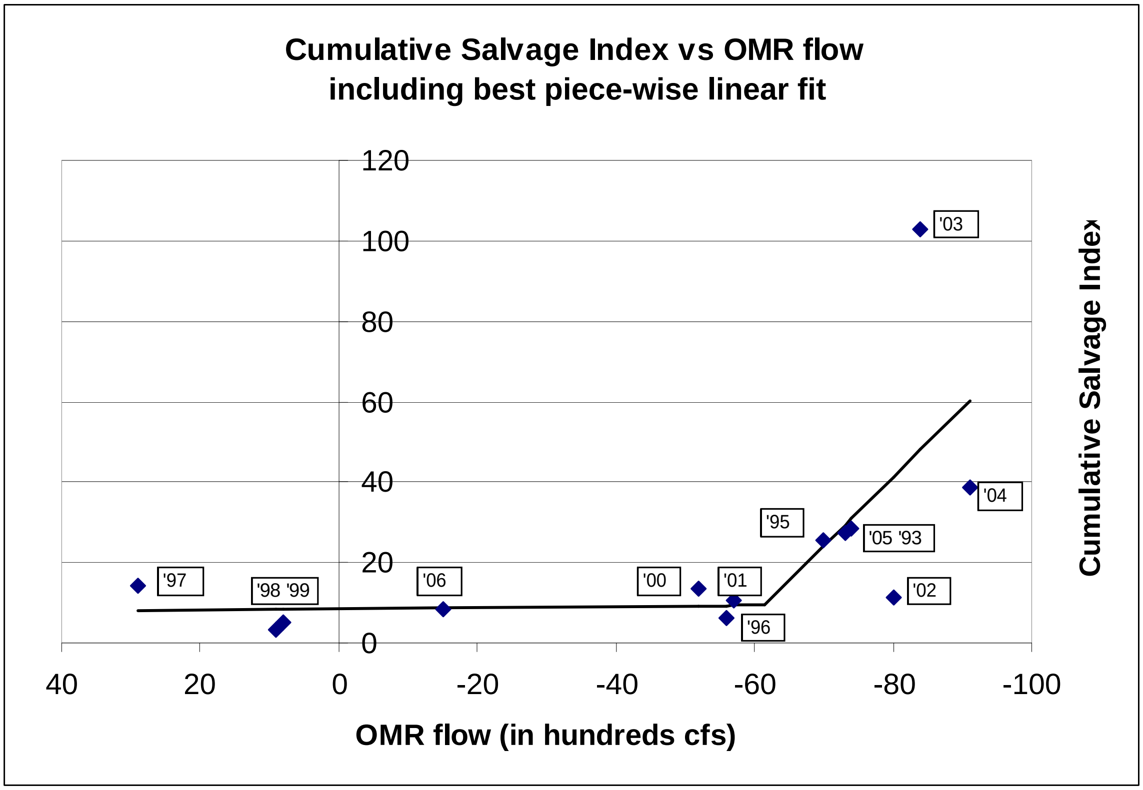
I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this declaration was executed on November 13, 2009 at St. Thomas, U.S. Virgin Islands.

RICHARD B. DERISO, Ph.D.

Appendix

Appendix 1: Supporting Technical Details to Analyses Described in "Declaration of Dr. Richard B. Deriso"

Point 1.



The Cumulative Salvage Index (Table B-2 & C-1) and corresponding Dec-Mar salvage weighted OMR (Figure B-13); note the OMR estimates were visually estimated from Figure B-13. Years span 1993-2006 but exclude 1994 because that was also excluded in Figure B-13.

Year	OMR	Cumulative Salvage Rate Index
1993	-74	28.4
1995	-70	25.5
1996	-56	6.27
1997	29	14.3
1998	9	3.39
1999	8	4.94
2000	-52	13.34
2001	-57	10.6
2002	-80	11.4
2003	-84	103
2004	-91	38.8
2005	-73	27.3
2006	-15	8.3

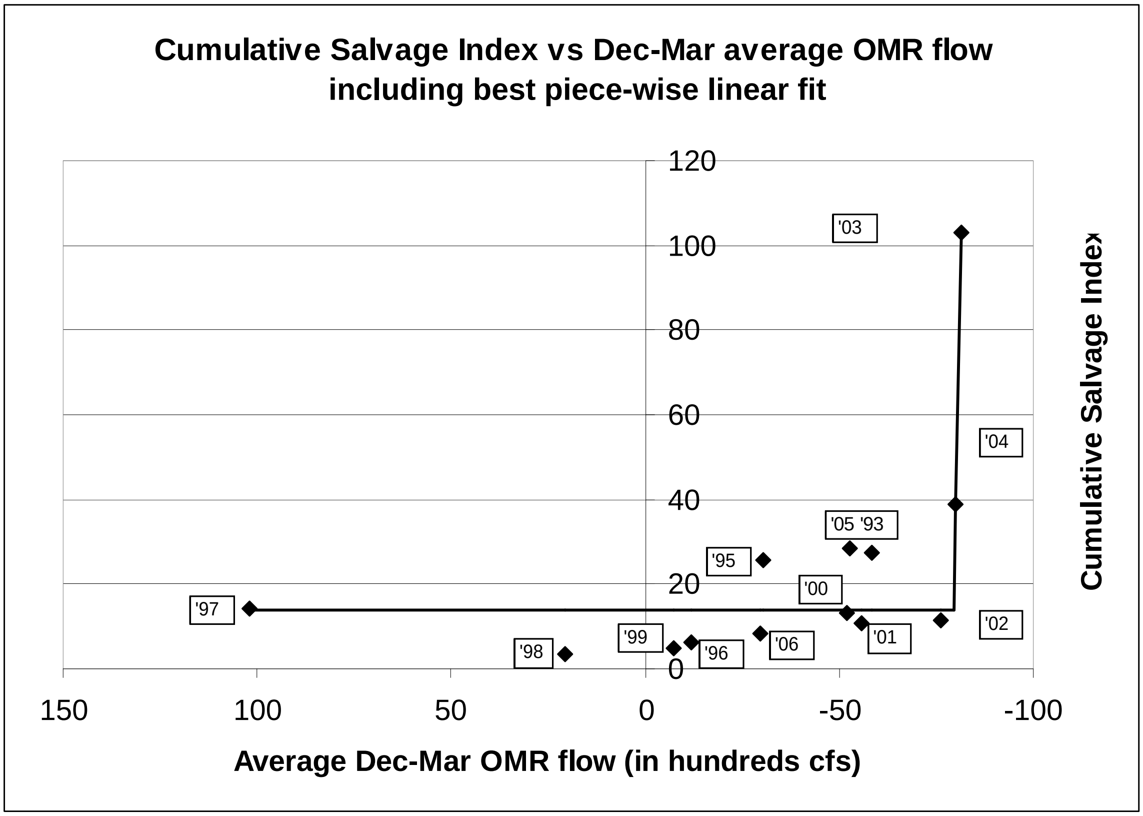
A piece-wise linear model was fit to the data above by minimizing the squared residuals between predicted and observed salvage rates. A logistic switch point was made part of the equation as an approximation to a 0/1 switch governing which piece of the model was appropriate for a given OMR. The best-fit regression equation is given as

$$Y = p[60.25 - 1.72(OMR+91)] + (1-p)[9.38 - .015(OMR+61.386)]$$

where p = 1 if OMR < -61.386 and p=0 otherwise and Y is the predicted salvage rate

Another set of OMR data was examined in relation to the cumulative salvage index. The second set of OMR flow data is the average December-March OMR flow. Daily OMR flow data were provided by FWS to the Metropolitan Water District of Southern California pursuant to a Freedom of Information Act request which were used to calculate several average OMR flows shown in this Appendix. A graph of salvage versus December-March average OMR flow is listed in Figure E-1 of the BiOp.

Year	Average Dec-Mar OMR flow (100's cfs)	Cumulative Salvage Index
1993	-52.798	28.4
1995	-30.315	25.5
1996	-11.817	6.27
1997	101.887	14.3
1998	20.465	3.39
1999	-7.402	4.94
2000	-51.784	13.34
2001	-55.587	10.6
2002	-76.153	11.4
2003	-81.611	103
2004	-80.045	38.8
2005	-58.584	27.3
2006	-29.757	8.3

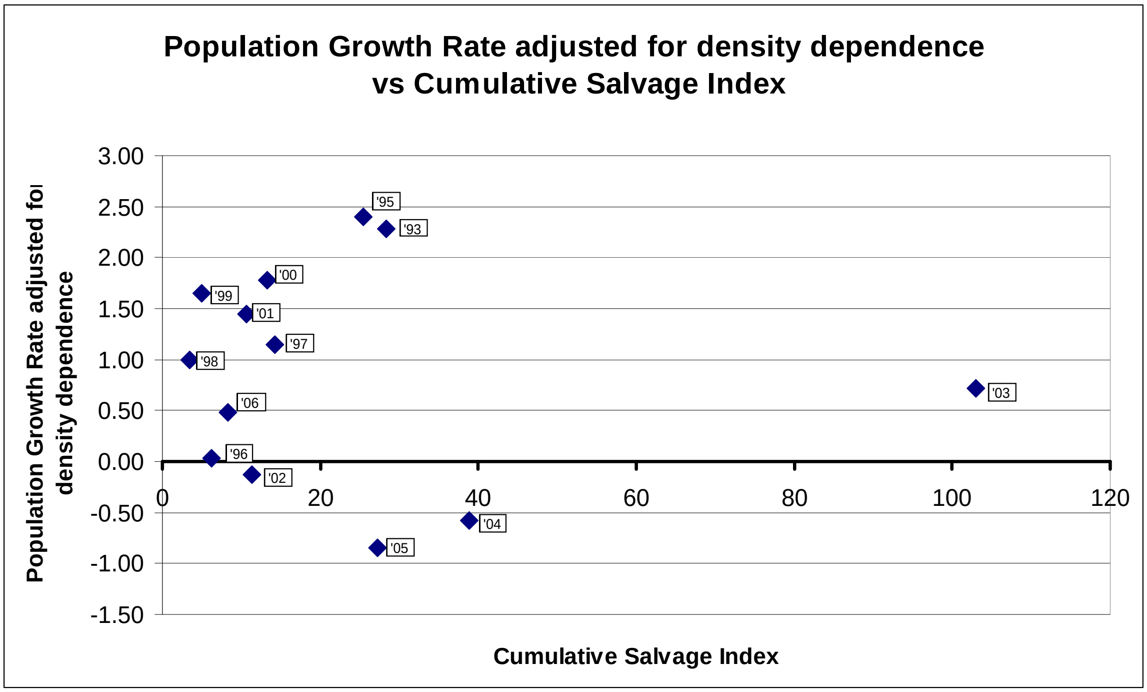


A piece-wise linear model was fit to the data above by minimizing the squared residuals between predicted and observed salvage rates. A logistic switch point was made part of the equation as an approximation to a 0/1 switch governing which piece of the model was appropriate for a given OMR. The slope of the linear piece of the model prior to the switch point was tested for statistical significance. The slope was not significantly different from zero so a piece-wise linear model with zero slope is chosen as the better model as shown in the figure above. The statistical test is based on a likelihood ratio test: The quantity 2*(change in logarithm of likelihood when going from the simple zero-slope model to more complex non-zero slope model) = 1.18, which falls short of the cut-off value of 3.84, which is the 5% significance level for a chi-square test statistic with one degree of freedom (Mood, A et al., *Introduction to the Theory of Statistics*, McGraw-Hill, Inc. (1974)). The switch-point occurs at average Dec-Mar OMR flows of -7,943 cfs. The best-fit regression model is

$$Y = p[102.99 - 40.92(OMR+81.611)] + (1-p)[13.977]$$

where $p = 1$ if $OMR < -79.436$ and $p=0$ otherwise and Y is the predicted cumulative salvage index

Point 2.



Year	Cumulative salvage index	S= FMWT year-1	*ln*(R/S) = ln(FMWT_0/FMWT_1)	Population growth rate adjusted for density-dependence
1993	28.4	156	1.93	2.28
1995	25.5	102	2.18	2.40
1996	6.27	899	-1.96	0.03
1997	14.3	127	0.87	1.15
1998	3.39	303	0.33	1.00
1999	4.94	420	0.72	1.65
2000	13.34	864	-0.13	1.78
2001	10.6	756	-0.23	1.45
2002	11.4	603	-1.47	-0.13
2003	103	139	0.41	0.72
2004	38.8	210	-1.04	-0.58
2005	27.3	74	-1.01	-0.84
2006	8.3	27	0.42	0.48

SUMMARY OUTPUT

ln(FMWT/FMWT_1)=a+b*cumulative salvage index+c*FMWT_1

Regression Statistics	
Multiple R	0.5387
R Square	0.2902
Adjusted R Square	0.1483
Standard Error	1.1390
Observations	13

ANOVA

	df	*SS*	*MS*	*F*
Regression	2	5.3046	2.6523	2.0445
Residual	10	12.9728	1.2973	
Total	12	18.2774		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.9687	0.6714	1.4428	0.180
cum. salvage index	-0.0041	0.0134	-0.3053	0.766
FMWT year-1	-0.0022	0.0011	-1.9665	0.078

The analysis was made by first applying a logarithmic transformation to the Ricker model to obtain equation (3.33) in Quinn and Deriso (1999), which is then treated as a multiple linear regression equation. The equation applied is shown in the table above. Statistical significance was determined using standard regession theory (Draper, N. and H. Smith. 1981. Applied Regression Analysis, 2nd edition. Wiley, New York). Population growth rate is defined as the logarithm of the ratio (R/S) (also defined as relative population growth rate, Owen-Smith (2007, p. 29), which is written as *ln*(R/S). Adding to *ln*(R/S) the estimated density-dependent term in a Ricker model (say c*S) one obtains the quantity "population growth rate adjusted for density-dependence."

Neither the cumulative salvage index nor the density-dependent term (FMWT year-1) are statistically significant (that is, P-values of 0.766 and 0.78, respectively, for the two terms are above the significance level of 0.05). The 0.05 significance level is a standard benchmark in applied statistics (Sigler, S. 2008. Fisher and the 5% level. Chance 21(4). Springer New York).

A reduced model was applied in which the only candidate explanatory variable was the cumulative salvage index. The reduced model was applied because the density-dependent term (FMWT year-1) was not statistically significant. The results confirm that the actual salvage rate was not statistically significant because the P-value of 0.419 is above the 0.05 significance level as seen in the results tabled below.

SUMMARY OUTPUT

ln(FMWT/FMWT_1)=a+b*cumulative salvage index

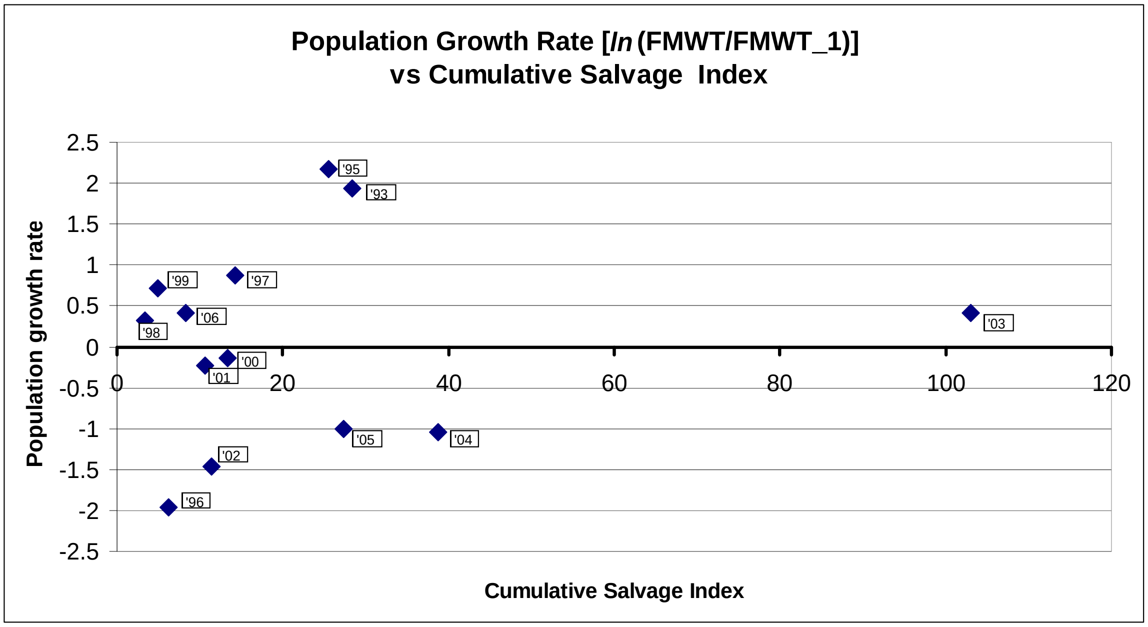
Regression Statistics	
Multiple R	0.125
R Square	0.016
Adjusted R Square	-0.074
Standard Error	1.279
Observations	13.000

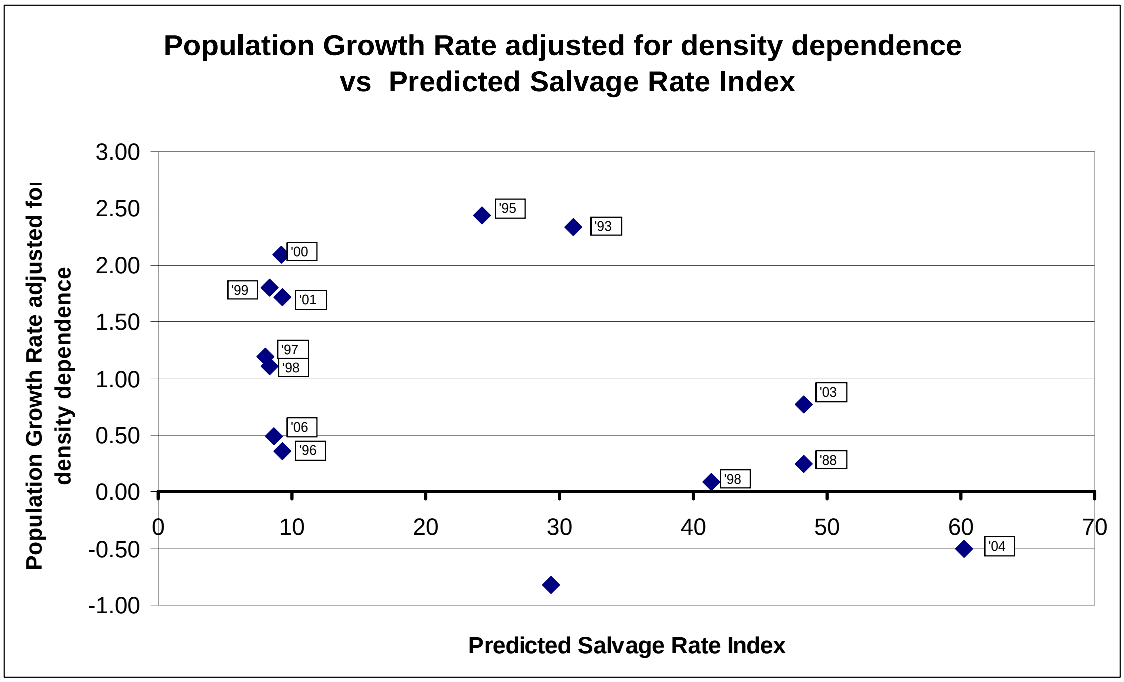
ANOVA

	df	*SS*	*MS*	*F*
Regression	1.000	0.288	0.288	0.176
Residual	11.000	17.990	1.635	
Total	12.000	18.277		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.055	0.476	-0.115	0.911
Cum. salvage index	0.006	0.014	0.419	0.683

As a visual aid, population growth rate and cumulative salvage index are graphed below. If there had been a strong negative effect of salvage index on population growth then the graph would have been expected to show a pronounced negative slope. Instead the graph shows no trend in population growth rate as the salvage index increases.





Year	Predicted salvage rate	*S* = FMWT year-1	*ln*(R/S) = ln(FMWT_0/FMWT_1)	Pop growth rate adjusted for density dependence
1988	48.23	280	-0.48	0.24
1993	31.05	156	1.93	2.33
1995	24.18	102	2.18	2.44
1996	9.30	899	-1.96	0.36
1997	8.00	127	0.87	1.20
1998	8.30	303	0.33	1.11
1999	8.32	420	0.72	1.80
2000	9.24	864	-0.13	2.09
2001	9.31	756	-0.23	1.72
2002	41.36	603	-1.47	0.08
2003	48.23	139	0.41	0.77
2004	60.25	210	-1.04	-0.50
2005	29.33	74	-1.01	-0.82
2006	8.67	27	0.42	0.49

SUMMARY OUTPUT

ln(FMWT/FMWT_1)=a+b* predicted salvage rate+c*FMWT_1

Regression Statistics	
Multiple R	0.652
R Square	0.425
Adjusted R Square	0.320
Standard Error	0.985
Observations	14.000

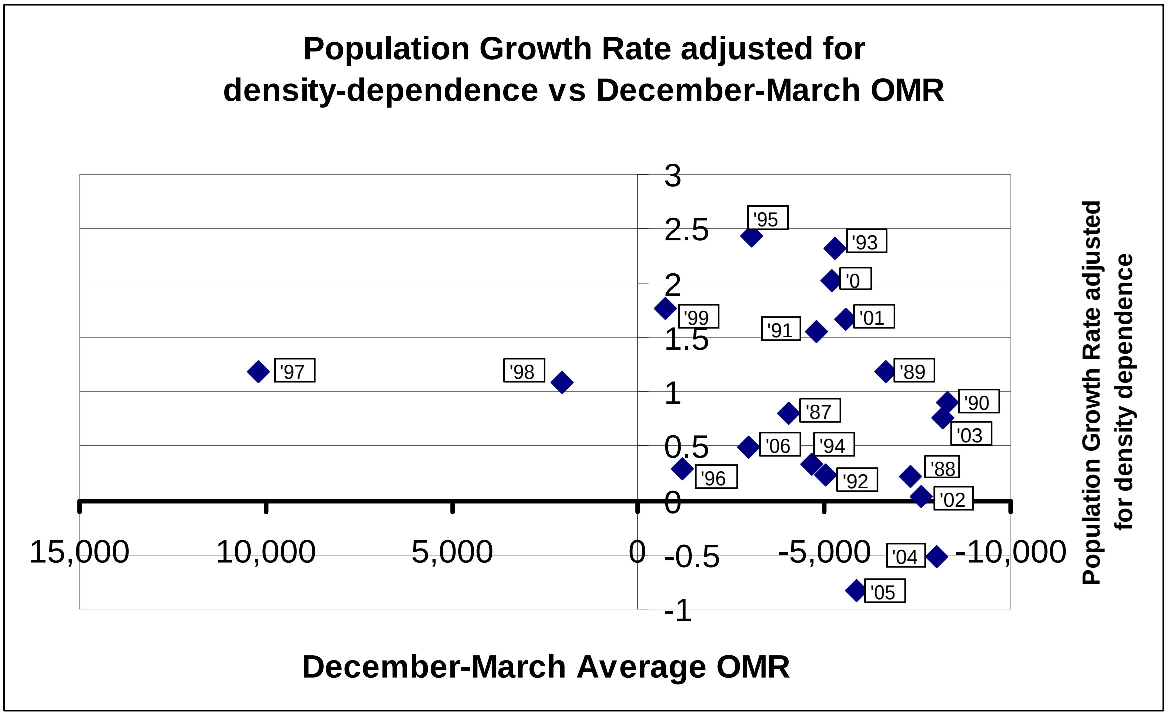
ANOVA

	df	*SS*	*MS*	*F*
Regression	2.000	7.881	3.940	4.058
Residual	11.000	10.682	0.971	
Total	13.000	18.563		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.609	0.642	2.506	0.029
predicted salvage rate	-0.027	0.016	-1.726	0.112
FMWT year-1	-0.003	0.001	-2.704	0.020

The analysis was made by first applying a logarithmic transformation to the Ricker model to obtain equation (3.33) in Quinn and Deriso (1999), which is then treated as a multiple linear regression equation. The equation applied is shown in the table above. The density-dependent term is statistically significant (P-value = 0.020 is below the 0.05 level). Predicted salvage rate is not statistically significant (that is, P-value 0.112 is above the significance level of 0.05).

Point 3.



Year	Dec-Mar Average OMR	FMWT year-1 (= FMWT_1)	FMWT year (= FMWT_0)	ln(FMWT_0/FMWT_1)	Population growth rate adjusted for density-dependence
1987	-4054.2	212	280	0.278	0.807
1988	-7319.8	280	174	-0.476	0.223
1989	-6647.8	174	366	0.744	1.178
1990	-8313	366	364	-0.005	0.908
1991	-4775	364	689	0.638	1.546
1992	-5037.4	689	156	-1.485	0.233
1993	-5279.8	156	1078	1.933	2.322
1994	-4656.2	1078	102	-2.358	0.331
1995	-3031.5	102	899	2.176	2.431
1996	-1181.7	899	127	-1.957	0.286
1997	10188.7	127	303	0.870	1.186
1998	2046.5	303	420	0.327	1.082
1999	-740.2	420	864	0.721	1.769
2000	-5178.4	864	756	-0.134	2.022
2001	-5558.7	756	603	-0.226	1.660
2002	-7615.3	603	139	-1.467	0.037
2003	-8161.1	139	210	0.413	0.759
2004	-8004.5	210	74	-1.043	-0.519
2005	-5858.4	74	27	-1.008	-0.824
2006	-2975.7	27	41	0.418	0.485

SUMMARY OUTPUT

ln(FMWT/FMRT_1)=a+b*(Dec-Mar OMR)+c*FMWT_1

Regression Statistics	
Multiple R	0.692
R Square	0.478
Adjusted R Square	0.417
Standard Error	0.915
Observations	20.000

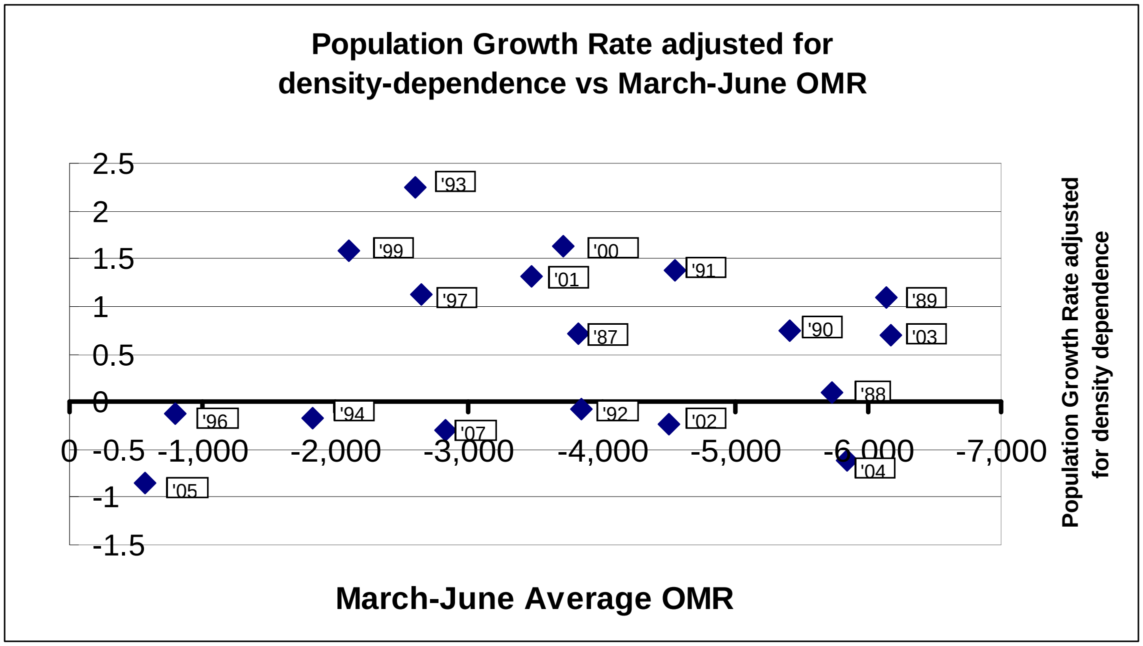
ANOVA

	df	*SS*	*MS*	*F*
Regression	2.000	13.034	6.517	7.792
Residual	17.000	14.218	0.836	
Total	19.000	27.253		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.102	0.377	2.920	0.010
Dec-Mar OMR	0.000	0.000	1.023	0.321
FMWT year-1	-0.002	0.001	-3.705	0.002

The analysis was made by first applying a logarithmic transformation to the Ricker model to obtain equation (3.33) in Quinn and Deriso (1999), which is then treated as a multiple linear regression equation. The equation applied is shown in the table above. The density-dependent term is statistically significant (P-value = 0.002 is below the 0.05 level). December-March Average OMR is not statistically significant (that is, P-value 0.321 is above the significance level of 0.05).

Point 4.



Year	Mar-Jun OMR	S=FMWT year-1 (= FMWT_1)	FMWT year (= FMWT_0)	ln(FMWT_0/FMWT_1)	Population growth rate adjusted for density dependence
1987	-3828.3	212	280	0.28	0.71
1988	-5732.3	280	174	-0.48	0.10
1989	-6132.3	174	366	0.74	1.10
1990	-5414.7	366	364	-0.01	0.74
1991	-4545.3	364	689	0.64	1.38
1992	-3847.1	689	156	-1.49	-0.08
1993	-2599.1	156	1078	1.93	2.25
1994	-1824.1	1078	102	-2.36	-0.16
1996	-798.1	899	127	-1.96	-0.12
1997	-2641.2	127	303	0.87	1.13
1999	-2100.9	420	864	0.72	1.58
2000	-3712.4	864	756	-0.13	1.63
2001	-3466.7	756	603	-0.23	1.32
2002	-4499.5	603	139	-1.47	-0.24
2003	-6174.4	139	210	0.41	0.70
2004	-5841.3	210	74	-1.04	-0.61
2005	-567.6	74	27	-1.01	-0.86
2007	-2828.7	41	28	-0.38	-0.30

SUMMARY OUTPUT

ln(FMWT/FMWT_1)=a+b*OMR+cS

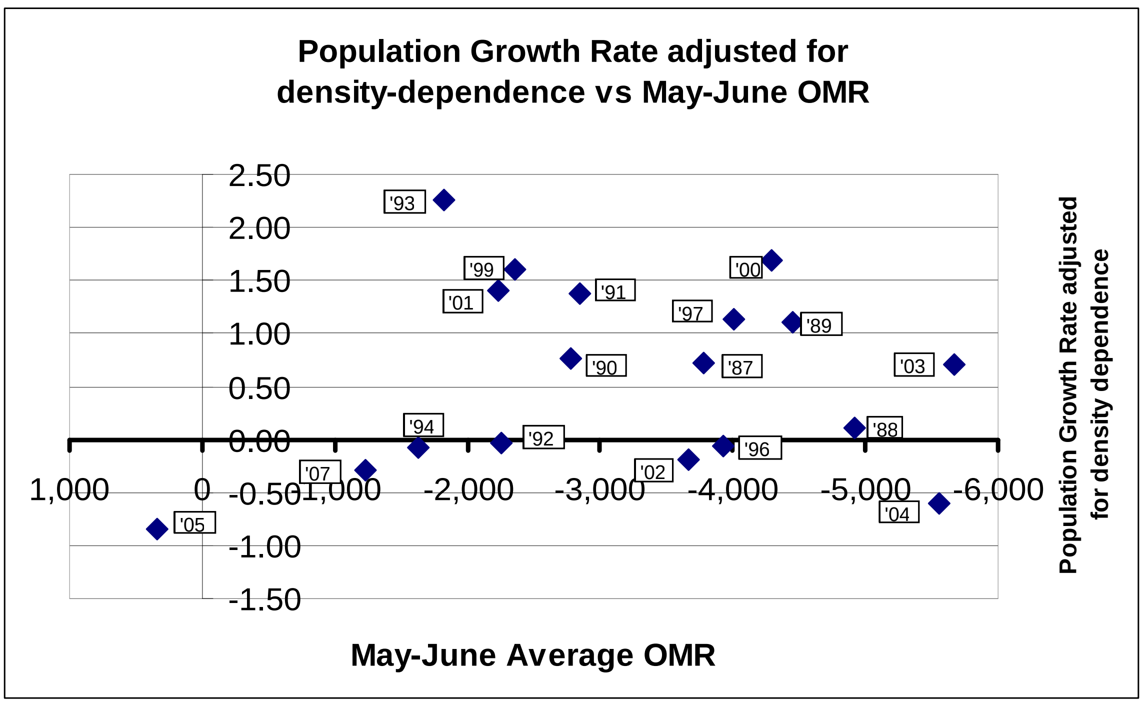
Regression Statistics	
Multiple R	0.613
R Square	0.376
Adjusted R Square	0.293
Standard Error	0.938
Observations	18

ANOVA

	df	*SS*	*MS*	*F*
Regression	2	7.961	3.981	4.525
Residual	15	13.196	0.880	
Total	17	21.157		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.374	0.690	0.541	0.596
Mar-Jun OMR	-0.000052	0.000135	-0.389	0.703
S=FMWT year-1	-0.002035	0.000739	-2.754	0.015

The analysis was made by first applying a logarithmic transformation to the Ricker model to obtain equation (3.33) in Quinn and Deriso (1999), which is then treated as a multiple linear regression equation. The equation applied is shown in the table above. The density-dependent term is statistically significant (P-value = 0.015 is below the 0.05 level). March-June average OMR is not statistically significant (that is, P-value 0.703 is above the significance level of 0.05).



Year	May-June OMR	FMWT year-1 (= FMWT_1)	FMWT year (= FMWT_0)	ln(R/S) or ln(FMWT_0/FMWT_1)	Population growth rate adjusted for density dependence
1987	-3777.0	212	280	0.28	0.72
1988	-4915.4	280	174	-0.48	0.11
1989	-4447.1	174	366	0.74	1.11
1990	-2777.1	366	364	-0.01	0.76
1991	-2236.3	364	689	0.64	1.40
1992	-2251.7	689	156	-1.49	-0.04
1993	-1819.5	156	1078	1.93	2.26
1994	-1629.8	1078	102	-2.36	-0.10
1996	-3932.3	899	127	-1.96	-0.07
1997	-4007.2	127	303	0.87	1.14
1999	-2353.8	420	864	0.72	1.60
2000	-4295.3	864	756	-0.13	1.68
2001	-2848.2	756	603	-0.23	1.36
2002	-3667.9	603	139	-1.47	-0.20
2003	-5673.5	139	210	0.41	0.70
2004	-5555.4	210	74	-1.04	-0.60
2005	343.3	74	27	-1.01	-0.85
2007	-1226.1	41	28	-0.38	-0.30

SUMMARY OUTPUT

ln(FMWT/FMWT-1)=a+b*OMR+cS

Regression Statistics	
Multiple R	0.613
R Square	0.376
Adjusted R Square	0.293
Standard Error	0.938
Observations	18

ANOVA

	df	*SS*	*MS*	*F*
Regression	2	7.963	3.982	4.527
Residual	15	13.194	0.880	
Total	17	21.157		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.421	0.589	0.714	0.486
May-June OMR	-0.00006	0.00014	-0.392	0.701
FMWT year-1	-0.00211	0.00071	-2.975	0.009

The analysis was made by first applying a logarithmic transformation to the Ricker model to obtain equation (3.33) in Quinn and Deriso (1999), which is then treated as a multiple linear regression equation. The equation applied is shown in the table above. The density-dependent term is statistically significant (P-value = 0.009 is below the 0.05 level). May-June average OMR is not statistically significant (that is, P-value 0.701 is above the significance level of 0.05).

Point 5.

A Ricker stock-recruitment model was applied to stock and recruitment data in which the juvenile summer townet survey index (TNS) and FMWT take the role of recruitment and stock, respectively. Fall X2 data were obtained from the IEP web site http://www.iep.ca.gov/dayflow/output/index.

Year	X2 year-1	S= FMWT year-1	TNS year	*ln*(TNS)	*ln*(R/S)= *ln*(TNS/FMWT_1)
1987	78.67	212	1.4	0.3	-5.020
1988	90.09	280	1.2	0.2	-5.452
1989	90.58	174	2.2	0.8	-4.371
1990	91.06	366	2.2	0.8	-5.114
1991	89.45	364	2	0.7	-5.204
1992	90.00	689	2.6	1.0	-5.580
1993	87.57	156	8.2	2.1	-2.946
1994	82.06	1078	13	2.6	-4.418
1995	86.14	102	3.2	1.2	-3.462
1996	74.00	899	11.1	2.4	-4.394
1997	78.05	127	4	1.4	-3.458
1998	81.70	303	3.3	1.2	-4.520
1999	68.74	420	11.9	2.5	-3.564
2000	83.44	864	8	2.1	-4.682
2001	85.00	756	3.5	1.3	-5.375
2002	83.66	603	4.7	1.5	-4.854
2003	84.68	139	1.6	0.5	-4.464
2004	83.65	210	2.9	1.1	-4.282
2005	82.61	74	0.3	-1.2	-5.508
2006	82.17	27	0.4	-0.9	-4.212
2007	82.52	41	0.4	-0.9	-4.630

1987-2007 for all analyses below
ln(R/S)=a+bX2+cS

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.490
R Square	0.240
Adjusted R Square	0.155
Standard Error	0.674
Observations	21.000

ANOVA

	df	*SS*	*MS*	*F*
Regression	2.000	2.579	1.289	2.841
Residual	18.000	8.170	0.454	
Total	20.000	10.748		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.317	2.310	0.137	0.892
X2 year-1	-0.055	0.027	-2.017	0.059
FMWT year-1	-0.001	0.000	-1.534	0.143

Neither the X2 variable or the density-dependent term, FMWT_(year-1) were statistically significant because their P-values of 0.059 and 0.143, respectively, are greater than the 0.05 significance level.

The density-dependent term was not significant so a reduced survival model was then analyzed which omitted the density-dependent term.

ln(R/S)= a+bX2

SUMMARY OUTPUT

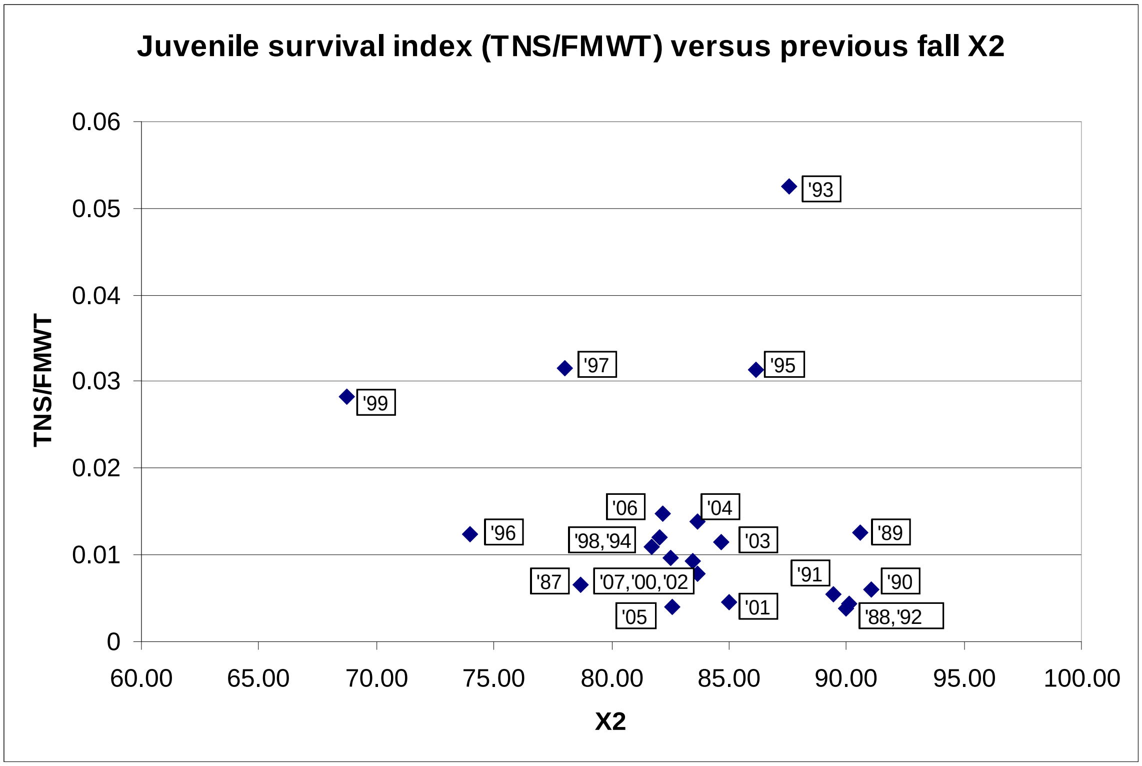
Regression Statistics	
Multiple R	0.375
R Square	0.141
Adjusted R Square	0.095
Standard Error	0.697
Observations	21.000

ANOVA

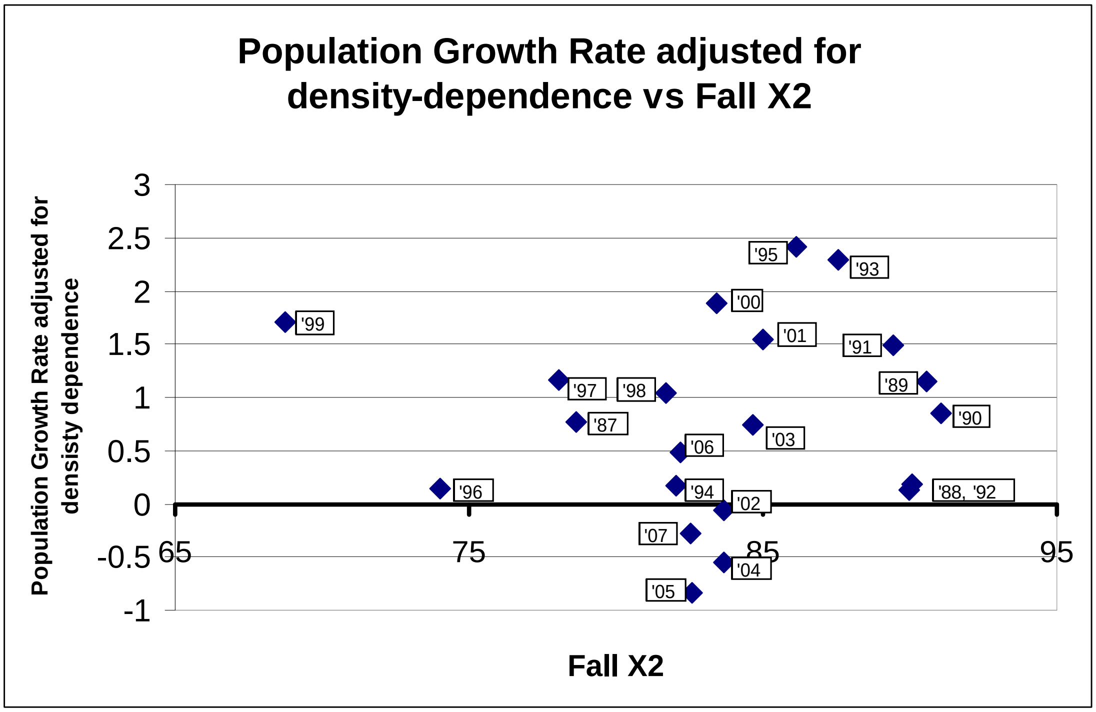
	df	*SS*	*MS*	*F*
Regression	1.000	1.511	1.511	3.108
Residual	19.000	9.237	0.486	
Total	20.000	10.748		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	-0.438	2.336	-0.188	0.853
X2 year-1	-0.049	0.028	-1.763	0.094

The X2 term is not statistically significant in the reduced model since P-value 0.094 is greater than the 0.05 significance level. The graph below is included as a visual aid to allow the reader to see that there is not a relationship between an index of juvenile survival (TNS/FMWT_1) and X2. If there had been a strong negative effect of X2 on juvenile survival then the graph would have been expected to show a pronounced negative slope. Instead the graph shows no trend in juvenile survival as X2 increases.



Point 6.



Year	Fall X2 year-1	S= FMWT year-1 (= FMWT_1)	FMWT year (= FMWT_0)	ln(FMWT_0/FMWT_1)	Population growth rate adjusted for density-dependence
1987	78.67	212	280	0.28	0.77
1988	90.09	280	174	-0.48	0.18
1989	90.58	174	366	0.74	1.15
1990	91.06	366	364	-0.01	0.85
1991	89.45	364	689	0.64	1.49
1992	90.00	689	156	-1.49	0.13
1993	87.57	156	1078	1.93	2.30
1994	82.06	1078	102	-2.36	0.16
1995	86.14	102	899	2.18	2.41
1996	74.00	899	127	-1.96	0.15
1997	78.05	127	303	0.87	1.17
1998	81.70	303	420	0.33	1.04
1999	68.74	420	864	0.72	1.70
2000	83.44	864	756	-0.13	1.89
2001	85.00	756	603	-0.23	1.54
2002	83.66	603	139	-1.47	-0.06
2003	84.68	139	210	0.41	0.74
2004	83.65	210	74	-1.04	-0.55
2005	82.61	74	27	-1.01	-0.84
2006	82.17	27	41	0.42	0.48
2007	82.52	41	28	-0.38	-0.29

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.634
R Square	0.402
Adjusted R Square	0.335
Standard Error	0.953
Observations	21.000

ln(FMWT/FMWT-1)=a+b(Fall X2)+cS

ANOVA

	df	*SS*	*MS*	*F*
Regression	2.000	10.985	5.493	6.046
Residual	18.000	16.353	0.908	
Total	20.000	27.338		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.249	3.269	0.076	0.940
Fall X2 year-1	0.006	0.038	0.165	0.870
FMWT year-1	-0.002	0.001	-3.418	0.003

The analysis was made by first applying a logarithmic transformation to the Ricker model to obtain equation (3.33) in Quinn and Deriso (1999), which is then treated as a multiple linear regression equation. The equation applied is shown in the table above. The density-dependent term is statistically significant (P-value = 0.003 is below the 0.05 level). Fall X2 is not statistically significant (that is, P-value 0.870 is above the significance level of 0.05).

Population growth rate is defined as the logarithm of the ratio (R/S) (also defined as relative population growth rate, Owen-Smith (2007, p. 29), which is written as *ln*(R/S). Adding to *ln*(R/S) the estimated density-dependent term in a Ricker model (say c*S) one obtains the quantity “population growth rate adjusted for density-dependence.”

Exhibit A

Exhibit A

Summary Professional Vitae

Richard B. Deriso

Inter-American Tropical Tuna Commission
Scripps Institution of Oceanography
La Jolla, CA 92093-0203

Formal Education

University of Washington
Ph.D. in Biomathematics (Quantitative Ecology) 1978

University of Florida
M.S. in Mathematics 1975

Auburn University
B.S. in Industrial Engineering 1972

Academic Honors

Tau Beta Pi, Pi Alpha Mu (scholastic honor societies)
1981 W. F. Thompson Award from American Institute of Fishery Research Biologists for publication (Deriso, 1980 CJAFS).

Major Research Interests

Fisheries Population Dynamics, Quantitative Ecology, applied mathematics, statistics.

Recent Professional Experience

Chief Scientist of the Tuna-Billfish Program, Inter-American Tropical Tuna Commission, 1988 - present.

Associate Adjunct Professor, Scripps Institution of Oceanography, UCSD, 1990 - 2006.

Ocean Studies Board member, U.S. National Research Council. 2002- 2004.

Affiliate Associate Professor of Fisheries, University of Washington, 1987 - 2006; 1982-1986, Assistant Professor.

Scientific and Statistical Committee member, Western Pacific Regional Fisheries Management Council, 1993 - present.

Population Dynamicist, International Pacific Halibut Commission, Seattle, WA, 1980 - 1988.

Visiting Research Assistant Professor, Marine Sciences, University of North Carolina at Chapel Hill, 1979 - 1980.

Consultant to several agencies and institutions, including US Minerals Management Service, ExxonMobil, Essa Technologies Ltd., Australian Fisheries Management Agency, Great Lakes Fishery Commission, Ontario Ministry of Natural Resources, University of Alaska at Juneau, Applied Biomathematics Inc., Living Marine Resources Inc., Marine Stewardship Council, National Marine Fisheries Service, North Carolina Sea Grant Program, US Environmental Protection Agency, New York State Department of Environmental Conservation, and Public Service Electric and Gas Company of New Jersey.

Other Professional Activities

Over 30 seminars given at various universities, agencies, and conferences.

Taught several graduate courses, including
FISH 557 course (Theoretical Models of Exploited Animal Populations, University of Washington) , QSCI 598 (Decision analysis for exploited populations, University of Washington), SIO 276 (Quantitative theory of populations and communities, Scripps Institution of Oceanography, with G. Sugihara).

Served on several committees and working groups, including groups with ICES, FAO, NAS, OSB, and NRC. Past co-chairman, NRC Committee on Fish Stock Assessment Methods.

Publications And Reports

Over 50 publications and reports, including

Deriso, R.B., Maunder, M.N., Pearson, W.H. 2008. Incorporating covariates into fisheries stock assessment models with application to Pacific herring. Ecol. App. 18(5): 1270-1286.

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Exhibit B

Exhibit B

Publications

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Attorneys for Plaintiff
THE METROPOLITAN WATER DISTRICT
OF SOUTHERN CALIFORNIA

UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES, SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA PARTIALLY CONSOLIDATED WITH: 1:09-cv-480 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	**REPLY DECLARATION OF DR. RICHARD B. DERISO IN SUPPORT OF PLAINTIFFS' MOTIONS FOR SUMMARY JUDGMENT AND PRELIMINARY INJUNCTION**
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	Ctrm: 3 Judge: Hon. Oliver W. Wanger

I, Dr. Richard B. Deriso, declare:

I. INTRODUCTION

1. This declaration responds to the declarations filed by Federal Defendants on January 8, 2010. I will focus particularly on the Declaration of Ken B. Newman, Doc. 484 ("Newman Decl."), and the Declaration of Frederick V. Feyrer, Doc. 481 ("Feyrer Decl."). In light of their criticisms, I believe it is important to begin by clarifying exactly what I did in my prior declarations.

2. First, I did not conduct any independent studies to determine that the analysis in the 2008 Delta Smelt Biological Opinion ("BiOp") was incorrect. Rather, I reviewed the BiOp, identified and explained errors and flaws in the analysis, and then illustrated what the correct analysis would show. As a professional in the field of fish population dynamics, it was evident to

me that the science employed by the United States Fish and Wildlife Service ("FWS") in the BiOp was not the best available science. My declarations show what FWS should have done using the *same* data in the *same* (indeed, less) amount of time. I did not critique the agency for failing to use more elaborate models or techniques, or for failing to integrate other concepts or ideas that the agency might have chosen to consider. Rather, I limited myself to simply reviewing what the agency did as described in the BiOp, and then evaluating whether the agency did it correctly or, as it turned out, incorrectly.

3. Second, my review of the BiOp and comments regarding the errors in it were guided by FWS's own words. The agency said that it was attempting to determine, through a quantitative analysis, whether the water projects were negatively impacting the smelt population. In the BiOp under the heading "Analytical Framework for the Jeopardy Determination," the agency explained that its intent was to "determine if implementation of the proposed action is likely to cause an appreciable reduction in the likelihood of both the survival and recovery of the delta smelt in the wild." BiOp at 139 (AR at 000154). With respect to the effects of the pumping plants, the agency explained under the heading "Effects Analysis Methods" that it did a quantitative analysis:

> The effects of Banks and Jones pumping on adult delta smelt entrainment, larval-juvenile delta smelt entrainment, and fall habitat suitability and its predicted effect on the summer townet survey abundance index are quantitatively analyzed. The remainder of proposed action elements and effects are not analyzed quantitatively . . . .

BiOp at 208-09 (AR at 000223-000224). After reviewing the BiOp, it is plainly evident that the agency did perform a "quantitative" analysis to determine whether pumping is likely to negatively affect the delta smelt population. *See, e.g.*, BiOp at 163 et seq., 202 et seq., 211-13, 347-50 (AR at 000178 et seq., 000217 et seq., 000226-000228, 000362-000365). The agency also relied on quantitative models to develop the reasonable and prudent alternatives ("RPAs"), as discussed more fully below. Any suggestion that the effects of the pumps and the corresponding RPAs were developed through a qualitative process is inconsistent with what the BiOp says.

4. Third, I explained in my declarations that it was immediately evident to me that the agency made basic errors, such as using raw salvage to draw conclusions about population impacts. To compound problems, the agency also made critical assumptions about the effects of the pumps that were integrated into their quantitative analysis, even though the data did not support those assumptions. For example, the BiOp states under the "Introduction" to the "Effects of the Proposed Action," FWS "assume[d] that the proposed CVP/SWP operations affect delta smelt throughout the year . . . ." BiOp at 203 (AR at 000218). An assumption like this is remarkable to me given the agency's earlier statement that it is trying to determine what the effects of the projects will be on the species. It is not common scientific practice to pose a question (i.e., what effects do the pumps have on the smelt?), but then assume the results (the pumps affect the smelt throughout the year). This is not how the best available science in fisheries population analysis is conducted.

5. Finally, the analysis I set forth in my declarations to explain the errors in the BiOp is not new science. Nowhere in my declarations did I generate a new type of methodology or a new approach. I employed generally-accepted techniques that have been the standard in the field of fisheries population dynamics for decades. *See* Doc. 401 ¶ 43, 55-57, 66, 69, 83 (citing references). They were also recommended by the independent peer review. *See* AR at 008818 (recommending use of a normalized salvage index instead of raw salvage); AR at 008819 (recommending transformation of the linear additive model [which could yield a multiplicative model]). I applied these techniques not to show a different approach among a range of reasonable alternatives, but rather to demonstrate how undisputed scientific standards and methods should have been applied to the data in the BiOp.

6. I will respond in more detail to the specific comments of Newman and Feyrer, but these prefatory comments are important. For anyone to suggest that what I set forth in my declarations should have been done differently, or is "too simple and too elementary" (Newman Decl. ¶ 5), reflects a basic misunderstanding of what I was doing—I was pointing out the problems with the BiOp, not proposing some sort of preferred approach going forward. Newman incorrectly frames my work as an independent study that is flawed because it lacks critical

elements that were thoroughly considered in the BiOp. Newman misses the point—I only reviewed the models, analyses, and data straight out of the BiOp and the record. The critiques directed at my declarations only serve to highlight the flaws that are in the BiOp. All I did was explain what FWS did, showed that their analysis contained errors, and presented what their analysis should have shown had they (using the same data from the BiOp) done it correctly.

7. In the discussion that follows, I will further respond to these purported criticisms by explaining the scope and purpose of my work. In doing so, I believe it is important to recognize exactly what was done in the BiOp to establish and provide justification for the RPAs. This is the context within which I found errors in the BiOp. Next, I will address each of Newman and Feyrer's individual critiques of my work with particular attention to how they illuminate errors in the BiOp itself.

II. MY DECLARATIONS SHOW THAT THE NUMERIC FLOW LIMITATIONS IN THE BIOP ARE BASED ON A FLAWED QUANTITATIVE STATISTICAL ANALYSIS

8. I understand that the flow limitations imposed by the BiOp on the water projects are a central focus of this litigation. While the BiOp contains extensive background discussion about the project operations and the smelt, the flow limitations that are ultimately established are specific numeric limitations. The BiOp explains that these numeric limitations are the product of a quantitative analysis, not a qualitative analysis. The ranges of flow limitations from -1250 cfs to -5000 cfs were derived using regressions that are presented in the BiOp—I reviewed those regressions and identified fundamental errors. Nevertheless, Newman claims that FWS considered a range of factors when developing the RPAs, and that I failed to consider these same factors in my analysis. Newman Decl. ¶ 8. Specifically, he criticizes my declarations for somehow ignoring the effects of observation noise, sampling errors, and spatial distribution, and for focusing on a single growth rate parameter. *Id.* Newman states that the BiOp "thoroughly consider[ed]," "recognized," and "acknowledged" these factors. *Id.* Newman does not suggest, however, that these factors were in any way incorporated into the RPAs that set the numeric flow limitations because they were not. The agency explained that "the rationale for each of the RPA components are presented in Attachment B of this biological opinion." BiOp at 279 (AR at

000294). Attachment B describes the specific models and analyses used—the same models and analyses that I have explained previously. Any claim that FWS relied on other factors is not supported by the record. That the BiOp may refer to the factors Newman discusses in other sections of the BiOp is fundamentally different from incorporating them into the models used to develop the RPAs. The RPA models in the BiOp do not account for observation noise, sampling errors, spatial distribution (beyond what I explain below), or any growth rate parameter, let alone multiple growth rate parameters.

9. An explanation of how the RPAs were developed illustrates why Newman's description is incorrect. The RPAs are distinct from the remainder of the BiOp in that they are largely mathematical.[1] Each RPA Action follows the same format: Objective, Action, Timing, Triggers, and Off-Ramps. BiOp at 329-30, 352, 357-58, 369 (AR at 000344-000345, 000367, 000372-000373, 000384). Aside from the descriptive "Objective" paragraph, these sections consist solely of numeric parameters within which the projects are to be managed. The precise numeric parameters in the RPAs are not the product of a qualitative, multi-factored approach—they are mathematical outcomes generated from a flawed quantitative statistical analysis. The BiOp describes exactly which models and formulas were used for each RPA Action in subsections of Attachment B entitled "Justification." These are summarized below.

A. The Flow Limitations in RPA Actions 1 and 2 Are the Direct Product of the Flawed Analysis in Figures B-13 and B-14

10. Newman comments on my analysis of the relationship between December-March Old and Middle River ("OMR") flows and adult salvage, which is found in RPA Actions 1 and 2. *See* Newman Decl. ¶ 11-17. RPA Actions 1 and 2 set OMR flows within the range -1250 cfs to -5000 cfs during the adult life stage. Under the heading "Justification for Flow Prescriptions in Action 1," FWS explains:

> The OMR-Salvage analysis herein was initiated using the relationship between December to March OMR flow and salvage

[1] The exception to this statement is RPA Actions Five and Six, which are not addressed in my prior declarations or in Defendants' rebuttal declarations.

> provided by P. Smith and provided as Figure B-13, below. Visual review of the relationship expressed in Figure B-13 indicates what appears to be a "break" in the dataset at approximately -5,000 OMR; however, the curvilinear fit to the data suggest that the break is not real and that the slope of the curve had already begun to increase by the time that OMR flows reached -5,000 cfs.

BiOp at 347 (AR at 000362)[2]. Thus, the BiOp itself attributes the -5000 cfs upper limit on OMR flows to Figure B-13. I have addressed this figure in prior declarations, as discussed below. To establish the lower limit, FWS explains:

> Fitting a different function to the data could also determine the location where salvage increased, i.e. identify the "break point" in the relationship between salvage and OMR flows. . . . A piecewise polynomial regression, sometimes referred to as a multiphase model, was used to establish the change (break) point in the dataset. . . . The piecewise polynomial regression analysis resulted in a change point of -1162, i.e. at -1162 cfs OMR, the slope changed from 0 to positive (Figure B-14).

BiOp at 348-49 (AR at 000363-000364). A second analysis was conducted by adding stochastic variation to the same piecewise polynomial regression in Figure B-14, which yielded a change point of -1800 cfs. BiOp at 350-51 (AR at 000365-000366). Thus, the BiOp attributes the -1250 cfs lower limit on OMR flows to the piecewise polynomial regression represented in Figure B-14.[3] I have addressed this figure in prior declarations, as discussed below. No other models or equations are provided in Actions 1 and 2 which lead to these numeric flow limitations. Stated succinctly, the -5000 upper flow limit is derived from Figure B-13, and the -1250 lower flow limit is derived from Figure B-14—that is where these numbers come from.

11. The analysis at Figures B-13 and B-14 is the exclusive quantitative analysis for the adult smelt OMR flow limits. It also has been referred to as the "Johnson" analysis, although that

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[2] There is no "Justification" provided for Action 2. Because the "Justification for Flow Prescriptions in Action 1" describes the change points used in Action 1 and Action 2, it is reasonable to assume that this section applies to both actions.

[3] There is no analysis in the BiOp which yields a change point of exactly -1250 cfs. The agency does not explain why it chose this specific number, but it does fall within the range of change points from the piecewise polynomial regression analyses, i.e., -1162 and -1800 cfs.

name does not appear in the BiOp itself.[4] This analysis was provided as the sole basis for the numeric range of flow limits that the agency may set when the trigger conditions are met. Indeed, the independent peer review recognized that the BiOp relies heavily on the quantitative analysis, remarking that the agency made "extensive use of the relationship between OMR flows and salvage." AR at 006523.[5]

12. My previous declarations explained the fundamental errors FWS committed in the "Johnson" analysis as represented by Figures B-13 and B-14: both models rely on raw salvage numbers rather than the cumulative salvage index, and neither model evaluates effects on the population growth rate.[6] *See* Doc. 401 ¶ 22, 27-37, 51-74; Doc. 455 ¶ 13-17; *see also* Doc. 401 ¶ 22, 52-54 (addressing Figure B-14 specifically); Doc. 455 ¶ 16 (same); Doc. 508 ¶ 38 (same). Thus, all of the statistical analyses presented as "Justification" for RPA Actions 1 and 2 share the same basic errors.

13. It is appropriate to address here Newman's critique of my population growth rate analysis. *See* Newman Decl. ¶ 7- 8, 16-17. He queries whether a model based on a single growth rate parameter can detect whatever signal may be produced from covariates such as "birth, mortality (from various sources at various times), and movement, which affect the total abundance during the fall months." Newman Decl. Exh. C.2. The answer, quite simply, is "yes." The population growth rate reflects these signals because it represents the species' ability to rebound from year to year after varying combinations of these factors have occurred. It is the aggregate of incremental survival rates throughout the year. As a result, any potentially significant effects to delta smelt would be reflected in the population growth rate if they impacted

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[4] The Figure B-13 and B-14 analysis is attributed to Dr. Michael Johnson, and has been alternately referred to as such by Defendants and their experts.

[5] The peer review also recognized that a regression analysis is reasonable, but could only remark that the one the agency used "appeared to be well done but was poorly described and largely undocumented." AR at 006523. I agree that it was poorly described and largely undocumented. The reviewers may have failed to appreciate that a salvage index was *not* used—the analysis is simply not what is done for population dynamics assessment.

[6] Further, the agency inexplicably elected not to use normalized salvage data when in fact there are meeting notes showing that they should have used it. *See* AR at 009454.

the population. Several examples of potential sources of mortality "from various sources at various times" are instructive.

14. First, the notion that high entrainment has had significant population level effects in certain years lacks any statistical support.[7] *See, e.g.*, Newman Decl. ¶ 13, 18 (discussing the potential for "sporadic" effects of salvage on population growth). The standard Ricker model that I have used would detect any significant entrainment effects, including "sporadic" or single-year effects, if those effects are quantified by a tested covariate such as OMR flow.[8] When referencing the sporadic effects theory, the BiOp presents a wide range of annual entrainment percent losses attributed to Kimmerer (2008). BiOp at 210 (AR at 000225). As shown in my previous declarations and elaborated further below, those entrainment losses are well estimated by OMR flow or a combination of OMR flow and spring X2. The sporadic effects theory is tied to the use of raw salvage, i.e., the idea that large numbers of raw salvage universally equate to significant impacts regardless of the size of the population or its ability to grow from year to year. As I have shown, when salvage numbers are scaled to the population, large salvage events do not necessarily equate to population level impacts. Further, large salvage events have not impacted the population growth rate.

15. Second, the theory that the projects may disproportionately entrain the most fecund individuals and thereby affect abundance more than overall entrainment numbers suggest (also known as the "Big Mama Hypothesis") is also belied by an analysis of the population growth rate. The population's ability to reproduce and maintain abundance levels is reflected in its growth rate, regardless of which individuals are being entrained. Entrainment would register

[7] The BiOp cites Manly and Chotkowski (2006) as finding a statistically significant relationship between exports and abundance. BiOp at 159 (AR at 000174). This citation is incorrect. Dr. Bryan Manly explained the results of this study in his declaration: "gross hydrology did not appear to have an effect on delta smelt subsequent abundance. Instead, in this and other work I did preceding this 2006 article, predictions of delta smelt abundances from the models used were almost the same whether hydrological variables, including exports, were in the models or not." Doc. 489 ¶ 5. Further, Manly stated, "I am not aware of any such statistical analyses that have shown that entrainment at the Central Valley Project and State Water Project pumps has an important effect upon overall delta smelt population abundance." Doc. 489 ¶ 3.

[8] To the extent the BiOp claims that certain effects are difficult to detect statistically, this is undoubtedly true. They are difficult to detect because they are not significant.

as significantly affecting the population growth rate if the most fecund individuals were being entrained *and* if the loss of those individuals was negatively impacting the population. As I have demonstrated, entrainment does not significantly affect the population growth rate.

16. Third, if entrainment at the pumps is only a small fraction of the take caused by project operations, which includes movement of smelt to the central and south Delta, this only provides further support for the need to evaluate effects using the population growth rate, not entrainment. FWS focused on raw salvage numbers to evaluate project effects. If take is occurring via other means and in other areas of the Delta, the population growth rate would be affected. Yet, FWS ignored the population growth rate altogether.

B. The Flow Limitations in RPA Action 3 Are the Direct Product of Kimmerer (2008)'s Assumed Correlation

17. Newman next critiques my analysis of the juvenile smelt RPAs, or Action 3. Newman Decl. ¶ 18. Action 3 sets OMR flows within the range -1250 cfs to -5000 cfs during the larval/juvenile life stage. These flows were calculated to meet a "protectiveness criterion" defined as "holding entrainment to ~1 percent of the individuals utilizing the Central and South Delta (south and east [upstream] of Station 815, see Map 2) across a 14-day particle modeling interval" or below 1 percent "[i]n circumstances where it is known or suspected that the Central Delta or South Delta is a principal source of emerging larvae." BiOp at 360 (AR at 000375). Under the heading "Justification for Different OMR Requirements of Action 3," FWS explains that the different flow levels are determined through a four-step process which predicts the probability of entrainment using particle tracking modeling. BiOp at 364 (AR at 000379).

18. RPA Action 3 does not contain any statistical analysis or other demonstration of a relationship between larval/juvenile entrainment and OMR flows which would justify flow restrictions in the spring. Rather, FWS assumed that predicted entrainment was correlated with OMR flows based on the Kimmerer (2008) study. *See* Doc. 401 ¶ 75; Doc. 508 ¶ 10-22. The correlation is shown in the Effects Analysis in Figure E-7, which is described as a "Scatterplot of average flow in Old and Middle rivers [from March–June] and the percentage of the larval and juvenile delta smelt population entrained in the SWP and CVP export pumps. The entrainment

estimates were taken from Kimmerer (2008)." BiOp at 253 (AR at 000268). Having assumed that entrainment is significant, the RPAs then use particle tracking modeling to predict entrainment risk and restrict flows accordingly.

19. As I have explained, Kimmerer's entrainment estimates cannot be used to show a relationship with OMR flows because Kimmerer was not testing for such a relationship—rather, he assumed one in order to generate entrainment estimates for given OMR flows. *See* Doc. 401 ¶ 75; Doc. 508 ¶ 10-22. Kimmerer states: "Principal assumptions for calculating daily loss for each survey were: . . . The relevant flow toward the export facilities is the southward flow in Old and Middle Rivers." AR at 018868. With this assumption built in, Kimmerer found that "[t]he variation in annual loss was related to flow conditions," but he acknowledged overtly that "this relationship is tautological, since Old and Middle River flow was used explicitly in the calculations." AR at 018875-018876. This means that the result was assumed. Thus, Kimmerer (2008) cannot be used as evidence that a correlation exists between entrainment and flows or to justify the spring OMR flow restrictions.

20. In my previous declarations I explained the fundamental errors that FWS committed by assuming that predicted larval/juvenile entrainment is correlated with OMR flows: when properly tested, there is no statistically significant relationship between juvenile salvage or the juvenile salvage rate and OMR flows, and there is no statistically significant relationship between spring OMR flows and the population growth rate. *See* Doc. 401 ¶ 23, 34-37, 75-76; Doc. 455 ¶ 23-29.

C. The Flow Limitations in RPA Action 4 Are the Direct Product of Feyrer (2007)'s Flawed Linear Additive Model

21. Newman also takes issue with my analysis of Fall X2 and delta smelt abundance, which is found in RPA Action 4. Newman Decl. ¶ 19. RPA Action 4 requires sufficient Delta outflow to maintain average Fall X2 no greater than 74 km following wet years and 81 km following above normal years. Under the heading "Justification," FWS explains that "the results of Feyrer et al. (2007) suggest that adverse effects on adult delta smelt during fall may be part of the reason that there is a statistical association between fall X2 and the production of young delta

smelt during the following year." BiOp at 373 (AR at 000388). While the BiOp contains several graphs which model the amount of habitat area associated with given X2 locations, the actual justification behind restricting X2 at all is Feyrer's "statistical association." This statistical association is the result of a linear additive model, which is reproduced in the Effects Analysis in Figure E-22. BiOp at 268 (AR at 000283).

22. My previous declarations explained the fundamental errors FWS committed by using a linear additive model: the best available science requires a multiplicative stock-recruit model, and FWS failed to evaluate Fall X2 effects on the population growth rate. *See* Doc. 401 ¶ 24, 38-44, 77-94.

23. A review of the RPA Justifications makes clear that FWS used only a defined set of models and analyses to generate the numeric flow restrictions in the RPAs. I reviewed only those models that the BiOp said it relied upon, and I explained the errors in those models. The additional factors raised by Newman are absent from these Justifications. What this means is that Newman's critiques of my methods and models are essentially critiques of the BiOp itself—my work serves merely as a lens through which one can see the errors in the BiOp.

III. RESPONSE TO NEWMAN'S INDIVIDUAL CRITICISMS

24. Newman also advances some more nuanced criticisms in his declaration. These are addressed individually below.

A. Newman Inflated the Observation Noise and Sampling Errors to Argue That "Ignoring" These Factors Is Error

25. Newman suggests that a life history model based on the Fall Midwater Trawl Index ("FMWT") is not reliable unless the "uncertainties" with that index are accounted for in the model. Newman Decl. ¶ 7. He emphasizes that population abundances are unknown and estimates of abundance, such as the FMWT, are "extremely noisy and potentially biased." *Id.* In essence, Newman is critiquing the quality of the FMWT. It is worth noting, however, that the BiOp describes the FMWT in very different terms:

> The FMWT provides the best available long-term index of the relative abundance of delta smelt [citations]. The indices derived from these surveys closely mirror trends in catch per unit effort

> (Kimmerer and Nobriga 2005), but do not at present support statistically reliable population abundance estimates, though substantial progress has recently been made (Newman 2008). FMWT derived data are generally accepted as providing a reasonable basis for detecting and roughly scaling interannual trends in delta smelt abundance.

BiOp at 153-53 (AR at 000168-000169). Moreover, in Newman's 2008 paper, he produced his own abundance estimates and compared them to the FMWT as follows:

> Before proceeding with criticism of the indices and presentation of the alternative estimation procedure, however, it should be emphasized that the ostensibly more rigorous statistical estimates of delta smelt presented herein do not differ in substantial ways from the FMWT indices, however technically flawed they might be. Relatedly, biases present in the new estimates are largely ones that the indices would share, particularly selection bias.

AR at 019783. Thus, to so heavily critique the FMWT is to sabotage the BiOp itself, which relies on this index as an estimate of abundance, as well as Newman's own work, which produced estimates similar to the FMWT.

26. Nonetheless, Newman critiques my work for relying on the FWMT without accounting for its many "uncertainties." Newman Decl. ¶ 7-8, 12, 15-17. He constructed a model that is similar to the one I used and then conducted simulation trials to test the reliability of that model. His results show that the model is not reliable because the observation noise and sampling error (collectively, "observation error") are too high. Newman Decl. Exh. C, Table 1. This is not surprising given the extremely high level of observation error he attributed to the FMWT in the trials—σ=1, or equivalently a coefficient of variation of 131 percent. That extraordinarily high level is not supported by the science. Rather, the available studies (three are discussed below in ¶ 28) support a level of observation error of 20 percent; and, when I conducted simulation trials using 20 percent, they showed that my model is reliable.

27. Newman's simulation trials in his declaration are front-loaded because a 131 percent observation error for the FMWT is an unrealistic number that is not supported by any scientific evidence or evidence in the record. The observation error associated with the FMWT has been tested in at least three studies of which I am aware. Two studies found an observation error (represented by the coefficient of variation or the standard deviation) of approximately 20

percent, and a third study found that the FMWT signal is strong, which is consistent with 20 percent. In contrast, there is no scientific evidence to support a 131 percent observation error, and in fact Newman does not cite to any literature or facts in his declaration to support use of this figure.

28. The first study is Newman (2008), *Sample Design-based Methodology for Estimating Delta Smelt Abundance*. AR at 019782. In this study, Newman produced abundance estimates that mirror the FMWT (correlation r=0.96 for September-December averages). AR at 019790. He states that the coefficient of variation for these monthly abundance estimates ranges from 22 to 130 percent with a median value of 41 percent. AR at 019789. This translates to average annual abundance estimates (September-December average) with a coefficient of variation of approximately 20 percent. A similar coefficient of variation was found in a second study conducted by Western Ecosystem Technology, Inc. under contract to the Metropolitan Water District of Southern California.[9] In this study, a statistical bootstrap estimation procedure was applied to the FMWT data.[10] The median coefficient of variation for bootstrapped annual FMWT-based estimates for the years 1987-2006 was 22 percent. A third study by Kimmerer and Nobriga (2005), *Development and Evaluation of Bootstrapped Confidence Intervals of IEP Fish Abundance Indices*, estimated confidence intervals for the annual average catch per trawl data from several surveys including the FMWT. AR at 018846. Kimmerer and Nobriga concluded that "differences in abundance among years can be readily distinguished," which indicates that the FMWT produces a strong signal that is not being obscured by observation noise. This conclusion is consistent with a moderate coefficient of variation such as 20 percent, and it is inconsistent with an extremely high coefficient of variation such as 131 percent.

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[9] This study is not included in the Administrative Record. In Appendix A, I have provided a spreadsheet showing a survey by year summary of the study results.

[10] As explained in Newman (2008), "There are several ways to carry out bootstrapping, but the general idea is to view the sample as if it were the population and then to resample from the sample and carry out the same estimation procedures applied to the original sample." AR at 019787.

29. I conducted my own simulation trials using a 20 percent coefficient of variation to represent the FMWT observation error. The results indicate that the model correctly detected a significant covariate effect 83 percent of the time, compared to a model with a 0 percent coefficient of variation (no observation error), which had 89 percent correct detection. The difference of 6 percent is a small reduction in detection rate. I found Type II errors in the range of 11-17 percent in the simulations, which are mostly larger than the 7-13 percent Type II errors found for a more complex age-structured simulation model in Deriso et al. (2007) but are nowhere near the pessimistic Type II errors of about 50 percent found in Newman's simulation results.[11] *See* Deriso et al., *Variance Estimation in Integrated Assessment Models and Its Importance for Hypothesis Testing*, 64 Canadian Journal of Fisheries & Aquatic Sciences 187-97 (2007).

30. By using a 131 percent coefficient of variation, Newman assumed that the FMWT was virtually useless as a measure of abundance. With this assumption, it is predictable that virtually any model based on the FMWT would not perform well. However, as the studies have shown, the FMWT has only moderate observation error and is more reliable than Newman portrays. Thus, I relied on the robustness of my model to produce results in the face of moderate observation error.

B. Spatial Distribution Does Not Affect the Population Growth Rate

31. Newman uses the lack of a spatial distribution component as a fall-back criticism of my declarations. *See* Newman Decl. ¶ 7-8, 12-14, 16-18. Though it is tempting from a lay perspective to assume that spatial distribution must somehow affect salvage and abundance, basic statistics prove this not to be the case.

32. As with any project effects, if entrainment was significant, it would impact the population growth rate regardless of whether spatial distribution was an important consideration.

[11] A Type II error is one minus the correct detection probability. The size of the Type II error depends not only on the size of the observation error, but also on the process error and other parameters in the model and also on the size and trend over time of the covariate.

See infra ¶ 13. My analysis demonstrates that entrainment does not impact the population growth rate for adults or for larvae/juveniles.

33. In my prior declaration I also tested the relationship between December-March OMR flow and population growth rate using a weight of the evidence approach, which Newman critiques on the grounds that "the difference in absolute AIC values is minor, about 0.90." *See* Newman Decl. ¶ 17. Actually, I used AICc criteria which is a small sample version of the AIC. The small sample version is recommended in Burnham and Anderson (2004) unless the ratio of the number of observations to parameters exceeds 40. With 21 observations and 3-4 parameters in my application, the small sample version is appropriate. *See* Burnham, K. & Anderson, D., *Multimodel Inference, Understanding AIC and BIC in Model Selection*, 33:2 Socio. Methods & Res. 270 (2004) ("A pervasive mistake in the model selection literature is the use of AIC when AICc really should be used.") My declaration reported a difference in AICc scores of 1.97. *See* Doc. 455 ¶ 20. The 1.97 falls right on the edge of the rule of thumb (difference = 2) described by Newman.

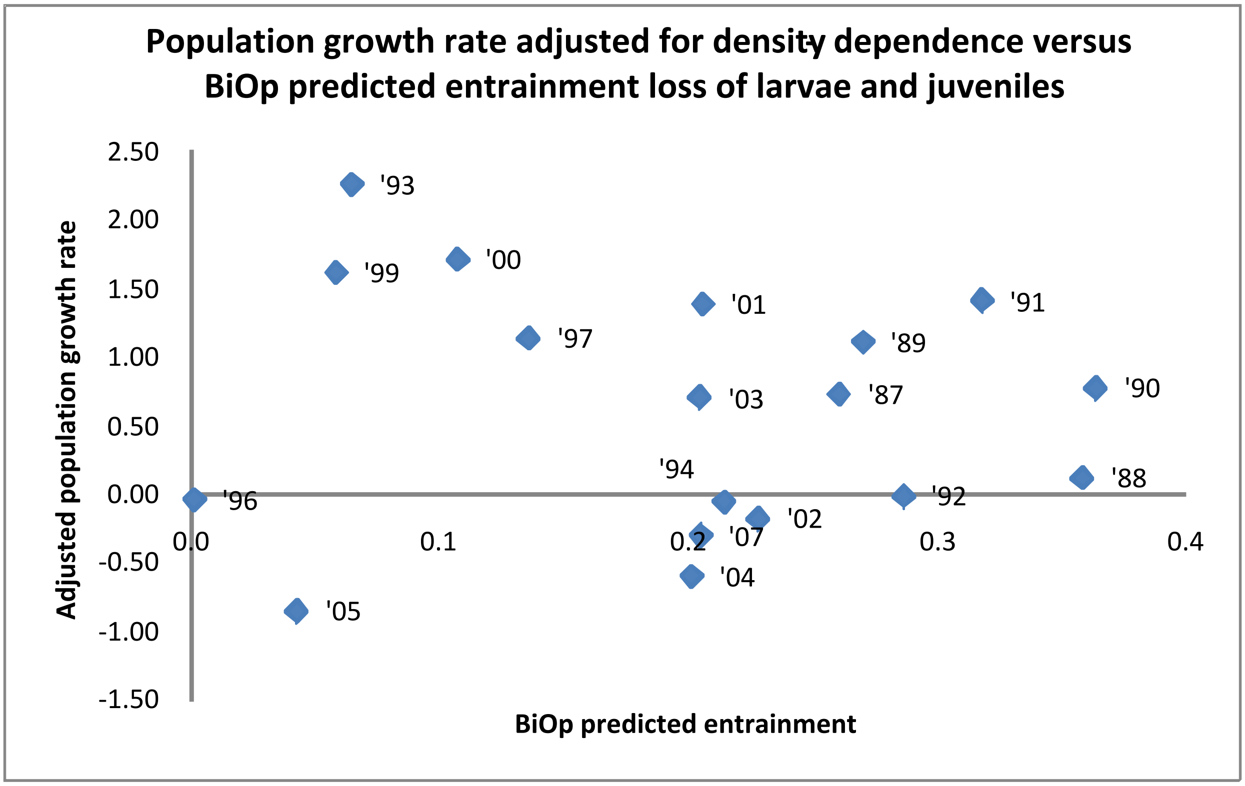
34. Even if spatial distribution was an important consideration, Newman also misses the critical point that the models used in the BiOp to develop the adult RPAs do not include a spatial distribution component. To evaluate entrainment effects, Figures B-13 and B-14 offer the single explanatory variable of salvage weighted December-March average OMR flow. Spatial distribution is wholly absent from the analysis. To explain the errors in FWS's modeling, I also evaluated the relationship between entrainment and the single variable of OMR flow, substituting the cumulative salvage index for raw salvage numbers as the correct measure of entrainment. I did not incorporate additional variables that were not considered in the BiOp. Thus, Newman's critique of my work applies equally to the BiOp and, if true, simply adds another fundamental error to the list of errors that the *agency itself* conducted.

35. For larvae/juveniles, the BiOp finds a significant correlation between spatially-explicit predicted entrainment loss and OMR flows. However, using the same data, I found that the predicted entrainment loss does not have a statistically significant impact on the population growth rate. This is consistent with my prior analysis, which found that spring OMR flows do

not have a statistically significant impact on the population growth rate. Thus, incorporating spatial distribution does not change the results I have reached previously. My analysis is explained in more detail below.

36. To develop the larval/juvenile RPAs, the BiOp relies on entrainment estimates from Kimmerer (2008) which account for spatial distribution. The BiOp fits a linear regression model to Kimmerer's estimates based on March-June OMR flows and the additional spatial component of X2. *See* BiOp at 220 (AR at 000235). The BiOp uses this model to predict entrainment loss. I used a Ricker stock-recruitment model to evaluate whether the predicted loss has a statistically significant effect on the population growth rate. Results show that the predicted loss is not significant at the p-value = 0.05 level (calculated p-value = 0.74). This is depicted visually in the partial residual plot below.[12] For additional technical detail, see Appendix B at Point 1. Appendix B at Point 2 shows a weight of evidence analysis, along the lines of the work presented in my previous declaration. *See* Doc. 455 ¶ 20. Results indicated a 74 to 83 percent weight of evidence in favor of a model fit that does not include predicted entrainment loss.

[12] Newman suggests that "[t]he recommended procedure for graphically examining the effect of a covariate over and above the effects of other covariates is to use an added variable plot." Newman Decl. Exh. C.2 fn. 2. Actually, multiple methods may be applied: "Perhaps the most commonly used methods for obtaining a graphical evaluation of the effect of adding an explanatory variable Z are the following: 1. The simple residual plot . . . 2. The added-variable plot . . . 3. The residual-plus-component plot." Johnson, B. & McCulloch, R. *Added-Variable Plots in Linear Regression*, 29:4 Technometrics (Nov. 1987) 427-33. The plots given in my previous declarations were of the third type, also known as a partial residual plot. Some authors argue that the partial residual plot provides a better diagnostic tool than the added-variable plot for finding curvilinear relationships between a covariate and the response variable. *See, e.g.*, Cook, D., *Added-Variable Plots and Curvature in Linear Regression*, 38:3 Technometrics (Aug. 1996) 275-78. In my application of the partial residual plot I was interested to examine any form of relationship, including curvilinear, present between population growth rate and OMR flow (and other candidate covariates examined). A partial residual plot is appropriate for this type of analysis.



37. In my prior declaration, I conducted a similar analysis that relied on March-June OMR flows as the predictor of entrainment loss. That analysis showed that OMR flow does not have a statistically significant effect on population growth rate. Doc. 401 ¶ 75-76. The analysis above uses the regression equation presented in the BiOp which, in addition to March-June OMR flow, has the spatial component March-June X2. The end result is the same, with or without spatial distribution.

38. In addition, the effects of spatial distribution are averaged out when values are aggregated over an entire season. Use of aggregate quantities leads to simpler models, but simpler models require fewer assumptions than complex models and they still achieve useful results.

C. The Population Growth Rate Is the Aggregate of Intermediate Survival Rates

39. Newman asserts that use of only one vital rate cannot accurately describe the sequence of birth rates and survival probabilities throughout the year. *See* Newman Decl. ¶ 7-8, 16-18. That assertion is contrary to standard fish population dynamics. The probability of

survival over any length of time is the product of survival over smaller intermediate increments of time (i.e., the probability of surviving through a year is the product of surviving through every month, day, hour, etc.). A typical spawner-recruit model aggregates all of these processes into a single term. Variability in smaller survival rates is combined into the variability of the population growth rate.

40. The principle that a single measure, call it α, can accurately describe the sequence of survival probabilities is explained in Quinn and Deriso (1999):

> For any fish population the cycle of regeneration can be visualized as
>
> Eggs→Larvae→Juveniles→Recruits→Spawners→Eggs→
>
> In the simplest model, abundance at each stage is assumed proportional to that of the previous stage.

Quinn, T. & Deriso, R., *Quantitative Fish Dynamics*, Oxford Univ. Press 86 (1999). Such a simple model ultimately ends with recruitment proportional to spawning stock, or $R=\alpha S$, where the measure α is the product of survivals through each stage times average net fecundity. If survival through each stage varies over time, then the measure α would be made a function of time. Essentially this means that the number of recruits is a function of their survival through each life stage. This simple spawner-recruit model is easily extended to include the Ricker spawner-recruit model. *Id.* at 89. This result is also shown in a derivation that models mortality rates continuously over time in Hilborn, R. & Walters, C., *Quantitative Fisheries Stock Assessment: Choice, Dynamics and Uncertainty*, Chapman & Hall (1992) at 261.

41. Nonetheless, it also should not be overlooked that the BiOp does not consider *any* growth rate parameter, whether the singular population growth rate or the incremental rates that Newman offers. Nowhere does Newman defend the BiOp for ignoring the population growth rate in its analysis. He essentially relies on the argument that unless the most complex analysis of incremental growth rates can be completed, no growth rate analysis should be conducted at all. This is certainly not an excuse for failing to evaluate population impacts using this important and standard measure, especially when basic analyses like the ones I conducted reveal fundamentally different conclusions than those made in the BiOp. Again, Newman's critiques should be

directed to the BiOp, which failed to analyze the population growth rate *or* the other vital rates he claims are so important.

42. Newman also makes the rather astounding statement that "[g]iven the apparent decline in abundances, variation in [vital] rates is not simply random variation around some mean values, but is also a reflection of systemic changes over time." Newman Decl. ¶ 7. What he is saying is that the smelt population decline cannot be the result of randomness—the fact that it is declining is sufficient evidence, *in and of itself*, that systemic changes are the cause. To the contrary, abundance is affected by positive and negative anomalies that occur in random patterns. These anomalies include environmental factors, such as the weather, which cannot be predicted. True randomness does not mean that these positive and negative anomalies balance each other out to keep the population level steady. It means that the smelt can basically be "unlucky" several years in a row and face a series of negative anomalies—much like flipping a coin ten times and getting ten "heads" and zero "tails" despite the equal probability of getting either one. *See, e.g.*, Baily, N., *The Elements of Stochastic Processes*, John Wiley & Sons 96 (1964) (even the simplest birth and death Markov population model, where the probability of a birth equals the probability of a death, will eventually result in a major decline of the modeled species due to random fluctuations in the number of births and deaths). This means that randomness could be causing the smelt's decline rather than systemic changes—there is no evidence to *rule out* this possibility. In sum, contrary to Newman's assertions, it cannot be assumed that populations will not experience a major decline in abundance absent some "systemic change."

D. The Results From Newman's Loess Scatterplot Smoother Are Inapplicable Because This Method Was Not Used in the BiOp

43. Newman does ultimately concede that salvage should be scaled by some measure of population abundance, and notes that the BiOp makes the same observation. Newman Decl. ¶ 11, 12. However, he then uses a loess scatterplot smoother to model the relationship between scaled salvage and OMR flows and finds a break-point at -4000 cfs. Newman Decl. ¶ 12. The loess method is basically a method to plot a smooth curve through data. Newman's result has no

bearing on my analysis because Newman used a new method whereas I applied the same method used in the BiOp.

44. In the Justification for RPA Actions 1 and 2, the BiOp used a method called a piecewise linear fit to detect abrupt shifts, or change points, in salvage for different OMR flows. I followed the same approach and used a piecewise linear fit to detect change points in salvage, substituting the cumulative salvage index (i.e., scaled salvage) for raw salvage numbers as the correct input variable. Thus, the significantly different result that I reached cannot be attributed to scientific debate over models and methods. Rather, it is the product of applying the same model with the correct variable—a substitution with which Newman agrees. *See* Newman Decl. ¶ 11.

45. Newman, on the other hand, introduces a brand new concept by calculating a change point using a loess scatterplot smoother. Not only does this method fall outside the scope of the BiOp, but to my knowledge, it is also not typically used to detect change points like the piecewise linear fit. *See* Vieth, E., *Fitting Piecewise Linear Regression Functions to Biological Responses*, 67:1 Journal of Applied Physiology (1989) 390-96; Liu, Z. & Qian, L., *Change-point Estimation via Empirical Likelihood for a Segmented Linear Regression*, manuscript available at: http://interstat.statjournals.net/YEAR/2009/abstracts/0902003.php (2009). Newman does not provide any references to support use of his alternative model.

E. Linear Models Are Fundamentally Different From Nonlinear Models

46. Newman next supports the BiOp's use of a linear additive model in the BiOp because "[l]inear models are often used as approximations to more realistic nonlinear models, and often over the range of covariate values of interest the nonlinear model may in fact be relatively linear." Newman Decl. ¶ 19. Except for the admission that nonlinear models are "more realistic," this statement is incorrect. There are at least two fundamental distinctions between linear and nonlinear models. First, a linear additive model adds several factors together to achieve a sum, without use of logarithms. Adding biological factors as fixed constants does not reflect biological reality where, for example, if there are zero spawners, there cannot be a positive number of offspring. The use of logarithms in a nonlinear model essentially ensures that this

problem can never occur. Second, a linear additive model treats environmental factors such as X2 as additive factors, which has the implausible property of reducing the absolute numbers of fish by the same quantity for a given value of X2 irrespective of the total population. A nonlinear model recognizes that environmental factors have a proportionate impact on the population. These are major differences that demonstrate why linear additive models are not the best available science in fisheries population dynamics.

47. Moreover, if linear and nonlinear models are interchangeable, as Newman propounds, it would not be possible for covariates to appear significant in one and insignificant in the other. The level of significance might shift by a small degree, at best. The fundamental difference between the two types of models is illustrated by the results of my work: the BiOp erroneously applied a linear model and found that Fall X2 is highly significant, and I applied the correct nonlinear model and found that Fall X2 is not significant. The results belie Newman's assertion.

F. P-Values Are the Standard for Measuring Statistical Significance

48. Newman also comments on my use of p-values to determine statistical significance, yet he does not seem to raise any real criticisms.[13] *See* Newman Decl. ¶ 19. I agree with his statement that "P-values are useful because they provide some measure of the inconsistency of the data with a particular null hypothesis." *Id.* Null hypothesis testing has widespread application in the sciences. For example, Anderson (2000), the same article cited by Newman, explains, "Our review of Ecology and the Journal of Wildlife Management found the use of null hypothesis testing to be pervasive. The estimated number of P-values appearing within articles of Ecology exceeded 8,000 in 1991 and has exceeded 3,000 in each year since 1984, whereas the estimated number of P-values in the Journal of Wildlife Management exceeded 8,000 in 1997 and has exceeded 3,000 in each year since 1994." Anderson, D., et al., *Null Hypothesis Testing: Problems, Prevalence, and an Alternative*, 64:4 Journal of Wildlife

[13] A p-value is the probability that the result obtained in a statistical test is due to chance rather than a true relationship between variables. Statistical significance is found when the p-value is less than 0.05.

Management (2000) 912. I also agree with Newman that p-values are a function of sample size. This is not a critique and it does not change the utility of p-values. P-values remain the standard for measuring statistical significance, and even Newman's cited literature notes the prevalence of this method.

G. The Incidental Take Statement Is an Average, Not a Statistical Calculation

49. The adult and juvenile incidental take formulas are based on an average of cumulative salvage from certain years that FWS chose as "representative" of RPA conditions. When I reviewed the BiOp, I found that some of these years were *not* representative of RPA conditions based on reasoning that FWS used elsewhere in the BiOp. *See* Doc. 401 at ¶ 98, 103-04. When the unrepresentative years are removed, the average changes dramatically (from 7.25 to 10.45, or 44 percent, for adults; and by 32-33 percent for juveniles for the months May-June). Newman does not defend the BiOp's use of unrepresentative years in the Incidental Take Statement ("ITS") calculation. He does not provide any justification for the skewed averages. Instead, he calculates the confidence intervals for the BiOp's take ratio and compares them against confidence intervals for the take ratio that I constructed with the unrepresentative years removed. He points out that the confidence intervals have significant overlap. Newman Decl. ¶ 20. Overlap in the confidence intervals makes for an interesting statistical observation, but it is irrelevant here because the ITS is not the product of a statistical analysis. Rather, it is a straight average—an average which is significantly affected when certain years are removed.

IV. RESPONSE TO FEYRER DECLARATION

50. Although Feyrer's declaration responded specifically to Hilborn, I address here those aspects which potentially apply to my own declarations.

51. Feyrer defends the BiOp's use of a conceptual life cycle model framework because a quantitative population model was not "fully developed, peer-reviewed, and made available" to FWS when it developed the BiOp. *See* Feyrer Decl. ¶ 28-31. Whether or not this is true, FWS explains that it evaluated the three most critical project effects using an exclusively *quantitative* analysis. *See infra*, ¶ 3. The lack of a "fully developed, peer-reviewed" model does not absolve

FWS from the errors it committed in the quantitative analysis that it undertook. I understand that FWS was subject to the best available science standard when conducting that analysis.

52. Moreover, Feyrer exaggerates the amount of time necessary to develop the correct modeling for use in the BiOp. The Ricker model that I applied is in fact a quantitative population model, and it did not take three years to apply such a basic model to the delta smelt data. FWS could have easily used such a model in the time it had. I also am now involved with the development and application of a stage-structured model of intermediate complexity along with colleagues Drs. Ray Hilborn and Mark Maunder. Preliminary results of our application have produced results consistent with those obtained with the simpler Ricker model; namely, that no significant effect has been found for seasonal OMR flow, either winter or spring, or for Fall X2 on the statistical fit of the model to survey indices (Summer Townet Survey, FMWT, and 20-mm survey). That intermediate model was developed in less than two months. Given the 18-month period between when the 2005 BiOp was invalidated by the Court (May 2007) and when the new BiOp was issued (December 2008), and given that the issue of jeopardy in a section 7 consultation suggests the need for some form of population level impact analysis, there was ample time, in my opinion, to have conducted the type of scientifically-valid modeling described above.

V. CONCLUSION

53. In all of the declarations from the Defendants, no one has provided a response that justifies the BiOp's use of raw salvage in setting OMR flow limits. The failure to scale raw salvage to the population is a serious error, especially given that the BiOp sets specific numeric flow limits premised on that flawed analysis. Even the Defendants' own experts "concur with Deriso's general notion of scaling salvage by some measure of population abundance." Newman Decl. ¶ 11. The similar error with the agency's OMR flow and Fall X2 analyses—failing to review the data for effects to the smelt's population growth rate—is also unjustified. Failing to use data consistently for the incidental take limit is a third such error. Given that the agency stated in the BiOp that it is determining the effects of the projects on the smelt population, these inexplicable errors reflect that the agency did not use the best available science. Through all of

my declarations, I have explained what the agency did, and then presented what the data actually shows had the agency performed its analysis correctly—(1) OMR flows do not have a statistically significant effect on the population growth rate of the smelt, and (2) the incidental take limit was set too low.

I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this declaration was executed on March 1, 2010 at La Jolla, Ca.

/s/ [signature]

DR. RICHARD B. DERISO

Appendix

APPENDIX A

In a study conducted by Western Ecosystems Technology, Inc. under contract to the Metropolitan Water District of Southern California, a statistical bootstrap estimation procedure was applied to the FMWT data. A survey by year summary of those results is given below:

Year	Survey	Point Estimate	Bootstrap Mean	Bootstrap SD	Bootstrap Median	Bootstrap L90	Bootstrap U90	Bootstrap L95	Bootstrap U95
1987	3	437,036	473,254	362,408	449,941	43,159	1,155,002	25,066	1,338,814
1987	4	168,703	176,964	67,998	169,284	78,632	300,933	65,716	325,975
1987	5	335,392	351,452	139,362	339,415	142,186	598,994	112,653	658,898
1987	6	357,700	376,887	212,344	359,189	113,053	778,881	98,288	860,134
1988	3	282,539	300,171	101,112	292,664	144,925	476,470	121,221	518,769
1988	4	310,076	344,573	145,267	334,304	127,337	601,479	93,440	661,149
1988	5	100,874	122,378	61,264	116,797	31,494	232,273	16,806	257,621
1989	3	298,005	317,942	83,141	312,467	191,613	460,531	169,976	494,892
1989	4	264,921	295,298	61,757	289,064	209,402	400,284	198,676	431,391
1989	5	390,513	513,868	140,763	504,742	297,237	756,846	263,990	809,239
1989	6	144,267	180,191	60,501	172,426	95,220	290,847	84,171	316,148
1990	3	611,257	665,054	348,075	618,387	256,580	1,201,873	218,004	1,418,309
1990	4	299,930	305,054	72,454	302,493	191,302	429,689	168,246	453,878
1990	5	893,672	911,977	358,610	878,397	388,106	1,561,189	322,648	1,711,412
1990	6	81,921	83,389	25,410	81,740	45,240	128,310	39,890	139,210
1991	3	602,990	641,284	224,069	625,256	308,125	1,047,498	256,510	1,128,449
1991	4	1,403,241	1,464,646	365,293	1,437,141	914,703	2,092,908	822,817	2,252,533
1991	5	1,301,346	1,332,300	376,552	1,313,764	763,990	1,983,042	664,005	2,128,791
1991	6	222,737	224,890	78,229	218,748	105,861	363,053	90,426	399,257
1991	7	881,615	935,053	265,919	928,191	511,747	1,392,051	453,113	1,505,423
1991	8	217,773	235,922	79,699	228,669	118,310	377,396	100,676	413,211
1991	9	157,416	172,173	70,896	165,884	65,853	297,046	52,506	328,323
1992	3	433,131	440,408	156,146	427,002	206,097	715,915	175,237	776,975
1992	4	24,931	25,294	16,353	23,630	2,359	55,704	0	61,377
1992	5	351,719	359,264	121,174	355,816	168,945	569,092	141,641	607,958
1992	6	170,476	172,211	73,056	165,709	61,557	303,823	46,706	336,762
1992	7	180,951	196,685	50,356	192,415	122,473	284,667	111,023	308,219
1992	8	110,909	112,850	28,652	111,189	67,861	161,588	60,210	174,005
1992	9	110,863	136,451	33,953	134,798	84,042	193,848	75,233	205,562
1992	12	15,947	29,290	13,510	28,241	9,077	52,923	5,347	58,850
1993	2	115,500	118,273	45,252	115,411	51,347	195,710	42,361	213,336
1993	3	2,661,031	2,731,287	947,785	2,654,535	1,337,066	4,315,127	1,131,822	4,691,875
1993	4	3,374,180	3,438,108	1,099,411	3,352,026	1,808,698	5,384,426	1,582,459	5,827,111
1993	5	595,386	607,545	162,489	598,032	353,116	887,154	308,804	943,113
1993	6	1,018,395	1,034,678	203,087	1,031,855	709,131	1,379,885	648,228	1,443,565
1993	7	74,893	75,702	24,758	74,662	37,037	118,185	31,733	127,131
1993	8	60,991	63,768	18,760	63,046	34,786	96,178	30,031	103,245
1993	9	105,425	114,232	33,586	111,607	62,809	171,916	54,675	185,985

Year	Survey	Point Estimate	Bootstrap Mean	Bootstrap SD	Bootstrap Median	Bootstrap L90	Bootstrap U90	Bootstrap L95	Bootstrap U95
1993	10	15,447	23,400	11,640	22,205	6,619	43,953	3,647	49,261
1993	11	21,131	36,635	14,174	35,415	15,982	60,993	11,715	66,608
1994	2	266,460	288,314	103,964	277,198	139,206	473,689	121,627	515,322
1994	3	482,987	501,696	350,815	465,429	50,799	1,173,762	38,721	1,294,535
1994	4	85,068	86,884	40,693	82,791	26,713	161,337	19,228	179,065
1994	5	58,716	59,470	31,224	55,017	16,128	115,985	12,982	131,618
1994	6	108,936	112,877	44,774	108,321	47,123	194,400	37,221	212,097
1994	7	496,011	511,042	102,102	507,053	353,248	687,619	325,243	726,808
1994	8	397,558	409,062	95,021	402,240	266,135	577,157	241,265	609,148
1994	9	465,421	487,602	100,053	481,944	335,190	659,920	310,281	701,131
1994	10	169,116	183,602	84,276	175,394	65,128	334,980	38,357	368,757
1995	3	1,174,889	1,227,713	322,584	1,199,659	801,868	1,713,682	741,158	1,873,136
1995	4	2,735,970	2,796,977	726,412	2,738,169	1,695,043	4,065,096	1,559,709	4,365,061
1995	5	2,963,232	3,009,747	780,008	2,973,193	1,815,346	4,367,611	1,622,647	4,662,188
1995	6	633,680	645,532	212,432	620,426	336,177	1,035,536	296,840	1,133,003
1995	7	246,609	253,018	58,729	250,797	160,580	353,918	146,402	377,138
1995	8	138,023	147,035	50,343	143,441	70,096	234,751	58,687	258,213
1995	9	106,818	120,278	32,624	118,634	69,099	177,182	61,289	189,266
1995	10	32,168	41,266	17,419	40,173	14,633	71,636	10,757	78,532
1996	2	123,431	144,236	54,621	139,329	63,986	240,798	52,015	265,401
1996	3	117,144	146,924	39,178	145,061	87,122	212,445	78,868	226,328
1996	4	116,381	141,356	42,525	137,577	77,601	216,942	68,137	233,674
1996	5	64,868	76,489	31,369	74,401	28,811	132,614	22,234	145,070
1996	6	829,097	840,310	288,026	826,447	366,163	1,322,083	325,697	1,393,477
1996	7	469,023	478,652	99,115	472,100	325,738	644,997	299,973	680,852
1996	8	673,102	726,718	181,615	718,722	440,256	1,031,867	393,270	1,105,901
1996	9	1,171,653	1,251,597	402,612	1,229,942	630,381	1,901,686	596,497	1,992,007
1997	2	36,798	46,900	19,817	45,099	17,865	82,129	13,914	90,069
1997	3	54,744	70,596	29,684	68,418	25,431	121,934	18,450	134,111
1997	4	959,470	976,590	423,683	930,895	375,454	1,741,337	311,328	1,923,047
1997	5	600,406	611,222	206,286	596,001	296,825	979,319	248,894	1,051,680
1997	6	879,777	895,890	131,755	889,516	690,182	1,123,397	656,876	1,173,479
1997	8	36,302	41,751	25,793	40,098	4,609	87,308	4,027	99,490
1997	9	221,692	233,248	47,533	229,987	161,518	314,093	149,038	336,362
1998	3	1,739,853	1,779,088	456,912	1,735,152	1,118,479	2,571,201	1,023,352	2,768,632
1998	4	648,355	658,009	135,205	649,693	447,485	896,689	411,946	948,251
1998	5	84,663	85,014	43,517	79,271	25,492	163,864	20,271	183,435
1998	7	244,639	254,654	68,812	251,347	148,645	375,601	132,003	398,291
1998	9	154,895	173,240	37,295	170,603	117,099	238,838	108,054	254,555
1999	3	2,022,783	2,102,259	517,102	2,070,631	1,331,387	2,961,126	1,207,484	3,178,862
1999	4	3,338,979	3,421,054	926,919	3,353,281	2,038,223	5,021,254	1,798,126	5,405,575
1999	5	902,012	941,131	166,149	935,443	683,744	1,225,024	639,736	1,295,069

Year	Survey	Point Estimate	Bootstrap Mean	Bootstrap SD	Bootstrap Median	Bootstrap L90	Bootstrap U90	Bootstrap L95	Bootstrap U95
1999	6	1,463,303	1,507,763	660,111	1,428,674	568,028	2,697,263	443,415	2,953,618
1999	8	206,162	216,623	75,273	213,555	93,781	341,546	78,099	365,216
1999	9	247,837	282,650	64,840	277,543	188,040	394,320	172,730	428,225
2000	3	4,257,944	4,413,578	1,263,481	4,280,220	2,647,221	6,651,013	2,350,376	7,170,019
2000	4	1,153,772	1,187,474	486,011	1,145,340	473,766	2,069,926	382,860	2,256,880
2000	5	598,874	610,842	137,607	606,987	390,004	839,606	351,886	899,219
2000	6	1,028,184	1,044,506	274,519	1,029,547	619,641	1,520,458	560,220	1,623,307
2000	8	748,073	926,833	289,426	915,634	468,490	1,425,990	398,073	1,512,330
2000	9	659,294	935,035	311,721	905,082	491,318	1,494,060	442,676	1,625,370
2001	3	777,758	821,961	263,262	799,454	429,936	1,296,427	372,632	1,397,891
2001	4	3,926,944	4,023,320	1,113,803	3,975,423	2,277,454	5,948,994	1,993,844	6,391,642
2001	5	167,194	172,969	59,753	169,137	82,459	277,627	65,423	301,405
2001	6	161,722	169,146	78,228	159,764	61,248	310,661	51,093	343,924
2001	7	409,547	416,074	116,047	406,632	243,633	627,708	216,799	673,066
2001	8	323,729	341,280	63,946	338,746	240,430	449,590	225,887	478,287
2001	9	194,133	225,522	56,218	221,519	138,996	323,241	125,063	346,115
2002	3	234,525	243,827	98,384	234,934	96,435	422,173	80,383	459,568
2002	4	410,707	419,768	130,374	406,924	228,664	655,271	206,192	715,289
2002	5	272,150	287,236	92,908	280,433	151,295	452,981	127,993	490,581
2002	6	330,177	343,238	122,278	331,653	163,886	561,125	146,126	616,171
2003	3	91,166	94,140	31,980	92,672	44,650	148,138	36,189	161,017
2003	4	1,162,161	1,183,633	528,711	1,123,719	456,347	2,154,798	386,755	2,387,965
2003	5	209,234	209,400	89,843	201,062	80,060	371,066	64,751	411,521
2003	6	233,784	237,341	103,623	229,431	78,558	420,298	61,108	458,022
2004	3	164,804	170,760	78,322	168,446	44,796	300,460	32,255	318,622
2004	4	339,032	350,524	163,906	338,482	111,167	629,157	93,218	712,201
2004	5	175,858	179,432	55,510	176,857	93,130	274,256	80,473	294,389
2004	6	64,582	65,447	26,883	62,932	25,766	114,094	20,241	124,427
2005	3	23,604	23,702	12,858	22,903	5,939	46,837	0	51,892
2005	4	74,555	76,160	31,883	73,136	29,081	133,780	22,554	149,698
2005	5	59,580	60,126	24,510	58,331	23,373	103,164	16,787	112,005
2005	6	52,168	53,077	17,775	52,442	25,115	83,904	20,427	90,642
2006	3	323,496	336,850	118,057	327,824	164,182	534,217	136,656	579,165
2006	4	32,333	33,023	15,451	31,864	9,335	59,987	6,635	65,187
2006	5	31,401	32,006	16,718	31,357	9,245	61,174	0	68,900
2006	6	6,267	6,297	5,232	6,220	0	14,130	0	18,380
2007	3	60,722	61,703	22,684	59,782	27,507	101,775	22,415	111,176
2007	4	34,963	35,265	20,072	33,619	6,565	71,757	0	79,223
2007	5	31,790	32,202	23,195	29,975	0	74,608	0	86,086
2007	6	59,427	66,457	27,430	64,456	24,680	114,734	19,913	123,488

APPENDIX B

Point 1.

The BiOp on page 220 shows a linear regression equation that was based on fitting March-June OMR and X2 to the March-June entrainment loss estimates made in Kimmerer (2008): "The equations are as follows: March-June percent entrainment = (0.00933*March-June X2) - (0.0000207*March-June OMR) – 0.556…" That equation also turns out to produce good estimates for the annual loss or larvae and juveniles as shown in the graph below.

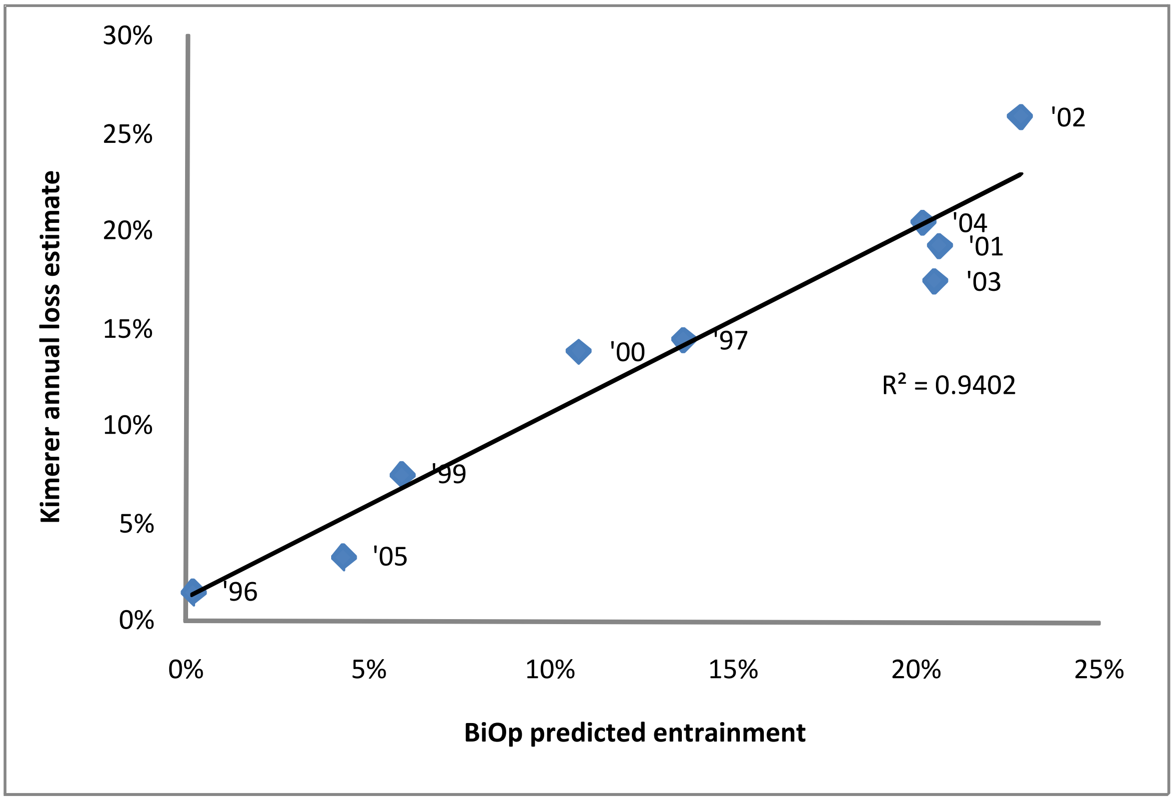


Figure caption: Annual loss of larvae/juveniles predicted by BiOp regression with March-June OMR and March-June X2 compared to Kimmerer (2008) estimates, excluding positive OMR flow years of 1995, 1998, and 2006.

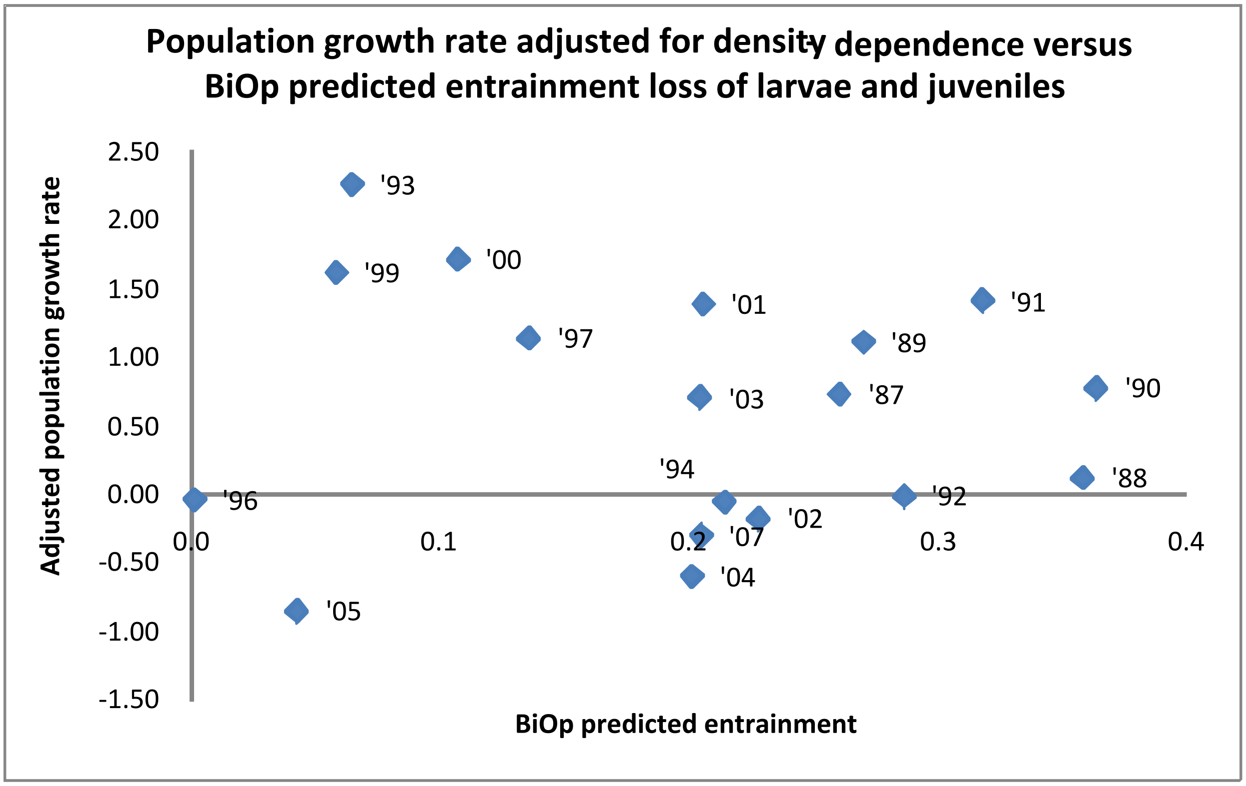
Those predicted entrainment losses are shown in tabular form below along with the OMR and X2 data used in the prediction equation and the annual loss of larvae and juveniles as estimated in Kimmerer (2008). Note that data for 1995, 1998, and 2006 are omitted because the OMR flow was positive in those years which resulted in the regression equation predicting negative entrainment for those years.

year	Mar-June OMR	Mar-Jun X2	BiOp predict	Kimmerer's annual loss estimate
1987	-3828.336066	79.05	26.08%	
1988	-5732.270492	85.2775	35.83%	
1989	-6132.303279	74.96	27.03%	
1990	-5414.737705	86.57	36.38%	
1991	-4545.278689	83.6025	31.81%	
1992	-3847.114754	81.7675	28.65%	
1993	-2599.057377	60.8	6.51%	
1994	-1824.057377	78.54	21.45%	
1996	-798.1147541	58.0175	0.18%	1.50%
1997	-2641.221311	68.3	13.59%	14.44%
1999	-2100.918033	61.2375	5.88%	7.52%
2000	-3712.409836	62.8625	10.74%	13.84%
2001	-3466.663934	73.965	20.59%	19.26%
2002	-4499.45082	74.0675	22.82%	25.88%
2003	-6174.434426	67.83	20.47%	17.45%
2004	-5841.295082	68.21	20.13%	20.46%
2005	-567.647541	62.93	4.29%	3.31%
2007	-2828.692984	75.3025	20.51%	

Data sources: OMR flows were provided by FWS in the FOIA response to MWD in 2009; X2 monthly averages are provided in the DOJ submittal; Kimmerer's annual loss of larvae and juveniles was obtained by digitizing the estimates presented in Figure 15 in his 2008 paper.

The life-cycle model used for this analysis is a standard Ricker stock-recruitment model in which consecutive year FMWT estimates take the role of stock and recruitment, respectively. The predicted entrainment losses shown above were then used in a Ricker stock-recruitment model to evaluate whether they had a statistically significant effect on population growth rate. Results of the analysis show that the BiOp predicted entrainment loss is not significant at the p-value = 0.05 level (calculated P-value = 0.74). Details of this analysis are given below.

Year	BiOp predicted entrainment loss	S = FMWT in year-1	R=FMWT in year t	ln(R/S) =ln(FMWT_0/FMWT_1)	Population growth rate adjusted for density
1987	0.26	212	280	0.28	0.73
1988	0.36	280	174	-0.48	0.12
1989	0.27	174	366	0.74	1.12
1990	0.36	366	364	-0.01	0.78
1991	0.32	364	689	0.64	1.42
1992	0.29	689	156	-1.49	-0.01
1993	0.07	156	1078	1.93	2.27
1994	0.21	1078	102	-2.36	-0.05
1996	0.00	899	127	-1.96	-0.03
1997	0.14	127	303	0.87	1.14
1999	0.06	420	864	0.72	1.62
2000	0.11	864	756	-0.13	1.72
2001	0.21	756	603	-0.23	1.39
2002	0.23	603	139	-1.47	-0.18
2003	0.20	139	210	0.41	0.71
2004	0.20	210	74	-1.04	-0.59
2005	0.04	74	27	-1.01	-0.85
2007	0.21	41	28	-0.38	-0.29



SUMMARY OUTPUT

ln(FMWT/FMWT_1)=a+b*entrainment +c*FMWT_1

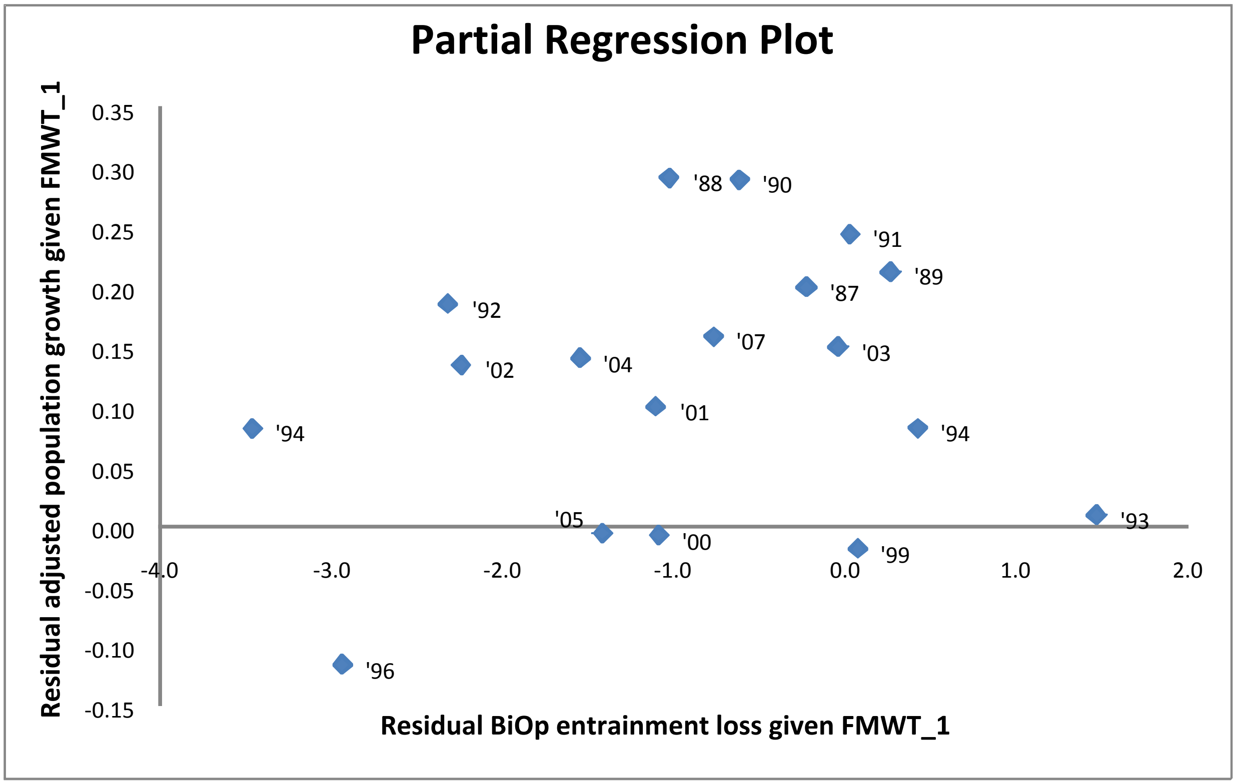
Regression Statistics	
Multiple R	0.6123
R Square	0.3749
Adjusted R Square	0.2915
Standard Error	0.9390
Observations	18

ANOVA

	df	*SS*	*MS*	*F*
Regression	2	7.9315	3.9658	4.4979
Residual	15	13.2255	0.8817	
Total	17	21.1570		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	0.7538	0.5781	1.3039	0.2119
BiOp predicted entrainment	-0.7271	2.1233	-0.3424	0.7368
FMWT previous year	-0.0021	0.0007	-2.9990	0.0090

A partial regression plot (also known as an added variable plot) was constructed and it is shown below. This plot confirms the graph given above that there does not appear to be a relationship between the BiOp predicted entrainment and population growth given both variables adjusted for the effect of FMWT_1.



A sensitivity analysis was completed which follows the same approach given above for the Ricker model application except entrainment in years 1995, 1998, and 2006 was set to zero. All years 1987-2007 were included in this analysis. The BiOp predicted entrainment loss is not significant at the 0.05 level of significance (p-value = 0.37). The analyses are tabled below.

SUMMARY OUTPUT

ln(FMWT/FMWT_1)=a+b*entrainment +c*FMWT_1

Regression Statistics	
Multiple R	0.6541
R Square	0.4279
Adjusted R Square	0.3643
Standard Error	0.9321
Observations	21

ANOVA

	df	*SS*	*MS*	*F*
Regression	2	11.6977	5.8488	6.7313
Residual	18	15.6401	0.8689	
Total	20	27.3378		

	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	1.0307	0.4159	2.4780	0.0233
BiOp entrainment	-1.5852	1.7209	-0.9212	0.3691
FMWT_1	-0.0023	0.0007	-3.4405	0.0029

Point 2.

Using a weight of evidence approach, I evaluated the relationship between the population growth rate and both BiOp predicted entrainment and abundance using the data shown above. Two models were constructed. The first model uses abundance as a single explanatory variable ("S only"), and the second model uses both abundance and BiOp predicted entrainment ("entrainment & S"). I compared these two models to see whether the model using BiOp predicted entrainment resulted in a better fit to the data. It did not. The results showed that the AICc score for the first model was below the AICc score for the second model, and indicated an 83 percent weight of evidence in favor of a model fit that does not include BiOp predicted entrainment.

	Number of observations	18
Number of Parameters	3	4
	S only	entrainment & S
RSS	13.33	13.23
ln(like)	-23.31	-23.24
AIC	52.62	54.48
AICc	54.33	57.56
Delta	0.00	3.22
e^-d/2	1.00	0.20
Weight	0.83	0.17

I repeated the weight of evidence analysis using the data above except that the omitted years of positive OMR flow (1995, 1998, and 2006) were included with an assigned entrainment loss of 0.0 for those years. The results given below showed that the AICc score for the first model was below the AICc score for the second model, and indicated a 74 percent weight of evidence in favor of a model fit that does not include BiOp predicted entrainment.

	Number of observations	21
Number of Parameters	3	4
	S only	entrainment & S
RSS	16.38	15.64
ln(like)	-29.36	-28.87
AIC	64.71	65.75
AICc	66.13	68.25
Delta	0.00	2.12
e^-d/2	4.37E-15	1.52E-15
Weight	0.74	0.26

CERTIFICATE OF SERVICE

I hereby certify that on March 1, 2010, I electronically filed the foregoing with the Court by using the Court's CM/ECF system.

Participants in the case who are registered CM/ECF users will be served by the Court's CM/ECF system.

I further certify that the court-appointed experts are not registered CM/ECF users. I have emailed the foregoing document to the following:

REPLY DECLARATION OF DR. RICHARD B. DERISO

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I declare under penalty of perjury under the laws of the State of California the foregoing is true and correct and that this declaration was executed on March 1, 2010, at San Francisco, California.

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UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA Partially Consolidated With: 1:09-cv-480 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	**DECLARATION OF DR. RICHARD B. DERISO IN SUPPORT OF PLAINTIFFS' MOTION FOR INJUNCTIVE RELIEF**
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	Date: July 26-29, 2011 Time: 8:30 a.m. Ctrm: 3 Judge: Hon. Oliver W. Wanger
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	

I, DR. RICHARD B. DERISO, declare:

1. The facts and statements set forth in this declaration are true of my own knowledge and if called as a witness, I can testify competently thereto.

2. My declaration is set forth in the following manner:

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I. INTRODUCTION AND SUMMARY

3. In my previous declarations, I addressed the analysis that the United States Fish and Wildlife Service ("FWS") performed in its 2008 Delta Smelt Biological Opinion ("BiOp"), including its errors in its analysis of Old and Middle River ("OMR") flows, the location of Fall X2, and the incidental take levels. *See* Doc. 167; Doc. 401; Doc. 455; Doc. 508; Doc. 605; Doc. 772; Doc. 814.

4. In this declaration, I have been asked to specifically focus on the issue of X2—a measurement of salinity in the Delta that the FWS has used as a proxy for suitable smelt habitat. The 2008 BiOp regulates the location of X2 as a means of influencing delta smelt habitat availability. The analysis performed by Mr. Feyrer, which is the basis of Fall X2 action, does not establish that the location of X2 will cause any harm to the species. The flaws in that analysis not only undermine its validity, but they also improperly suggest that the species will be impacted by changes in X2. The current science, most recently aided by the development of the quantitative lifecycle model, shows that X2 does not impact the species.

5. The scientific tools for analyzing the available data for smelt have improved greatly since Mr. Feyrer's analysis. Dr. Mark Maunder and I have used the available data on the Delta smelt and developed a peer-reviewed life-cycle model. *See* **Exhibit A**, Mark Maunder and Richard Deriso, *A state-space multi-stage lifecycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt* (Dec. 27, 2010) (in press), attached hereto. Using that life-cycle model, we have further concluded that there is no statistical support for the proposition that the location of X2 drives changes in smelt abundance.

6. The results of the model also provide important information that may be used for future management of the species. Specifically, the model indicates that food availability, predator abundance, temperature, and density dependence are the most critical factors impacting the Delta smelt population.

7. Drawing on all of the available data on smelt populations and stressors, including data from the National Center for Ecological Analysis and Synthesis ("NCEAS"), the data

confirms that X2 does not explain the variation in delta smelt population growth rate over time and should not be relied upon as a factor to improve smelt abundance.

II. THE EXISTING LIFE-CYCLE MODEL FOR DELTA SMELT REPRESENTS THE CURRENT BEST AVAILABLE SCIENCE AND CONFIRMS THAT X2 IS NOT A FACTOR IMPACTING THE SMELT POPULATION GROWTH RATE

8. In its X2 modeling efforts, FWS failed to undertake the standard first step in evaluating the effect of a potential stressor on a species: namely, using a standard quantitative life-cycle model to evaluate whether the stressor has a statistically significant effect on the population growth rate of the species. It is well-accepted that when data sets exist for a species population and the suspected stressors on that population, an analysis should be performed to determine whether those data sets are correlated. That is why life-cycle models are developed—to perform that analysis and to test the validity of the hypothesis that the stressor has impacted the species population. I can think of no reason why a life-cycle model that follows the population of the smelt through its life stages (as measured by surveys) was not employed for the Delta smelt in the BiOp.

9. As discussed by Dr. Ray Hilborn in his previous declaration, the use of life-cycle models (also called quantitative population dynamics models) is standard procedure in biological opinions prepared by the FWS and NMFS. Doc. 393 at ¶ 12. FWS has used them for a variety of species that include, at a minimum, the short-tailed albatross, the pronghorn antelope, the marbled murrelet, the fat threeridge mussel, the California gnatcatcher, the Florida panther, the Stellar's eider, the golden-cheeked warbler, the black capped vireo, and the polar bear. *Id.* NMFS has also used life-cycle models in BiOps for several species of turtle, North Atlantic right-whales, beluga whales, Stellar's sea lions, and a wide range of salmon stocks. *Id.* Thus, in assessing the impact of humans on ESA-listed species, the use of life-cycle models is the accepted standard. *Id.*

10. The National Research Council ("NRC") also has recognized the importance of employing a life-cycle model to delta fish species. The NRC stated that complicated life history patterns can be most effectively understood by using a modeling framework that embodies a

species' complete life-cycle, and it recommended "that development of such models be given a high priority within the agencies."[1]

11. Fundamentally, life-cycle models analyze potential stressors against the population growth rate of a species. The population growth rate is a standard measurement of the rate of change in the population level from year to year. In other words, the population growth rate shows trends in the change in population, not absolute changes in population size. By using a standard quantitative life-cycle model, such as the Ricker model, scientists can determine to what degree changes in the level of the stressor correlate with changes in the population growth rate. These quantitative life-cycle analyses are powerful because they allow managers to identify the degree to which individual stressors drive changes in the population.

12. Moreover, because the population growth rate measures changes in abundance across the entire life-cycle of a species, it captures the full effect of the stressor throughout the life-cycle and corrects for any transitory perturbations that do not actually affect the population growth rate. For example, in many species the population naturally fluctuates throughout the year. A study that only analyzes the population during one of the downward fluctuations might incorrectly assume that a stressor had a negative effect on the population, whereas a population-growth rate analysis would expand beyond the natural fluctuation and reveal that the suspected stressor actually caused no change to the overall population growth rate.

13. Dr. Mark Maunder and I have used the available data on the delta smelt to develop a life-cycle model for the species that can be used as a tool to evaluate numerous potential stressors for their significance in explaining the trends in the smelt population growth rate. The model has been accepted for publication in a leading fisheries journal, has already undergone peer review, and is now in press set for publication later this year. *See* **Exhibit A**.

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[1] "A Scientific Assessment of Alternatives for Reducing Water Management Effects on Threatened and Endangered Fishes in California's Bay Delta," A Report of the National Research Council of the National Academies, March 19, 2010, p. 25-26.

14. Our life-cycle model represents the different life-cycle stages of the species (adult, larval, juvenile) and how the population abundance changes between these stages. It models survival from one life stage to the next, as well as the stock-recruit (i.e., parent-offspring) relationship. The model is able to test multiple factors or covariates (including factors relating to environmental conditions and mortality rates based on entrainment) for their influence on the survival and stock-recruit relationships. Thus, each factor represents a hypothesis about what conditions or events make a difference for smelt survival and recruitment. Those factors can then be objectively evaluated by the model against the data for the smelt through its various life stages year over year.[2]

15. In order to determine which factors are important for explaining changes in delta smelt survival and recruitment, Dr. Maunder and I have tested multiple covariates and multiple combinations of covariates. We determined that of all the factors we tested, food abundance, temperature, predator abundance, and density dependence are the most crucial factors impacting the Delta smelt population. **Exhibit A** at p. 31. Specifically, survival is positively related to food abundance and negatively related to temperature and predator abundance. *Id.* at 31. In a related analysis (explained more fully in Section IV below), the life-cycle model also demonstrated that the location of X2 does not have <u>any</u> statistical support as an explanatory stressor on the species. *See* Deriso and Maunder, *Evaluation of Fall X2 on delta smelt* (October 2010), attached hereto as **Exhibit B**. Thus, the data shows that manipulating the location of X2 is not a sensible approach

[2] In prior declarations and briefs FWS attempted to identify obstacles to life-cycle modeling, such as that a life-cycle model would need to incorporate "spatial and temporal" structure. Newman Decl., Doc. 484 at ¶ 5. But spatial and temporal information on the species can be incorporated into the model without building them into the model structure itself. In many cases the data already accounts for these factors implicitly. In our application of the model for the journal, spatial and temporal structure is implicitly incorporated in the life-cycle model analysis by way of the structure of the covariates developed in Manly (2010). Those covariates are based on area weighted measurements in which the weightings are based on sample time and area measurements of delta smelt abundance. This approach of incorporating fine-scale temporal and spatial structure into the data rather than the structure of a model follows a standard approach in entrainment and impingement analysis (*see e.g.*, Swartzman, G., Deriso, R., and C. Cowan. 1977. Comparison of simulation models used in assessing the effects of power-plant-induced mortality on fish populations. Proc. Conference on assessing the effects of power plant induced mortality on fish populations. Editor, W. Van Winkle. Pergamon Press: 333-361; An Empirical Methodology for Estimating Entrainment Losses at Power Plants Sited on Estuaries. Transactions of the American Fisheries Society. Volume 110, Issue 2, 1981, Pages 253 - 260).

to improving the smelt population and that, instead, efforts should be focused on addressing environmental conditions affecting the species, such as its food supply.

III. THERE IS NO SCIENTIFIC EVIDENCE OR STATISTICAL SUPPORT FOR THE PROPOSITION THAT THE LOCATION OF X2 WILL HARM THE SMELT POPULATION

16. I am aware that in its summary judgment decision in December 2010, this Court found that the BiOp failed to explain or justify the requirement that X2 be held at the locations specified. Doc. 757 at 125-26. As discussed in my previous declarations (Docs. 167, 401, 605) and as I will explain in more detail below in Section IV, the fact is that *there can be no rational explanation* for FWS's arbitrary X2 locations, precisely because X2 does not correlate to smelt population growth rate.

A. FWS's Finding of a Statistically Significant Relationship Between X2 and Delta Smelt Juvenile Abundance was Wrong

17. On March 19, 2010, the NRC published a report assessing the scientific basis of the FWS and NMFS's BiOps' water management regulations. The report focused on whether provisions of the two BiOps were scientifically justified and conceptually sound. Specifically, the NRC appointed a committee of experts to focus on the scientific bases of the RPAs in the BiOps, assess whether the RPAs might be in conflict with one another, and consider the effects of "other stressors" on listed fish species.

18. The NRC found that "the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action [RPA Action 4] difficult to understand." NRC Report at 4. The NRC further noted that X2 regulations would "have high water requirements" and might "adversely affect salmon and steelhead under some conditions." *Id.* Because of the uncertain science and the high social and ecological costs of X2 regulations, the NRC concluded that more clarification was needed as to how specific X2 targets were chosen and what likely beneficial effects would result. *Id.* For instance, the NRC found that each step in FWS's regulation of X2 was based on a series of linked analyses. These included the relationship between the "occurrence of fish" and environmental variables; the relationship of environmental

variables to habitat area; the relationship of habitat area to X2; and the relationship of X2 to changes in delta smelt juvenile abundance. Although each of these steps contains a high degree of uncertainty, the NRC found that the final BiOp analysis did not adequately take uncertainty into account.

19. Mr. Feyrer's 2007 paper[3] analyzed the effect of "EQ," a metric of environmental quality that incorporated salinity, temperature and secchi depth (a measurement of water clarity), on the delta smelt. Mr. Feyrer found a relationship between measurements of salinity and the likelihood that fish would be found at a particular survey location, and found a statistically significant relationship between salinity, secchi depth, and delta smelt abundance. Feyrer et al. 2007 at 728, 731.

20. However, Mr. Feyrer himself acknowledged two significant caveats to his study. First, the study only considered abiotic factors, such as salinity and water clarity, and did not include any biotic variables, such as competition, predation and food availability. *Id.* at 732. In particular, Mr. Feyrer singled out food availability as an omitted variable that was likely affecting smelt abundance. *Id.* For this reason, Mr. Feyrer concluded that delta smelt abundance is "probably controlled by multiple interacting factors," and predicted that "[c]urrent efforts in parameratizing life-cycle models for delta smelt . . . are likely to better quantify the relative importance of water quality on their population dynamics." *Id.* at 731. Second, Mr. Feyrer acknowledged that "the degree to which EQ could be used for management purposes is unclear." *Id.* at 732. Salinity, which Mr. Feyrer measured by specific conductance of the water, cannot be regulated directly, but only through X2, which is a "surrogate" for salinity across a broad region of the Delta. *Id.*

21. As a result, even Mr. Feyrer qualified his findings in 2007 and recognized that life-cycle models are the appropriate tool for determining the validity of stressors on population dynamics.

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[3] *See* Frederick Feyrer, et al., *Multidecadal trends for three declining fish species: habitat patterns and mechanisms in the San Francisco Estuary, California, USA*, Can. J. Fish. Aquat. Sci. 64:723-734 (2007) (AR018278-306).

22. Mr. Feyrer wrote a subsequent draft manuscript in 2008[4] considering X2, delta smelt "habitat index," and X2's effect on smelt abundance.[5] However, only a portion of this manuscript was subsequently published in 2010. Notably, Mr. Feyrer's linear additive model developed in his 2008 analysis did not survive the subsequent peer-review and manuscript revision process, and therefore that flawed work does not appear, in any form, in Mr. Feyrer's published 2010 paper.[6]

23. When I incorporated the available data into an appropriate standard stock-recruit model, I determined that there was no statistically significant relationship between X2, stock abundance, and recruit abundance. The relationship between X2 and abundance using the proper model is plotted in Figure 2 below:

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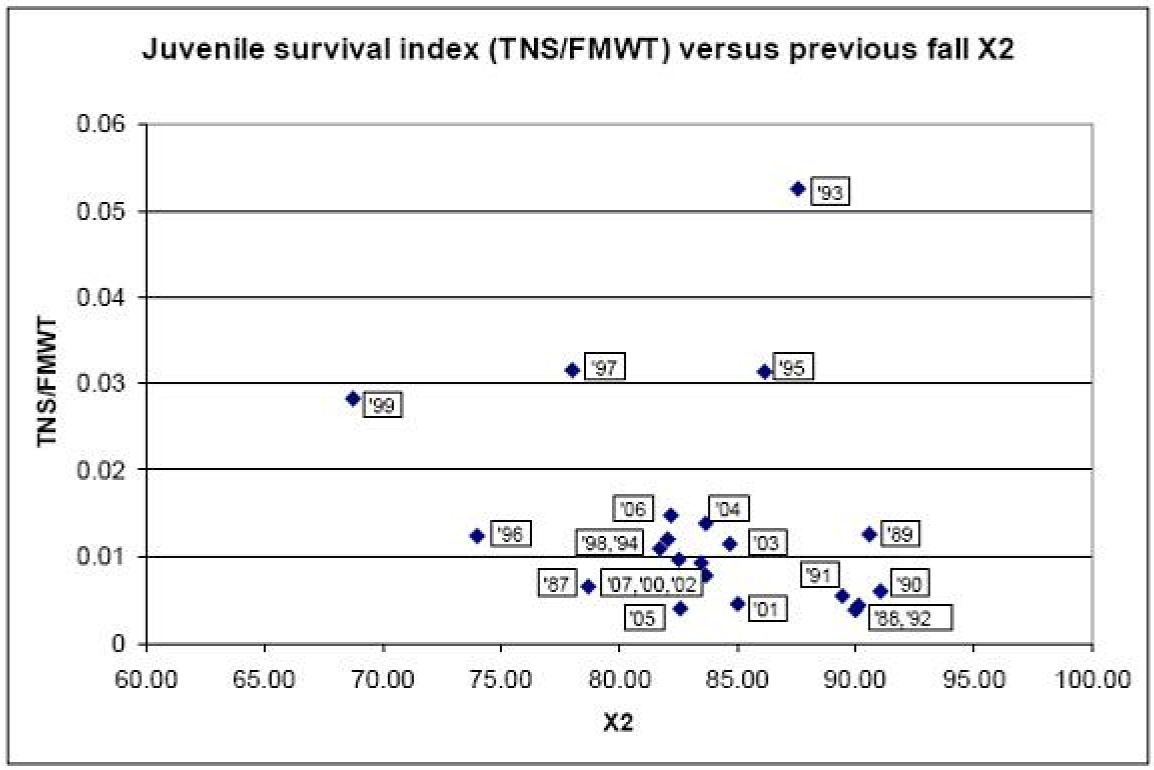
[4] *See* Frederick Feyrer, et al., *Modeling the Effects of Water Management Actions on Suitable Habitat and Abundance of a Critically Imperiled Estuarine Fish (Delta Smelt* Hypomesus transpacificus*)* (2008) (AR018266-277).

[5] Importantly, this Court's summary judgment decision from December 2010 mistakenly stated that Feyrer et al.'s 2008 paper had been peer-reviewed ("The BiOp expressly recognizes that the modeling does not precisely represent historic X2, as do the *peer-reviewed studies* on which the BiOp relies in part for this component. *See* BiOp at 204; *AR 018278-018306 (Feyrer, et al. (2008))*." Doc. 757, p. 103 (emphasis added)). However, this was not the case. The paper was merely a draft manuscript in-review and had not yet advanced to the peer-review phase.

[6] Frederick Feyrer, et al., Modeling the Effects of Future Outflow on the Abiotic Habitat of an Imperiled Estuarine Fish, Estuaries and Coasts 34:120-128 (2010) (AR 018278-306).

Figure 2.

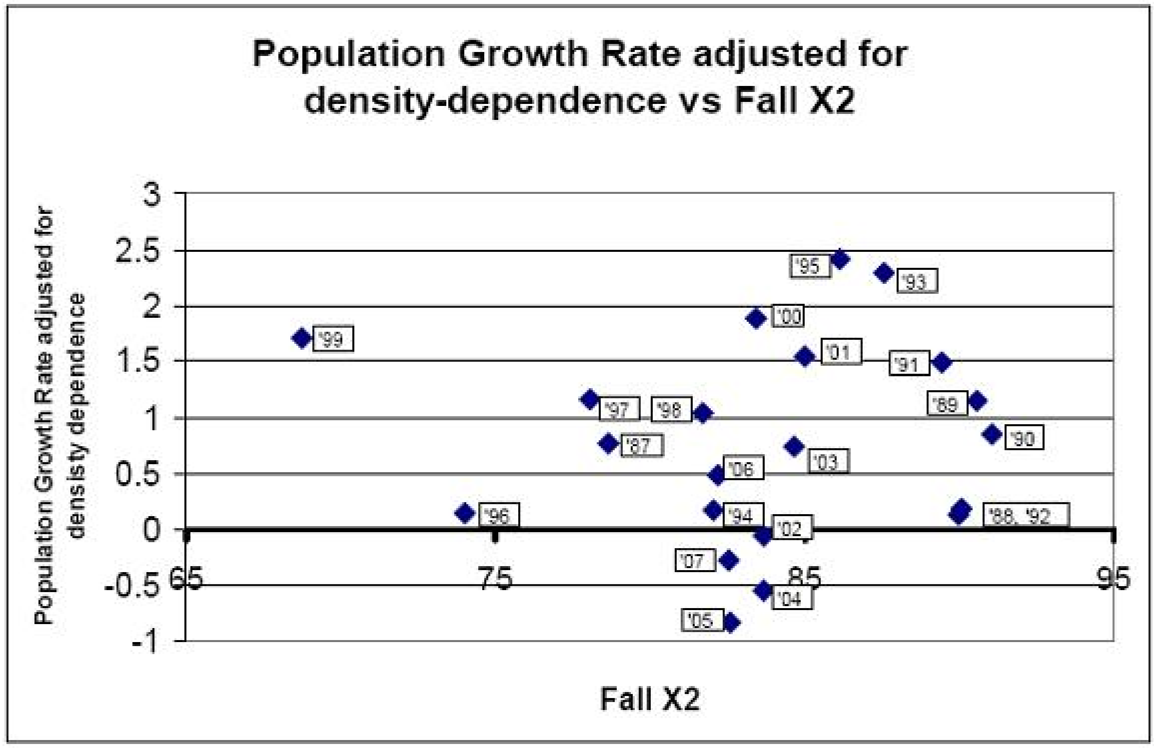


24. As the figure above demonstrates, the relationship between X2 and survival is a simple scatterplot with no trend or tendency evidencing a statistically significant relationship between X2 and delta smelt abundance.

B. Even Basic Population-Growth Rate Analyses Indicate That There is No Basis for FWS's X2 Restrictions

25. When I performed my first quantitative life-cycle analysis of the effect of X2 on delta smelt abundance, I found that the location of X2 has no statistically significant effect on the population growth rate of the species, as shown in Figure 3 below:

Figure 3.



26. The figure above demonstrates that even in this basic analysis, there is no discernible correlation between X2 and the population growth rate for smelt. Thus, this analysis, taken with the multiplicative stock-recruit analysis described above, shows that X2 does not have a statistically significant effect on delta smelt abundance growth rate either in a given water year (from adults to juveniles) or across the full life-cycle (adults to adults). These rudimentary life-cycle analyses indicate that there is no basis for using X2 to benefit smelt populations.

C. Utilizing a Full Quantitative Life-Cycle Model Analysis Confirms That X2 has No Effect on Changes in Smelt Population Growth Rate Over Time

27. As Mr. Feyrer indicated in his 2007 article, the development of a full quantitative life-cycle model that incorporates a number of biotic and abiotic parameters is a necessary step to "better quantify the relative importance of water quality on [delta smelt] population dynamics." Feyrer et al. 2007 at 731. As described previously, Dr. Mark Maunder and I have completed a state-space multi-stage life-cycle model for the smelt, and the results confirmed my initial

analyses showing that X2 has no effect on the population growth of the delta smelt over time. *See* Exhibit A.

28. We evaluated and ranked a number of models that included different mixes of covariates based on the strength of evidence in the data for including each covariate in the model. That procedure involved using Akaike Information Criterion (AIC)[7] to rank models that included different mixes of covariates based on the strength of evidence in the data for including each covariate in the better models. This method, which is standard for comparing the quality of different statistical models, evaluates how much the addition or subtraction of covariates from a model improves it in fitting the data on the smelt. Through this winnowing process and by testing multiple covariates and multiple combinations of covariates, Dr. Maunder and I determined that of all the factors tested, food abundance, predator abundance, temperature, and density dependence are the most important factors controlling the population dynamics of delta smelt. *See id.*

29. In a subsequent analysis, Dr. Maunder and I used our state-space quantitative life-cycle model to focus specifically on whether there was <u>any</u> statistical support for the influence of X2 on delta smelt abundance. *See* **Exhibit B**. First, we ran the model with the covariates that had been selected through the process above: food abundance, temperature, predator abundance. We then ran the model again, including Fall X2 either before or after density dependence.

30. The results of the analysis showed that the incorporation of X2 did not improve the quality of the model, indicating there was no statistical support for Fall X2 impacting smelt survival from adults to larvae. *See* **Exhibit B**.

31. Finally, we used our model approach to perform another exploratory analysis of a set of covariates that included some of the data provided by NCEAS. Among the covariates provided by NCEAS were measures of both Fall and Spring X2. Dr. Maunder and I performed a

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[7] AIC represents a measure of the goodness of fit of an estimated statistical model and is utilized as a tool for model selection. AIC weights are often used to provide a measure of the relative support for a model and to conduct model averaging. Exhibit A at 13. To interpret AIC scores, one compares the AIC values for a set of models fit to the same data set. The model with the lowest AIC score is the preferred model.

model selection process again using the covariates and came to the same result: the model that was selected by the process did not incorporate either measure of X2—the results again show that X2 has no statistical support. *See* Deriso and Maunder, *Exploratory analysis of set two covariates in the delta smelt life-cycle model* (December 2010), attached hereto as **Exhibit C**.

IV. CONCLUSION

32. In his 2007 paper, Mr. Feyrer acknowledged that the development of a full quantitative life-cycle model, one that included both biotic and abiotic habitat variables, would allow for better quantification of the relationship between X2 and changes in delta smelt abundance.

33. The NRC Report already raised concerns about the lack of support for using X2 as a regulatory control, observing that "[a]lthough there is evidence that the position of X2 affects the distribution of smelt, the weak statistical relationship between the location of X2 and the size of smelt populations makes the justification for this action difficult to understand." NRC Report at 4.

34. Now, Dr. Maunder's and my new quantitative life-cycle model confirms that, in fact, there is not even a "weak statistical relationship" between X2 and changes in smelt abundance—no such relationship is supported by the data.

35. Using the most current data on the delta smelt and a peer-reviewed life-cycle model, definitively proves that there is no statistical support for X2-based regulations.

I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this Declaration was executed on June 16, 2011 at La Jolla, California.

DR. RICHARD B. DERISO

CERTIFICATE OF SERVICE

I hereby certify that on June 16, 2011, I electronically filed the foregoing with the Court by using the Court's CM/ECF system.

Participants in the case who are registered CM/ECF users will be served by the Court's CM/ECF system.

I further certify that the court-appointed experts are not registered CM/ECF users. I have emailed the foregoing document to the following:

DECLARATION OF DR. RICHARD B. DERISO

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I declare under penalty of perjury under the laws of the State of California the foregoing is true and correct and that this declaration was executed on June 16, 2011, at San Francisco, California.

/s/ Lynda Robisch
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Exhibit A-1

A state-space multi-stage lifecycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt

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Abstract

Multiple factors acting on different life stages influence population dynamics and complicate the assessment and management of populations. To provide appropriate management advice, the data should be used to determine which factors are important and what life stages they impact. It is also important to consider density dependence because it can modify the impact of some factors. We develop a state-space multi-stage life cycle model that allows for density dependence and environmental factors to impact different life stages. Models are ranked using a two-covariate-at-a-time stepwise procedure based on AICc model averaging to reduce the possibility of excluding factors that are detectable in combination, but not alone. Impact analysis is used to evaluate the impact of factors on the population. The framework is illustrated by application to delta smelt, a threatened species that is potentially impacted by multiple anthropogenic factors. Our results indicate that density dependence and a few key factors impact the delta smelt population. Temperature, prey, and predators dominated the factors supported by the data and operated on different life stages. The included factors explain the recent declines in delta smelt abundance and may provide insight into the cause of the pelagic species decline in the San Francisco Estuary.

Key words: delta smelt; density dependence; model selection; population dynamics; state-space model;

Introduction

Multiple factors acting on different life stages influence population dynamics and complicate the assessment and management of natural populations. To provide appropriate management advice, the available data should be used to determine which factors are important and what life stages they impact. It is also important to consider density dependent processes because they can modify the impact of some factors and the strength of density dependence can vary among life stages (Rose et al. 2001). Management can then better target limited resources to actions that are most effective. Unfortunately, the relationships among potential factors, the life stages that they influence, and density dependence are often difficult to piece together through standard correlation or linear regression analyses.

Life cycle models are an essential tool in evaluating factors influencing populations of management concern (Buckland et al. 2007). They can evaluate multiple factors that simultaneously influence different stages in the presence of density dependence. They also link the population dynamics from one time period to the next propagating the information and uncertainty. This link allows information relating to one life stage (i.e., abundance estimates) to inform processes influencing other life stages and is particularly important when data is not available for all life stages for all time periods. The life cycle model should be fit to the available data to estimate the model parameters, including parameters that represent density dependence, and determine the data based evidence of the different factors that are thought to influence the population dynamics. Finally, the model should be used to direct research or provide management advice.

Deriso et al. (2008) present a framework for evaluating alternative factors influencing the dynamics of a population. It extends earlier work by Maunder and Watters (2003), Maunder and Deriso (2003), and Maunder (2004) and is similar to approaches taken by others (e.g., Besbeas et al. 2002; Clark and Bjornstad 2004; Newman et al. 2006). The Deriso et al. framework involves several components. First, the factors to be considered are identified. Second, the population dynamics model is developed to include these factors and then fitted to the data. Third, hypothesis tests are performed to determine which factors are important. Finally, in order to provide management advice, the impact of the factors on quantities of management interest, are assessed. They illustrate their framework using an age-structured fisheries stock assessment model fit to multiple data sets. Their application did not allow for density dependence in the population dynamics, except through the effect of density on the temporal variation in which ages are available to the fishery.

Inclusion of density dependence is important in evaluating the impacts on populations. Without density dependence, modeled populations can increase exponentially. This is unrealistic and can also cause computational or convergence problems in fitting population dynamics models to data. Density dependence can also moderate the effects of covariates. This is important because factors affecting density independent survival may be much less influential in the presence of density dependence compared to factors that affect carrying capacity (e.g., habitat). It is also important to correctly identify the timing of when the factors influence the population with respect to the timing of density dependence processes and available data. The approach also provides a framework for amalgamating the two paradigms of investigating population regulation outlined by Krebs (2002); the density paradigm and the mechanistic paradigm.

Here we develop a life cycle model that allows for density dependence at multiple life stages and allows for factors to impact different life stages. We apply the framework of Deriso et al. (2008) where the first component also includes identifying the life stages that are impacted by each factor and where density dependence occurs. We illustrate the framework by applying it to Delta smelt. Delta smelt is an ideal candidate to illustrate the modeling approach because there are several long-term abundance time series for different life stages and a range of hypothesized factors influencing its survival for which covariate data is available. Life cycle models have been recommended to evaluate the factors effecting delta smelt (Bennett 2005; Mac Nally et al. 2010; Thomson et al. 2010).

Delta smelt is of particular management concern due to declines in abundance and the myriad of anthropogenic factors that could be causing the decline. Delta smelt is endemic to the San Francisco Estuary, which has multiple stressors including habitat modification, sewage outflow, farm runoff, and water diversions, to name just a few. Delta smelt was listed as threatened under the U.S. and California Endangered Species Acts in 1993. Several other pelagic species in the San Francisco Estuary have also experienced declines, but the factors causing the declines are still uncertain (Bennett 2005; Sommer et al. 2007). Recent studies have investigated the factors hypothesized to have caused the declines at both the species and ecosystem level, but the results were not conclusive (Mac Nally et al. 2010; Thomson et al. 2010).

Materials and Methods

Model

The model is stage based with consecutive stages being related through a function that incorporates density dependence. For simplicity and to be consistent with the predominant dynamics of delta smelt, we assume an annual life cycle. However, it is straightforward to extend the model to a multiple year life cycle or to stages that cover multiple years (i.e., adding age structure; e.g., Rivot et al. 2004; Newman and Lindley 2006). Within a year the number of individuals in each stage is a function of the numbers in the previous stage. The number of individuals in the first stage is a function of the numbers in the last stage in the previous year (i.e., the stock-recruitment relationship), except for the numbers in the first stage in the first year, which is estimated as a model parameter. The functions describing the transition from one stage to the next are modeled using covariates. A state space model (Newman 1998; Buckland et al. 2004; Buckland et al. 2007) is used to allow for annual variability in the equation describing the transition from one life stage to the next. Traditionally, state space models describe demographic variability (e.g., using a binomial probability distribution to represent the number of individuals surviving based on a given survival rate; e.g., Dupont 1983; Besbeas et al. 2002) however environmental variability generally overwhelms demographic variability (Buckland et al. 2007) so we model the process variability (e.g., Rivot et al. 2004; Newman and Lindley 2006) using a lognormal probability distribution (Maunder and Deriso 2003). Our approach differs from modeling the log abundance and assuming additive normal process variability (e.g., Quinn and Deriso 1999, page 103) and the population dynamics function models the expected value rather than the median. The difference in the expectation will simply be a scaling factor ($\exp\left[-0.5\sigma^2\right]$) unless the variance of the process variability changes with time.

(1) $$N_{t,s} \sim \text{Lognormal}\left(f\left(N_{t,s-1}\right), \sigma^2_{s-1}\right) \qquad s > 1$$

(2) $$N_{t,1} \sim \text{Lognormal}\left(f\left(N_{t-1,nstages}\right), \sigma^2_{nstages}\right)$$

Where *t* is time, *s* is stage, *nstages* is the number of stages in the model, and σ_s is the standard deviation of the variation not explained by the model (process variability) in the transition from stage *s* to the next stage.

The three parameter Deriso-Schnute stock-recruitment model (Deriso 1980; Schnute 1985) is used to model the transition from one stage to the next. The Deriso-Schnute model is a flexible stock-recruitment curve in which the third parameter (γ) can be set to represent the Beverton-Holt ($\gamma = -1$) and Ricker ($\gamma \to 0$) stock-recruitment models (Quinn and Deriso 1999, page 95).

(3) $$f(N) = aN(1 - b\gamma N)^{\frac{1}{\gamma}}$$

where the parameter *a* can be interpreted as the number of recruits per spawner at low spawner abundance or the survival fraction at low abundance levels. In cases for which only the relative abundance at each stage can be modeled (as in the delta smelt example), *a* also contains a scaling factor from one survey to the next. The parameter *b* determines how the number of recruits per spawner or the survival rate decreases with abundance. Constraints can be applied to the parameters to keep the relationship realistic: $a \geq 0$, $b \geq 0$. The additional constraint $a \leq 1$ can be applied when the relationship is used to describe survival and the consecutive stages are modeled in the same units.

Covariates are implemented to influence the abundance either before density dependence [$g(N,x)$] or after density dependence [$h(x)$]. Although, when no density dependence is present the two methods are identical.

(4) $$f(N) = ag(N,x)(1 - b\gamma g(N,x))^{\frac{1}{\gamma}} h(x)$$

(5) $$g(N,x) = N \exp\left[\sum \lambda x\right]$$

(6) $$h(x) = \exp\left[\sum \beta x\right]$$

Where λ and β are the coefficients of the covariate (x) for before and after density dependence, respectively, and are estimated as model parameters.

For survival it might be important to keep the impact of the environmental factors within the range 0 to 1 and the logistic transformation can be used, e.g.,

(7) $$ag(N,x) = N \frac{\exp\left[a' + \sum \lambda x\right]}{1 + \exp\left[a' + \sum \lambda x\right]}$$

Where the parameter a' defines the base level of survival (i.e. $a = \frac{\exp[a']}{1+\exp[a']}$) and replaces a of the density dependence function.

If the covariate values are all positive, the negative exponential can be used, e.g.,

(8) $$g(N,x) = N\exp\left[-\sum \lambda x\right] \qquad \lambda \geq 0 \quad x \geq 0$$

A combination of the above three options may be appropriate depending on the application.

The importance of the placement of the covariates (i.e., before or after density dependence) relates to both the timing of density dependence and the timing of the surveys, which provide information on abundance. Covariates could be applied to the other model parameters. For example, covariates that are thought to be related to the carrying capacity (e.g., habitat) could be used to model *b*.

The model is fit to indices of abundance ($I_{t,s}$). The abundance indices are assumed to be normally distributed, but other sampling distributions could be assumed if appropriate. Typically, if the index of abundance is a relative index and not an estimate of the absolute abundance, the model is fit to the index by scaling the model's estimate of abundance using a proportionality constant (*q*, often called the catchability coefficient) (Maunder and Starr 2003).

(9) $$I_{t,s} \sim \text{Normal}\left(qN_{t,s}, \nu_{t,s}^2\right)$$

However, the scaling factor is completely confounded with the *a* parameter of the Deriso-Schnute model and therefore the population is modeled in terms of relative abundance that is related to the scale of the abundance indices for each life stage and only makes sense in terms of total abundance if the abundance indices are also in terms of total abundance. Therefore, the proportionality constant (*q*) should be set to one. Other data could also be used in the analysis if appropriate (e.g., information on survival from mark-recapture studies; Besbeas et al. 2002; Maunder 2004).

Model parameters to estimate

The model parameters estimated include the initial abundance of the first stage $N_{1,1}$, the parameters of the stock-recruitment model for each stage $\mathbf{a},\mathbf{b},\boldsymbol{\gamma}$, the coefficients of the covariates $\boldsymbol{\lambda},\boldsymbol{\beta}$, the standard deviation of the process variability for each stage $\boldsymbol{\sigma}$, and the standard deviation of the observation error (used in defining the likelihood function) for each index of abundance $\boldsymbol{\nu}$. The observation error standard deviation, $\boldsymbol{\nu}$, is often fixed based on the survey design or restricted so that there is not a parameter to estimate for each survey and time period (e.g. Maunder and Starr 2003). The state space model can be implemented by treating the process variability as random effect parameters (de Valpine 2002). The likelihood function that is optimized is calculated by integrating over these parameters (Skaug 2002; Maunder and Deriso 2003). Therefore, they are not treated as parameters to estimate. However, realizations of the random effects can be estimated by using empirical Bayes methods (Skaug and Fournier 2006) so that the unexplained process variation can be visualized. The estimated parameters of the model are:

Parameters = $\{N_{1,1}, \mathbf{a}, \mathbf{b}, \boldsymbol{\gamma}, \boldsymbol{\lambda}, \boldsymbol{\beta}, \boldsymbol{\sigma}, \boldsymbol{\nu}\}$

Implementation in AD Model Builder

Dynamic models like the multistage life cycle model described here can be computationally burdensome if they are carried out in a state-space modeling framework (i.e., integrating over the state-space or equivalently the process variability) and efficient parameter estimation is needed if multiple hypotheses are being tested. Implementation is facilitated by the use of Markov chain Monte Carlo and related methods (Newman et al. 2009) and their use has increased in recent years (Lunn et al. 2009). In particular, authors have found a Bayesian framework convenient for implementation (Punt and Hilborn 1997). An alternative approach is to use the Laplace approximation to implement the integration (Skaug 2002). AD Model Builder (http://admb-project.org/) has an efficient implementation of the Laplace approximation using automatic differentiation (Skaug and Fournier 2006). The realizations of the random effects are estimated by using empirical Bayes methods adjusted for the uncertainty in the fixed effects (Skaug and Fournier 2006). ADMB was originally designed as a function minimizer and therefore likelihoods are implemented in terms of negative log-likelihoods and probability distributions are implemented in terms of negative log-probabilities. A more complete description of ADMB and its implementation of random effects can be found in Fournier et al. (in review).

The population is modeled using random effects to implement the state space model (de Valpine 2002)

(12) $$N_{t,s} = f\left(N_{t,s-1}\right)\exp\left[\sigma_{s-1}\varepsilon_{t,s-1} - 0.5\sigma_{s-1}^2\right]$$

(13) $$N_{t,1} = f\left(N_{t-1,nstages}\right)\exp\left[\sigma_{nstages}\varepsilon_{t-1,nstages} - 0.5\sigma_{nstages}^2\right]$$

(14) $$\varepsilon_{t,s} \sim N(0,1)$$

A penalty is added to the objective function to implement the random effects,

(15) $$\sum_{t,s}\varepsilon_{t,s}^2 \ .$$

The negative log-likelihood function for the abundance indices ignoring constants is

(16) $$-\ln[L] = \sum_{t,s}\ln\left[v_{t,s}\right] + \frac{\left(I_{t,s} - qN_{t,s}\right)^2}{2v_{t,s}^2}$$

Model selection

Model selection (Hilborn and Mangel 1997) can be used to determine if the data supports density dependence for a particular stage or the factors that impact the population dynamics. In our analysis different models are represented by different values of the model parameters. The relationship between one stage and the next is density independent if $b = 0$. Therefore, a test for density dependence tests if $b = 0$. When $b = 0$,

$\boldsymbol{\gamma}$ has no influence on the results and unless a hypothesis about $\boldsymbol{\gamma}$ is made (i.e., Beverton-Holt, $\gamma = -1$ or Ricker, $\gamma \to 0$), testing between density independence and density dependence requires the estimation of two additional parameters ($b, \boldsymbol{\gamma}$). A factor has no influence on the model when its coefficient ($\boldsymbol{\lambda}, \boldsymbol{\beta}$) is fixed at zero. Therefore, testing a factor requires estimating one parameter for each factor tested. There are a variety of methods available for model selection and hypothesis testing, each with their own set of issues (e.g., Burnham and Anderson 1998; Hobbs and Hilborn 2006). Given these issues, we rely on Akaike information criteria adjusted for sample size (AICc) and AICc weights to rank models and provide an idea of the strength of evidence in the data about an a priori set of alternative hypotheses (factors) but they are not used as strict hypothesis tests (Andersen et al. 2000; Hobbs and Hilborn 2006).

The AIC is useful for ranking alternative hypotheses when multiple covariates and density dependence assumptions are being considered. The AICc (Burnham and Anderson 2002), is given by

(10) $$AIC_c = -2\ln L + 2K + \frac{2K(K+1)}{n-K-1}$$

where L is the likelihood function evaluated at its maximum, K is the number of parameters, and n is the number of observations. A better model fit is one with a smaller AICc score.

AIC weights are often used to provide a measure of the relative support for a model and to conduct model averaging (Hobbs and Hilborn 2006). AIC weights are essentially the rescaled likelihood penalized by the number of parameters, which is considered the likelihood for the model (Anderson et al. 2000).

$$(11) \quad w_i = \frac{\exp[-0.5\Delta_i]}{\sum_j \exp[-0.5\Delta_j]}$$

Where Δ is the difference in the AICc score from the minimum AICc score.

The correct modeling of observation and process variability (error) is important for hypothesis testing. If process variability is not modeled, likelihood ratio and AIC based tests are biased towards incorrectly accepting covariates (Maunder and Watters 2003). Other tests, such as randomization tests, should be used if it is not possible to model the additional process variability (e.g., Deriso et al. 2008). Incorrect sampling distribution assumptions (e.g., assumed values for the variance) can influence the covariate selection process and the weighting given to each data set can change which covariates are chosen (Deriso et al 2007). If data based estimates of the variance are not available, estimating the variances as model parameters or using concentrated likelihoods is appropriate (Deriso et al. 2007). Missing covariate data need to be dealt with appropriately, such as by using the methods described in Gimenez et al. (2009) and Maunder and Deriso (2010).

Parameter estimation of population dynamics models generally requires iterative methods, which take longer than calculations based on algebraic solutions, and therefore limit the number of models that can be tested (Maunder at al. 2009). This is problematic when testing hypotheses because, arguably, all possible combinations of the covariates and density dependent possibilities should be evaluated. All possible combinations should be used because a covariate by itself may not significantly explain process variation, but in combination they do (Deriso et al. 2008) and some covariates may only be significant if density dependence is taken into consideration. However, modeling of process variability, as we suggest, may minimize this possibility. In many cases, time and computational resource limitations may prevent testing all possible combinations and therefore we suggest the strategy described in Table 1.

We stop evaluating covariates when the lowest AICc model in the current iteration is at least 4 AICc units higher than the model with the lowest overall AICc (step 2e). The approach is based on a compromise between eliminating models for which *there is definite, strong, or very strong evidence that the model is not the K-L best model* ($4 \leq \Delta$)) and the fact that there is a maximum Δ when adding covariates to the lowest AICc model. We have chosen to carry out the selection process by using the sum of the AICc weights over all models that include the corresponding factor (step 2d). This selection process chooses factors that have high support in general, work in combination with other factors, and are therefore less likely to preclude additional factors in subsequent steps. This approach embraces the multiple hypothesis weight of evidence framework and is somewhat consistent with model averaging. We also remove models for which any of the estimated covariate coefficients are the incorrect sign as assumed a priori (step 2b). Modification of this procedure may be needed depending on the available computational resources, the number of covariates and model stages, and the relative difference in the weight of evidence among models.

Burnham and Anderson (2002) note that in general, there are situations where choosing to make inferences using a model other than the lowest AICc model can be justified (page 330) based on professional judgment, but only after the results of formal selection methods have been presented (page 334). For example, model parameterizations that do not make sense biologically might be eliminated from consideration. Burnham and Anderson (2002) give an example (page 197) where a quadratic model is rejected because it could not produce the monotonic increasing dose response that was desired. Sometimes AICc will select a model that fits to quirks or noise in the data but does not provide a useful model. The selected best model is a type of estimate, and so like a parameter estimate it can sometimes be a poor estimate (Ken Burnham, Colorado State University, personal communication).

Parameter estimates from stock recruitment models in integrated assessments are often biased towards extremely strong density dependent survival (recruitment is independent of stock size) (Conn et al. 2010) and this is unrealistic for stocks that have obtained very low population sizes. We therefore identify values of the Deriso-Shnute stock-recruitment relationship (for the Beverton-Holt and Ricker special cases) b parameter that are realistic (see Appendix). We assume that recruitment (or the individuals surviving) can't be greater than 80% of that expected from the average population size when the population is at 5% of the average population size seen in the surveys during the period studied. Models with unrealistic density dependence are given zero weight in that step of the model selection prodecure (step 2b).

Impact analysis

To determine the impact of the different factors on the stock, we conducted analyses using values of the covariates modified to represent a desired (e.g. null) effect. Following Deriso et al. (2008) these analyses were conducted simultaneously within the code of the original analyses so that the impact assessments shared all parameter values with the original analyses. This allowed estimation of uncertainty in the difference between the models with the covariate included and with the desired values of the covariate. The results are then compared for the quantities of interest, which may be a derived quantity other than the covariate's coefficients. For example, if a covariate is related to some form of mortality, the coefficient is set to zero to determine what the abundance would have been in the absence of that mortality (e.g., Wang et al. 2009).

Application to Delta smelt

The multi-stage lifecycle model is applied to delta smelt to illustrate the application of the model, covariate selection procedure, and impact analysis. Delta smelt effectively live for one year and one spawning season. Some adults do survive to spawn a second year, but the proportion is low (Bennett 2005) and we ignore them in this illustration of the modeling approach. The delta smelt life cycle is broken into three stages (Figure 1). The model stages are associated with the timing of the three main surveys, (1) 20mm trawl (20mm), (2) summer tow net (STN), and (3) fall mid-water tow (FMWT), and roughly correspond to the life stages larvae, juveniles, and adults, respectively. The reason for associating the model stages with the surveys is because the surveys are the only data used in the model and therefore information is only available on processes operating between the surveys. The population is modeled from 1972 to 2006 because these are the years for which data for most of the factors are available. The STN abundance index is available for the whole time period. The FMWT abundance index is available for the whole time period except for 1974 and 1979. The 20mm abundance index is only available starting in 1995. Other survey data are available (e.g., the Spring Kodiak trawl survey), but they are not used in this analysis.

The FMWT and STN survey indices of abundance are the estimates taken from Manly (2010b) tables 2.1 and 2.2. The standard errors were calculated by bootstrap procedures (Manly, 2010a). The 20mm survey index was taken from Nations (2007). The index values and standard errors are given in the supplementary material. The results of the bootstrap analysis suggest that the abundance indices are normally distributed (Manly 2010a).

Two types of factors are used in the model (Table 2). The first are standard factors relating to environmental conditions. The second are mortality rates based on estimates of entrainment at the water pumps. The mortality rates are converted to the appropriate scale to use in the model. Let u represent the mortality fraction such that the survival fraction is $1-u=\exp[\beta x]$ and x will be used as a covariate in the model. Setting $\beta=1$ gives $x=\ln[1-u]$.

Several factors were chosen for inclusion in the model (Table 3). These factors are used for illustrative purposes only and they may differ in a more rigorous investigation of the factors influencing delta smelt. The environmental factors are taken as those proposed by Manly (2010b). The entrainment mortality rates are calculated based on Kimmerer (2008); the rates were obtained by fitting a piece-wise linear regression model of winter Old Middle River (OMR) flow to his adult entrainment estimates and his larval/juvenile entrainment estimates were fitted to a multiple linear regression model with spring OMR flow and spring low salinity zone (as measured by X2). The values from Kimmerer (2008) were used for years in which they are available and the linear regression predictions were used for the remaining years. Manly (2010b) provided several variables as candidates to account for the changes in delta smelt abundance from fall to summer and summer to fall. The fall to summer covariates could influence the adult and larvae stages, while the summer to fall covariates could influence the juvenile stage. The factors proposed by Manly (2010b) are those that are considered to act directly on delta smelt. There are many other proposed factors that act indirectly through these factors. We also include secchi disc depth as a covariate for water turbidity/clarity since it was identified as a factor by Thomson et al. (2010). Exports were also identified as an important factor and were assumed to be related to entrainment. However, we chose to use direct measures of entrainment. Interactions among the factors were not considered in the application. However, some of the covariates implicitly include interactions in their definition and construction.

Some manipulation of the data was carried out before use in the model (the untransformed covariates values used in the model are given in the supplementary material). Delta smelt average length was missing for 1972-1974, 1976, and 1979, and was set to the mean based on Maunder and Deriso (2010). The factors were normalized (mean subtracted and divided by standard deviation) to improve model performance, except for the covariates relating to predator abundance, which were just divided by the mean, and the entrainment mortality rates, which were not transformed. These exceptions are factors that are hypothesized to have a have a unidirectional impact and setting their coefficients to zero is needed for impact analysis. Setting the coefficient for the entrainment mortality rate covariates to one can be used to determine the impact if the entrainment estimates are assumed to be correct.

The standard approach outlined above and in table 1 is applied to the delta-smelt application. The Ricker model was approximated by setting $\gamma = -\exp[-10]$. We also constrained $\gamma < 0$ to avoid computational errors. It is difficult to scale the survey data to absolute abundance, so they are all treated as relative abundance and are not on the same scale. The scaling parameter a is not limited to $a \leq 1$ and the exponential model is used for all covariates. To illustrate the impact analysis, we implement three scenarios. In the first scenario, the covariates are all set to zero. This means that environmental conditions are average, predation is zero, and entrainment is zero. We implement the second scenario if one or both of the entrainment covariates are selected for inclusion in the model. In this case, only the entrainment coefficients are set to zero. In the third scenario we take the final set of covariates and add the entrainment covariates (or substitute them if they we already included in the model) with their coefficients set to one and rerun the model. In this case, only the entrainment coefficients are set to zero in the impact analysis.

Results

AICc values and weights were calculated for all possible combinations of density dependence that included no density dependence (No), a Beverton-Holt Model (BH), a Ricker model (R), and estimation of both b and γ (DD) (Table 3). Density dependence was clearly preferred for survival from juveniles to adults (J), but it is not clear if the density dependence is Beverton-Holt, Ricker, or somewhere in between. The Beverton-Holt and Ricker models for juvenile survival appear to be influenced by three consecutive data points (years 1976-1978) of high juvenile abundance with corresponding average adult abundance (Figures 2 and 3). The evidence for and against density dependence is about the same for the stock-recruitment relationship from adults to larvae (A). With slightly more evidence for no density dependence if survival from juveniles to adults is Beverton-Holt and slightly more evidence for Beverton-Holt density dependence if the survival from juveniles to adults is Ricker. The evidence for no density dependence in survival from larvae to juveniles (L) is moderately (3 to 4 times) higher than for density dependence. Therefore, we proceed with four density dependence scenarios: (1) Beverton-Holt density dependence in survival from juveniles to adults (JBH); (2) Beverton-Holt density dependence in survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship from adults to larvae (JBHABH); (3) Ricker density dependence in survival from juveniles to adults (JR); and (4) Ricker density dependence in survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship from adults to larvae (JRABH).

The number and the type of factors supported by the data depended on the assumptions made about density dependence (Tables 4 and 5). The models with density dependence for both survival from juveniles to adults and a stock recruitment relationship for adults to larvae included more covariates in the lowest AICc models (8 and 9 covariates for Beverton-Holt and Ricker density dependence in survival from juveniles to adults, respectively) than the models that included only density dependence for survival from juveniles to adults (5 covariates each). Several temperature, prey and predator covariates (TpAJ, EPAJ, EPJA, TpJul, Pred1) were selected in the first few steps and were included in all models. The April-June abundance of predators (Pred2) was selected in the first few steps in one model, but not selected at all in the others.

Overall, the model with Ricker density dependence in survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship from adults to larvae had better AICc scores than the other models (Table 5). This differs from the similarity in scores obtained when no covariates were included in the models (Table 3). For all density dependent assumptions, there were alternatives with more (or less) covariates than the lowest AICc model (within the models for that density dependence assumption), for which there was not *definite, strong, or very strong evidence that the model is not the K-L best model* ($4 \leq \Delta$) suggesting that these factors should also be considered as possible factors that influence the population dynamics of delta smelt (Table 5). Although, the asymmetrical nature of the AICc scores for nested models should be kept in mind.

The magnitude and the sign of the covariate coefficients are generally consistent across models (Table 6). The covariates were standardized so that the size of the coefficients are generally comparable across covariates. The coefficients are similar magnitudes for most covariates except those for water clarity (Secchi) and, particularly, adult entrainment (Aent), which had much larger effects. These both occurred before the stock-recruitment relationship from adults to larvae, which had a very strong density dependence effect. Pred2 had a small effect. The confidence intervals on the coefficients support inclusion of the covariates in the lowest AICc models except for Pred2 (Table 6). The effects for Secchi and Aent appear to be unrealistically large and their coefficients have a moderately high negative correlation. This appears to be a consequence of the unrealistically strong density dependence estimated in the stock-recruitment relationship from adults to larvae for those models (see Table S6).

The five lowest AIC_c models in iteration 6 of the two factors at a time procedure had a *b* parameter of the Beverton-Holt stock recruitment relationship from adult to larvae that was substantially greater than the critical value used to define realistic values of the parameter. The sixth model had an AIC of 812.53, which is worse than the lowest AICc model of iteration 5. The lowest AICc model with Beverton-Holt survival from juveniles to adults and Beverton-Holt stock recruitment relationship from adult to larvae also had an unrealistic *b* parameter and the next lowest AICc model had an AIC of 812.33. Therefore, the lowest AICc model after accounting for realistic parameter values is the lowest AICc model from iteration 5 with Ricker survival from juveniles to adults and Beverton-Holt stock recruitment relationship from adult to larvae with one additional covariate (Table 5, AICc = 808.47). The confidence intervals for the pred2 covariate for this model contained zero and removing the Pred2 covariate essentially had no effect on the likelihood. Therefore, we chose this model without the Pred2 covariate as the lowest AICc model (AICc = 806.63). Several models had an AICc score within 2 units of this model, which according to the Burnham and Anderson guidelines "*there is no credible evidence that the model should be ruled out*". Therefore, to illustrate the sensitivity of results to the model choice we also provide results for the model with the fewest parameters that was within 2 AICc units of the lowest AICc model. This alternative model is that selected with two additional parameters in iteration 3 of the selection procedure (Table 5, AICc=810.20). Removing the Pred2 covariate improved the AICc score (808.63) so we also eliminated the Pred2 covariate from this model.

The models fit the survey data well (Figures 4 and 5), in fact better than expected from the survey standard errors, indicating that most of the variation in abundance was modeled by the covariates or unexplained process variability. The unexplained process variability differed among the stages (Figure 6; Table 7). Essentially all the variability in survival between larvae and juveniles was explained by the covariates. The amount of variability in the survival from juveniles to adults explained was higher than in the stock-recruitment relationship, but they show similar patterns (Figure 6; Table 7).

There was substantial correlation among estimated parameters (see supplementary material). The lowest AIC model has moderate and high correlation between the covariate coefficients and several model parameters and also among the covariate coefficients themselves (Table S6). The alternative model has fewer parameter correlations (Table S7). The parameters of the density dependence function were highly positively correlated. The relative number of larvae in the first year is negatively correlated with parameters influencing larval survival including the survival fraction at low abundance (a), the standard deviation of the process variability, and the prey covariate coefficients. The coefficients for the prey and temperature covariates influencing larval survival are correlated. This is partly related to the fact that some of these covariates are also correlated (Table S5). The coefficients for water clarity (Secchi) and adult entrainment (Aent) in the lowest AIC model were highly negatively correlated and were correlated with the parameters of the density dependence survival function that relates adults and larvae. The coefficient for adult entrainment is also unrealistically large. The coefficient for Pred1 is correlated with the parameters of the density dependence relationship for juvenile survival, and is also highly positively correlated with year. The coefficient for EPJA is positively correlated with the parameter that controls density dependence for juvenile survival. The coefficient for EPJul in the lowest AIC model is correlated with several parameters.

The impact analysis of the selected covariates shows that the adult abundance under average conditions, with no predators, and entrainment mortality set to zero, differs moderately from that estimated in the original model (Figure 7). In particular, the recent decline is not as substantial under average conditions indicating that the covariates describe some of the decline, although there is still substantial unexplained variation and a large amount of uncertainty in the recent abundance estimates. Entrainment is estimated to have only a small impact on the adult abundance in either the lowest AICc model, which uses the estimated adult entrainment coefficient and the juvenile entrainment coefficient is zero, or the alternative model, in which both the juvenile and adult entrainment coefficients are set to one (Figure 8). The lowest AICc model with the two entrainment coefficients set at 1 did not converge and results are not shown for that analysis, although the results are expected to be similar.

Discussion

We developed a state-space multi-stage lifecycle model to evaluate population impacts in the presence of density dependence. Application to delta-smelt detected strong evidence for a few key factors and density dependence operating on the population. Both environmental factors (e.g., Deriso et al. 2008) and density dependence (e.g., Brook and

Bradshaw 2006) have been detected in a multitude of studies either independently or in combination (e.g., Sæther 1997; Ciannelli et al. 2004). Brook and Bradshaw (2006) used long-term abundance data for 1198 species to show that density dependence was a pervasive feature of population dynamics that holds across a range of taxa. However, the data they used did not allow them to identify what life stages the density dependence operates on. Ciannelli et al. (2004) found density dependence in different stages of walleye Pollock. In our application we found evidence against density dependent survival from larvae to juveniles, strong evidence for density dependence in survival from juveniles to adults, and weak evidence for density dependence in the stock-recruitment relationship from adults to larvae, which includes egg and early larval survival. Other studies have suggested that density dependence is more predominant at earlier life stages (e.g., Fowler 1987; Gaillard et al. 1998), although the life history of these species differs substantially from delta smelt. The density dependence in survival from juveniles to adults found in our study was probably heavily influenced by three consecutive years of data. Unfortunately, this is a common occurrence in which autocorrelated environmental factors cause autocorrelation in abundance within a stage and this likely influences other studies as well. We only allowed factors to influence density independent survival, either before or after density dependence, however the factors could also influence the strength or form of the density dependence (Walters 1987). For example, Ciannelli et al. (2004) found that high wind speed induced negative density dependence in the survival of walleye Pollock eggs. Our analysis is one of the few, but expanding, applications investigating both density dependent and density independent factors in a rigorous statistical framework that integrates multiple data sets within a life cycle model. The framework amalgamates the density and the mechanistic paradigms of investigating population regulation outlined by Krebs (2002) while accommodating the fact that most available data is observational rather than experimental. More detailed mechanistic processes could be included in the model if the appropriate observational or experimental data are available.

One factor is often erroneously singled out as the only major cause of population decline (e.g., over fishing; Sibert et al. 2006). However, there is a substantial accumulation of evidence that multiple factors interact to cause population declines. Our analysis found support for a variety of factors that influence delta smelt population dynamics. We also showed that together these factors explain the decline in the delta smelt population. Deriso et al. (2008) also found support that multiple factors influenced the decline and suppression of the Prince William Sound herring population, including one or more unidentified factors related to a particular year.

Three of the first four factors included in the delta smelt application acted on the survival between larvae and juveniles. This is also the period where no density dependence in survival occurred. The final model estimates that the factors explain all the variability in survival from larvae to Juveniles. The 20mm trawl survey, which provides information on juvenile abundance, only starts in 1995 so there is less data to explain and this may be partly why the unexplained process variability variance goes to zero. The process variability for the other stages may partly absorb the variability in survival from larvae to juveniles.

Deriso et al. (2008) showed that multiple factors influence populations and that analysis of factors in isolation can be misleading. We also found that multiple factors influence the dynamics of delta smelt and that evaluating factors in isolation can produce different results than evaluating them in combination. The type of density dependence assumed also impacted what factors were selected. Specifically, one predator covariate (Pred2) would be the first selected covariate based simply on AICc for two of the density dependent assumptions, but was not selected by the two factor stepwise procedure (see supplementary material). However, this covariate was selected in the first step of the two factor stepwise procedure for another density dependent assumption, which happened to be the final model with the lowest AICc. In the final model the confidence intervals on the coefficient indicate that this factor should not be included in the model. Exploratory analysis showed that this covariate had about a 0.6 correlation with a temperature (TpAJ) and a prey covariate (EPAJ) that were consistently selected in the first or seconds steps, which operated on the same stage (larvae), when these covariates were combined together. The covariate was also highly correlated with time (see supplementary material). We did find, to some extent, which other covariates were included in the model and the order in which they were included changed depending on the density dependence assumptions. However, apart from the one predator covariate, the four density dependence assumptions tended to select the same factors in the first few steps of the model selection procedure, although the order of selection differed.

Several of the model parameters show moderate to strong correlations. The three covariates included in the lowest AIC model, but not in the alternative model (EPJul, Secchi, and Aent), are highly correlated with other model parameters. The only coefficients that show strong correlation with each other in the alternative model are EPAJ and TPJul. These covariates have a moderate negative correlation while the coefficients have a positive correlation, and therefore offset each other. High correlation may indicate that the data do not provide enough information to separate the effects represented by the two parameters. However, hypothesis tests and the confidence intervals of the coefficients are used to judge if a particular hypothesis (covariate) is supported by the data. If there is not enough information in the data to separate two hypotheses, the hypothesis tests will fail to include one of the covariates or the confidence interval of the covariate's coefficient will contain zero. The parameters of the density dependence function were highly positively correlated as previously observed for stock-recruitment relationships (Quinn and Deriso 1999) and reparameterization might improve the estimation algorithm. The inclusion of several covariates (TpAJ, EPAJ, EPJA, TpJul, Pred1) were robust to the form of density dependence (Table 4) and only showed low to moderate correlation among their coefficients. The predator covariate coefficient was highly correlated with the juvenile survival density dependence parameters making the inclusion of this covariate less convincing. The predator covariate was also positively correlated with year. The coefficients for water clarity and adult entrainment, which were included in the lowest AIC model, but excluded from the alternative model, were highly confounded with density dependence and required constraining the density dependence to reasonable parameter space. This may indicate that the effect of adult entrainment only shows up when abundance is very low. A model within 2 AIC units of the lowest AIC model did not contain either adult entrainment or water clarity, but did include all the robust factors. The coefficient for adult entrainment is also unrealistically large suggesting that the model including water clarity and adult entrainment is unreliable.

The covariates were included in the model as simple log-linear terms. There may be more appropriate relationships between survival and the covariates. For example, good survival may be limited to a range of covariate values so a polynomial that describes a dome shape cure may be more appropriate. There may also be interactions among the covariates. Neither of these was considered in the delta smelt application. Although, some of the covariates were developed based on combining different factors such as water clarity and predator abundance. Some of the covariates were highly correlated (see supplementary material), but those with the highest correlations were either for different stages or not selected in the final models.

Density dependence and environmental factors could influence other population processes (e.g. growth rates) or the ability (catchability) of the survey to catch delta smelt. Modeling of catchability has been extensively researched for indices of abundance based on commercial catch data (Maunder and Punt 2004) and results have shown that the relationship between catch-per-unit-effort and abundance can be nonlinear (Harley et al. 2001; Walters 2003). Rigorous statistical methods have been developed to account for habitat quality in the development of indices of abundance from catch and effort data (Maunder et al. 2006). Methods have been developed to integrate the modeling of catchability within population dynamics models as a random walk (Fournier et al. 1998) or as a function of covariates (Maunder 2001; Maunder and Langley 2004). Surveys are less likely to be effected by systematic changes in catchability because sampling effort and survey design tend to be more consistent over time than effort conducted by commercial fishing fleets. Most fisheries stock assessments assume that there are no systematic changes in survey catchability unless there is an obvious change (e.g. change in survey vessel). Previous studies using the data in this study have also assumed that catchability is constant over time (Mac Nally et al. 2010; Thomson et al. 2010). However, catchability may change due to factors such as changes in the spatial distribution of the species or population density. Similar methods as used for survival can be used to model catchability as a function of density or environmental factors. The standard deviations used in the likelihood functions are based on bootstrap analysis that takes the within year sampling variability into consideration, but does not account for between year variation in catchability. Random influences on catchability beyond those caused by simple random sampling can be accommodated by estimating the standard deviation of the likelihood function used to fit the model to the survey data (Maunder and Starr 2003). However, the fit to the delta smelt data appears better than expected from the bootstrap confidence intervals suggesting that the observation error is smaller than estimated by the bootstrap procedure. Systematic and additional random variation in catchability could bias the evaluation of strength and statistical significance of density dependence and environmental factors (Deriso et al. 2007).

The estimates of the *b* parameter of the Beverton-Holt stock-recruitment relationship between adults and larvae produced density dependence that was unrealistically strong in a few models. Consequently, this caused estimates of some coefficients that were also unrealistic (e.g., the coefficient for adult entrainment was nearly two orders of magnitude higher than expected). Even when a model was selected for which the *b* parameter was considered reasonable, the coefficient for adult entrainment was still an order of magnitude greater than expected. This illustrates that naively following AICc model selection without use of professional judgment is not recommended. We could have included all models in the sum of the AICc weights by bounding the *b* parameter in the parameter estimation process (the parameter would probably be at the bound), but we considered inference based on models with a parameter at the bound inappropriate. An alternative approach would be to use an informative prior for *b* (Punt and Hilborn 1997) to pull it away from unrealistic values, but we did not have any prior information that was considered appropriate.

Andersen et al. (2000) warn against data dredging as a method to test factors that influence population dynamics. In their definition of data dredging they include the testing of all possible models, unless, perhaps, if model averaging is used. This provides somewhat of a dilemma when using a multi-stage life cycle model because there are often multiple candidate factors for each life stage and they may only be detectable if included in the model together. For this reason, we use an approximation to all possible models and rely on AICc and AICc weights to rank models and provide an idea of the strength of evidence in the data about the models and do not apply strict hypothesis tests. Some form of model averaging using AICc weights might be applicable to the impact analysis, although the estimates of uncertainty would have to include both model and parameter uncertainty. The estimates of uncertainty in our impact analysis under estimate uncertainty because they do not include model selection uncertainty and use of model averaging might provide better estimates of uncertainty (Burnham and Anderson 2002). In addition, we use symmetric confidence intervals and approaches that provide asymmetric confidence intervals may be more appropriate (e.g., based on profile likelihood or Bayesian posterior distribution).

Our results suggest that of all the factors that we tested, food abundance, temperature, predator abundance and density dependence are the most important factors controlling the population dynamics of delta smelt. Survival is positively related to food abundance and negatively related to temperature and predator abundance. There was also some support for a negative relationship with water clarity and adult entrainment, and a positive relationship with the number of days where the water temperature was appropriate for spawning. The first variables to be included in the model were those related to survival from larvae to juveniles, followed by survival from juveniles to adults, and finally the stock-recruitment relationship. Mac Nally et al. (2010) also found that high summer water temperatures had an inverse relationship with delta smelt abundance. Thomson et al. (2010) found exports and water clarity as important factors. We did not include exports, but included explicit estimates of entrainment. We found some support for adult entrainment, but it was not one of the main factors and the coefficient was unrealistically high and highly correlated with the coefficient for water clarity. Mac Nally et al. (2010) and Thomson et al. (2010) only used the FMWT data and did not look at the different life stages, which probably explains why the factors supported by their analyses differ from what we found.

We found strong evidence for density dependence in survival from juveniles to adults, some evidence for density dependence for the stock-recruitment relationship from adults to larvae and evidence against density dependence in survival from larvae to juveniles. This might be surprising since the population is of conservation concern due to low abundance levels. However, the available data covers years, particularly in the 1970s, where the abundance was high and data for these years provide information on the form and strength of the density dependence. At the recent levels of abundance, density dependence is probably not having a substantial impact on the population and survival is impacted mainly by density independent factors. Previous studies only found weak evidence for a stock-recruitment relationship and suggested that density independent factors regulate the delta smelt population (e.g., Moyle et al. 1992). Bennett (2005) found that the strongest evidence for density dependence was between juveniles and pre-adults. Mac Nally et al. (2010) found strong support for density dependence, but Thomson et al. (2010) did not.

Several pelagic species in the San Francisco Estuary have also experienced declines, but the factors causing the declines are still uncertain (Bennett 2005; Sommer et al. 2007). Thomson et al. (2010) used Bayesian change point analysis to determine when the declines occurred and included covariates to investigate what caused the declines. They were unable to fully explain the decline and unexplained declines were still apparent in the early 2000s. The impact analysis we applied to delta smelt suggests that the factors included in the model explain the low levels of delta smelt in the mid 2000s. Although, there is still substantial annual variation in the delta smelt abundance and uncertainty in the estimates of abundance for these years.

The theory for state-space stage-structured life cycle models is well developed (Newman 1998; de Valpine, P. 2002; Maunder 2004), they have been promoted (Thomson et al. 2010; Mac Nally et al. 2010), they facilitate the use of multiple data sets (Maunder 2003), provide more detailed information about how factors impact a population, they encompass all the statistical modeling advances advocated by Rose et al. (2001), and we have shown that they can be implemented. Therefore, we recommend that they are an essential tool for evaluating factors impacting species of concern such as delta smelt.

Acknowledgements

Brian Manly provided the survey data. Brian Manly and B.J. Miller provided the covariate data. Richard Deriso was funded by Metropolitan Water District of Southern California. Mark Maunder was funded by San Luis & Delta-Mendota Water Authority. Ray Hilborn provided advice on the modeling. Ken Burnham provided comments on a previous version of the paper. Members of a working group convened at the National Center for Ecological Analysis and Synthesis contributed to the work through discussions with Mark Maunder. Members of the working group included Ralph Mac Nally, James R. Thomson, Wim J. Kimmerer, Frederick Feyrer, Ken B. Newman, Andy Sih, William A. Bennett, Larry Brown, Erica Fleishman, Steven D. Culberson, Gonzalo Castillo, Howard Townsend, Dennis D. Murphy, John M. Melack, and Marissa Bauer. Comments by two anonymous reviewers improved the manuscript.

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Appendix: Calculating realistic values for the *b* parameter of the Beverton-Holt and Ricker versions of the Deriso-Schnute stock-recruitment model.

The third parameter (γ) of the Deriso-Schnute stock-recruitment model (Deriso 1980; Schnute 1985)

$$f(N) = aN(1 - b\gamma N)^{\frac{1}{\gamma}}$$

can be set to represent the Beverton-Holt ($\gamma = -1$) and Ricker ($\gamma \to 0$) models (Quinn and Deriso 1999, page 95), which correspond to

$$f(N) = \frac{aN}{1 + bN} \text{ and } f(N) = aN \exp[-bN]$$

The recruitment at a given reference abundance level (e.g., the carrying capacity N_0) can be calculated as

$$R_0 = \frac{aN_0}{1 + bN_0} \text{ and } R_0 = aN_0 \exp[-bN_0]$$

The recruitment when the abundance is at a certain fraction (p) of this reference level can be calculated as

$$R_p = \frac{apN_0}{1 + bpN_0} \text{ and } R_p = aN_0 \exp[-bpN_0]$$

A standard reference in fisheries is the recruitment as a fraction of the recruitment in the absence of fishing (the carrying capacity) that is achieved when the abundance is 20% of the abundance in the absence of fishing (steepness).

$$h = \frac{R_{0.2}}{R_0} = \frac{{}^1\!/_{N_0} + b}{{}^5\!/_{N_0} + b} \text{ and } h = \frac{R_{0.2}}{R_0} = 0.2\exp[0.8bN_0]$$

To set b for a given steepness

$$b = \frac{5h - 1}{N_0 - hN_0} \text{ and } b = \frac{\ln[5h]}{0.8N_0}$$

The 20% reference level was probably chosen because the objective of fisheries management has traditionally been to maximize yield and it is generally considered that when a population falls below 20% of its unexploited level the stock cannot sustain that level of yield. In the delta smelt application the concern is about low levels of population abundance and we do not estimate the unexploited population size. Therefore, a more appropriate reference level might be 5% of the average level observed in the surveys.

$$h_{0.05} = \frac{R_{0.05}}{R_{ave}} = \frac{1/N_{ave} + b}{20/N_{ave} + b} \text{ and } h_{0.05} = \frac{R_{0.05}}{R_{ave}} = 0.05\exp[0.95bN_{ave}]$$

$$b = \frac{20h_{0.05} - 1}{N_{ave} - h_{0.05}N_{ave}} \text{ and } b = \frac{\ln[20h_{0.05}]}{0.95N_{0.05}}$$

This specification is also more appropriate when considering both the Beverton-Holt and Ricker models because the Ricker model reduces at high abundance levels and the recruitment at an abundance level that is 20% of the carrying capacity could be higher than the recruitment at carrying capacity. We restrict the models to those that have *b* estimates such that the expected recruitment when the population is at 5% of its average level (over the survey period) is equal to or less than 80% of the recruitment expected when the population is at its average level (Table A1). This is equivalent to a Beverton-Holt $h_{0.2}$ = 0.95 based on the abundance reference level being the average abundance from the surveys, which is probably conservative is the sense of not rejecting high values of *b*.

Appendix References

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Table A1. Maximum values of the parameter *b* for inclusion of models in the model selection process.

		Maximum *b*	
	Average abundance	Beverton-Holt	Ricker
20mm (larvae)	7.99	9.3867	0.3653
STN (juveniles)	6140	0.0122	0.0005
FMWT (adults)	459	0.1634	0.0064

Exhibit A-2

Table 1. Algorithm for evaluating covariates for the delta smelt application.

1) Evaluate density dependence

a) Calculate all combinations of density dependent processes without the inclusion of factors.

Combinations include: a) density independent; b) Beverton-Holt; c) Ricker; and d) estimate both *b* and *γ*. These can be at any of the three stages.

b) Choose the density dependence combination that has the lowest AICc or if there are several that have similar support, choose multiple combinations.

2) Evaluate covariates

a) For each densitity dependence scenario chosen in (1b) run all possible one and two covariate combinations

b) For each combination, set the AICc weight to zero if the sign is wrong for either of the coefficients in the combination or if the *b* parameter of a density dependence function is unrealistically high.

c) Sum AICc weights for a given covariate across all models that include that covariate

d) Select the two covariates with the highest summed AICc weights to retain for the next iteration

e) Iterate a-d until the AICc value of the best model in the current iteration is more than 4 units higher than the lowest AICc model

3) Double check all included covariates

a. Check confidence intervals of the estimated coefficients for all included covariates to see if they contain zero.

b. For all coefficients that contain zero remove the associated covariate and see if the AICc is degraded. If the AICc is not degraded, exclude that covariate from the model.

Table 2. The variables used as candidates to account for the changes in delta smelt abundance. A = occurs between adult and larval stages, L = occurs between larval and juvenile stages, J = occurs between juvenile and adult stages. Norm = subtract mean and divide by standard deviation, Mean = divide by mean, Raw = not scaled. The covariate is attributed to after density dependence unless it is known to occur before density dependence. This is because density dependence generally reduces the influence of the covariate. *= the effect of entrainment on survival is negative, but the covariate is formulated so setting the coefficient to 1 implies the assumption that entrainment is known without error, so the coefficient should be positive.

Factor	Name	Covar	Stage	B(efore)/ A(fter)	Sign	Description	Data scaling	Justification
1	SpDys	1	A	B	+	Days where temperature is in	Norm	This measures the number of days of

						the range 11-20C		spawning—the longer the spawning season, presumably the better chance of survival.
2	TpAJ	2	L	B	- or +	Average water temperature Apr-Jun in delta smelt habitat	Norm	Temperature affects growth rate and survival of early life stages.
3	TpAJ	2	A	A	- or +			
4	TpJul	3	L	A	-	Average water temperature July in delta smelt habitat	Norm	Higher water temperatures can be lethal. Could also include August temperature.
5	EPAJ	4	L	B	+	Minimum eurytemora and pseudodiaptomus density April-Jun	Norm	Measures height of food "gap" in spring, as eurytemora falls from spring maximum and pseudodiaptomus rises from ~0.
6	EPAJ	4	A	A	+			
7	EPJul	5	L	A	+	Average eurytemora and pseudodiaptomus density July	Norm	Measures food availability in summer until STN survey, identified as problem by Bennett based on smelt condition.
8	Pred1	6	J	A	-	Sep-Dec abundance other	Mean	Predation is a source of direct mortality,

					predators		measured as the product of relative density from beach seine data with the square of average sechi depth
9	Pred1	6	A	B	-		
10	Pred1	6	A	A	-		
11	StBass	7	J	A	-	Sep-Dec abundance striped bass	Mean	A major predator, whose abundance is measured as actual number of adults.
12	StBass	7	A	B	-			
13	StBass	7	A	A	-			
14	DSLth	8	L	A	+	Delta smelt average length	Norm	See Bennett (2005) for length vs fecundity relationship, linear for 1-year-olds.
15	DSLth	8	J	A	+			
16	DSLth	8	A	A	+			
17	TpJS	9	J	A	-	Maximum 2-week average temperature Jul-Sep	Norm	Measure of whether lethal temperature is reached in hot months.
18	EPJA	10	J	A	+	Average eurytemora	Norm	Measures food availability in summer between

						and pseudodiaptomus density July-August		STN and FMWT surveys, identified as problem by Bennett based on smelt condition.
19	Secchi	11	A	B	-	Jan-Feb Weighted Secchi depth	Norm	Protection from predators
20	Secchi	11	A	A	-			
21	Jent	12	L	A	+ *	Juvenile entrainment	Raw	Entrained in by water pumps
22	Aent	13	A	B	+ *	Adult entrainment	Raw	Entrained in by water pumps
23	Pred2	14	L	B	-	Apr-Jun abundance other predators	Mean	Predation is a source of direct mortality, measured as the product of relative density from beach seine data with the square of average sechi depth
24	Pred2	14	A	A	-			

Table 3. AICc weights for all possible density dependence models without covariates. L = survival from larvae to juveniles; J = survival from juveniles to larvae; A = the stock recruitment relationship from adults to larvae; No = no density dependence, BH = Beverton-Holt density dependence; R = Ricker density dependence; DD = Deriso-Schnute density dependence (i.e. estimate γ)

		J-No	J-BH	J-R	J-DD	Sum
L-No	A-No	0.000	0.079	0.062	0.027	0.168
	A-BH	0.000	0.075	0.067	0.026	0.168
	A-R	0.000	0.059	0.052	0.020	0.131
	A-DD	0.000	0.069	0.064	0.023	0.156
	Sum	0.000	0.281	0.245	0.096	0.622
L-BH	A-No	0.000	0.022	0.017	0.007	0.047
	A-BH	0.000	0.020	0.018	0.007	0.045
	A-R	0.000	0.016	0.014	0.005	0.035
	A-DD	0.000	0.018	0.017	0.006	0.040
	Sum	0.000	0.076	0.066	0.025	0.167

L-R	A-No	0.000	0.022	0.017	0.007	0.047
	A-BH	0.000	0.020	0.018	0.007	0.045
	A-R	0.000	0.016	0.014	0.005	0.035
	A-DD	0.000	0.018	0.017	0.006	0.040
	Sum	0.000	0.076	0.066	0.025	0.167
L-DD	A-No	0.000	0.006	0.005	0.002	0.013
	A-BH	0.000	0.005	0.005	0.002	0.012
	A-R	0.000	0.004	0.004	0.001	0.009
	A-DD	0.000	0.004	0.004	0.001	0.010
	Sum	0.000	0.020	0.017	0.006	0.043

Table 4.

Order of inclusion of factors into the analysis. JBH = Beverton-Holt density dependence from the Juvenile to Adult stage; JBHABH = Beverton-Holt density dependence from the juvenile to adult stage and Beverton-Holt density dependence from the adult to larvae stage (the stock-recruitment relationship); JR = Ricker density dependence from the Juvenile to Adult stage; JRBH = Ricker density dependence from the juvenile to adult stage and Beverton-Holt density dependence from the adult to larvae stage (the stock-recruitment relationship). See Tables 2 and 3 for definitions. *This covariate was excluded from the final model because the confidence interval of its coefficient included zero and including the covariate degraded the AICc.

Factor	name	Stage	B(efore)/A(fter)	JBH	JBHABH	JR	JRABH
2	TpAJ	L	B	1	1	2	2
4	TpJul	L	A	2	2	2	3
5	EPAJ	L	B	1	1	1	1
7	EPJul	L	A		4		5
8	Pred1	J	A	2	2	3	3
18	EPJA	J	A	3	3	1	2
19	Secchi	A	B		3		4
22	Aent	A	B		4		4
23	Pred2	L	B				1*

Table 5. AICc values for each step in the model selection process. Shaded values are the lowest AICc for that density dependence configuration. See Table 4 for definitions.

	Step 1		Step 2		Step 3		Step 4		Step 5		Step 6		Step 7	
	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2
JBH	841.06	833.44	827.58	824.00	823.01	823.30	824.61	825.95	828.28	831.08				
JBHABH	832.46	824.68	818.25	815.18	813.92	814.32	814.17	811.85	812.33	814.75				
JR	841.80	833.67	826.25	821.40	820.00	821.10	822.58	823.71	826.26	828.86				
JRBH	833.16	824.93	817.96	814.72	811.60	810.20	810.72	810.38	808.47	809.23	810.86	813.39	817.03	820.83

Table 6. Estimates of coefficients (and 95% confidence intervals) from the lowest AICc models for each density dependence assumption. Definitions of abbreviations and a description of the covariates can be found in Table 2 and the density dependence configurations in Table 4. The alternative model is the model that has the fewest covariates and the AICc is less than 2 AICc units greater than the lowest AICc model.

Factor	name	Stage	B/A	JBH	JBHABH	JR	JRABH	JRABH no Pred2	Alternative
2	TpAJ	L	B	-0.32 (-0.46, -0.18)	-0.21 (-0.36, -0.07)	-0.32 (-0.45, -0.19)	-0.20 (-0.34, -0.06)	-0.22 (-0.36, -0.09)	-0.31 (-0.44, -0.18)
4	TpJul	L	A	-0.29 (-0.50, -0.08)	-0.30 (-0.49, -0.12)	-0.28 (-0.49, -0.07)	-0.28 (-0.47, -0.09)	-0.32 (-0.50, -0.13)	-0.30 (-0.50, -0.11)
5	EPAJ	L	B	0.39 (0.15, 0.63)	0.40 (0.18, 0.62)	0.37 (0.13, 0.61)	0.32 (0.09, 0.55)	0.36 (0.14, 0.58)	0.47 (0.23, 0.71)
7	EPJul	L	A		0.32 (0.07, 0.58)		0.31 (0.05, 0.56)	0.33 (0.07, 0.59)	
8	Pred1	J	A	-0.45 (-0.84, -0.06)	-0.49 (-0.90, -0.08)	-0.37 (-0.71, -0.03)	-0.42 (-0.77, -0.07)	-0.44 (-0.78, -0.09)	-0.40 (-0.75, -0.05)
18	EPJA	J	A	0.21 (0.00, 0.42)	0.22 (0.00, 0.45)	0.44 (0.21, 0.66)	0.46 (0.22, 0.69)	0.46 (0.22, 0.69)	0.46 (0.23, 0.69)
19	Secchi	A	B		-1.08 (-1.97, -0.19)		-1.24 (-2.27, -0.22)	-1.15 (-2.11, -0.20)	
22	Aent	A	B		9.50 (0.62, 18.38)		10.97 (0.93, 21.01)	10.32 (0.99, 19.65)	
23	Pred2	L	B				-0.19 (-0.52, 0.13)		
	a	L		396 (334, 458)	451 (373, 529)	396 (337, 456)	593 (307, 879)	454 (376, 532)	410 (340, 481)
	a	J		0.74 (0.01, 1.48)	0.77 (-0.02, 1.56)	0.39 (0.18, 0.6)	0.42 (0.19, 0.65)	0.43 (0.2, 0.66)	0.41 (0.19, 0.63)
	a	A		0.03 (0.02, 0.04)	0.2 (-0.13, 0.53)	0.03 (0.02, 0.04)	0.27 (-0.24, 0.78)	0.25 (-0.18, 0.67)	0.08 (0, 0.16)
	b	L		0	0	0	0	0	0
	$b\ (10^{-4})$	J		8.38 (-0.19, 16.95)	7.95 (-0.57, 16.48)	1.43 (1.01, 1.84)	1.42 (1.01, 1.84)	1.44 (1.02, 1.85)	1.43 (1.01, 1.84)

b (10^{-2})	A	0	1.48 (-1.41, 4.38)	0	2.35 (-2.77, 7.47)	1.93 (-1.96, 5.81)	0.52 (-0.34, 1.39)
γ	L						
γ	J	-1	-1	0	0	0	0
γ	A		-1		-1	-1	-1
σ	L	0.07 (-0.32, 0.45)	0 (-0.35, 0.35)	0.04 (-0.5, 0.59)	0 (-0.35, 0.35)	0 (-0.26, 0.26)	0.1 (-0.2, 0.39)
σ	J	0.52 (0.36, 0.67)	0.55 (0.39, 0.71)	0.46 (0.31, 0.6)	0.48 (0.32, 0.63)	0.48 (0.32, 0.63)	0.47 (0.32, 0.62)
σ	A	0.79 (0.57, 1.01)	0.61 (0.45, 0.77)	0.82 (0.59, 1.04)	0.61 (0.45, 0.77)	0.62 (0.46, 0.78)	0.71 (0.52, 0.9)
$h_{0.05}$	L	1	1	1	1	1	1
$h_{0.05}$	J	0.24 (0.09, 0.4)	0.24 (0.08, 0.4)	0.11 (0.09, 0.14)	0.11 (0.09, 0.14)	0.12 (0.09, 0.14)	0.11 (0.09, 0.14)
$h_{0.05}$	A	1	0.29 (-0.06, 0.64)	1	0.38 (-0.09, 0.85)	0.34 (-0.07, 0.75)	0.15 (0, 0.3)

Table 7. Estimates of standard deviation of the process variation and the percentage of the process variation explained by the covariates for the lowest AICc model.

	Standard deviation without covariates	Standard deviation with covariates	%variation explained
Larvae	0.72	0.00	100%
Juvenile	0.63	0.48	43%
Adult	0.71	0.62	24%

Figure captions

Figure 1. Life cycle diagram of delta smelt with survey, entrainment, and density dependence timing.

Figure 2. Relationship among stages in the model for the lowest AICc model that has Ricker survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship. Points are the model estimates of abundance, lines are the estimates from the stock recruitment models without covariates or process variation, crosses are the estimates without covariates.

Figure 3. Relationship among stages in the alternative model (the model that has the fewest covariates and the AIC is less than 2 AIC units greater than the lowest AIC model). Points are the model estimates of abundance, lines are the estimates from the stock recruitment models without covariates or process variation, crosses are the estimates without covariates.

Figure 4. Fit (line) to the survey abundance data (circles) for the lowest AICc model that includes Ricker survival between juveniles and adults and a Beverton-Holt stock-recruitment relationship. Confidence intervals are the survey observations plus and minus two standard deviations as estimated from bootstrap analysis.

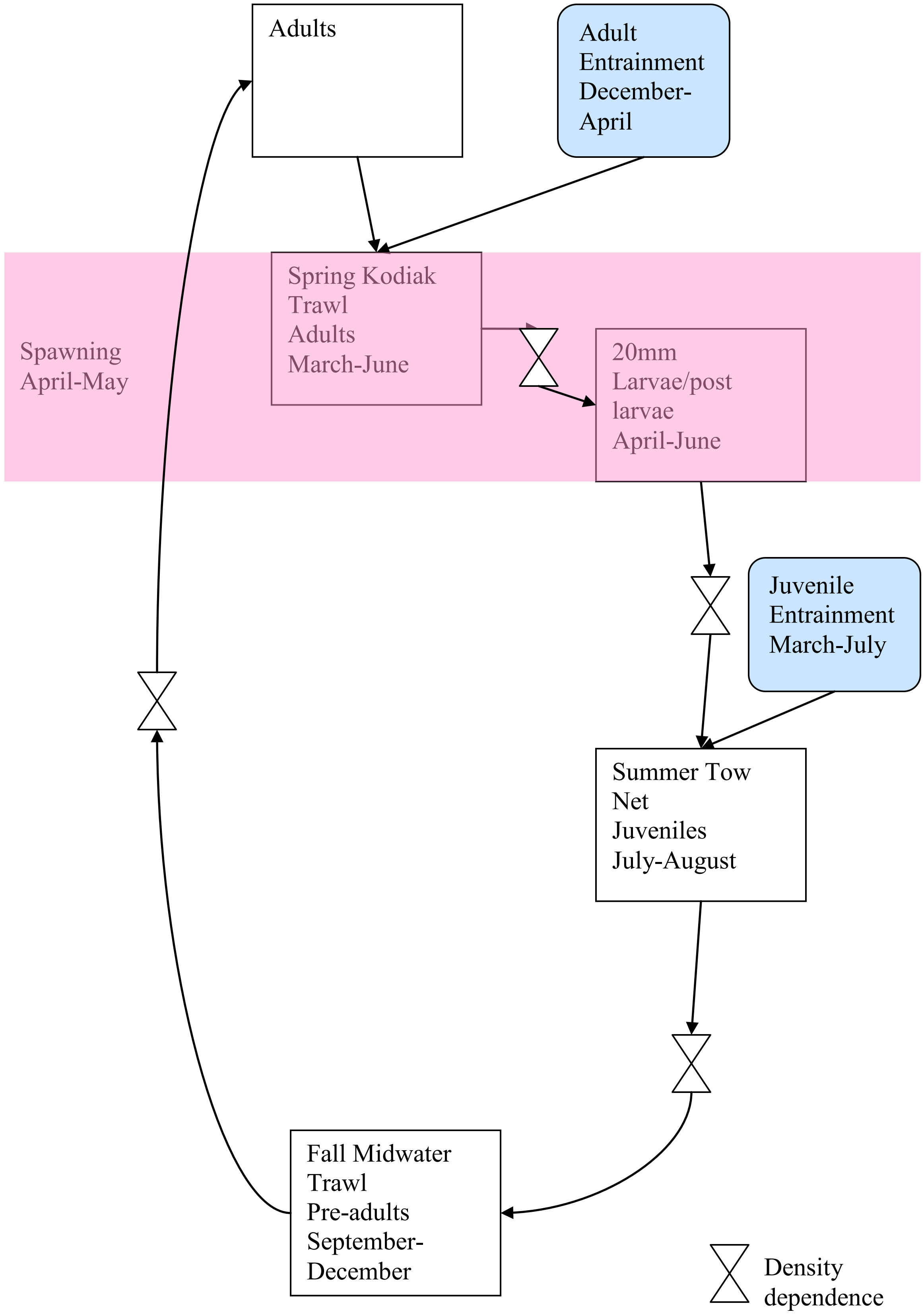
Figure 5. Fit (line) to the survey abundance data (circles) for the alternative model (the model that has the fewest covariates and the AIC is less than 2 AIC units greater than the lowest AIC model) that includes Ricker survival from juveniles to adults and a Beverton-Holt stock recruitment relationship. Confidence intervals are the survey observations plus and minus two standard deviations as estimated from bootstrap analysis.

Figure 6. Estimates of the realizations of the process variation random effects ($\exp\left[\sigma_s \varepsilon_{t,s} - 0.5\sigma_s^2\right]$) for the lowest AICc model that includes Ricker survival between juveniles and adults and a Beverton-Holt stock-recruitment relationship (top) and the alternative model (the model that has the fewest covariates and the AIC is less than 2 AIC units greater than the lowest AIC model) (bottom).

Figure 7. Estimates of abundance with and without covariates (coefficients of the covariates set to zero) (top) and ratio of the two with 95% confidence intervals (bottom, y-axis limited to show details) from the lowest AICc (left panels) model that has Ricker survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship and the alternative model (the model that has the fewest covariates and the AIC is less than 2 AIC units greater than the lowest AIC model) (right panels).

Figure 8. Estimates of the adult abundance with and without adult entrainment (top) and the ratio of adult abundance without adult entrainment to with adult entrainment (bottom, y-axis limited to show details) from the lowest AICc model (left panels) with Ricker

survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship and the alterative model (the model that has the fewest covariates and the AIC is less than 2 AIC units greater than the lowest AIC model) (right panels).


Adults
Adult Entrainment December-April
Spawning April-May
Spring Kodiak Trawl Adults March-June
20mm Larvae/post larvae April-June
Juvenile Entrainment March-July
Summer Tow Net Juveniles July-August
Fall Midwater Trawl Pre-adults September-December
Density dependence

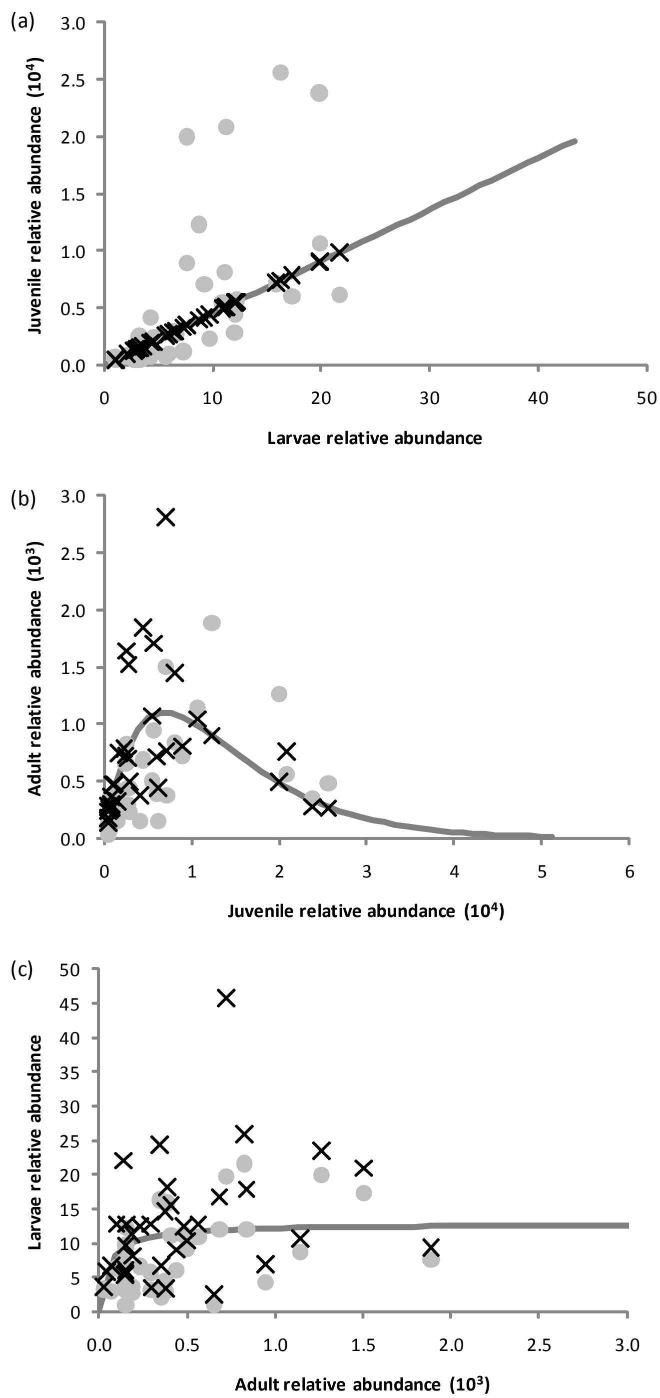

(a)
Juvenile relative abundance (10^4)
Larvae relative abundance
(b)
Adult relative abundance (10^3)
Juvenile relative abundance (10^4)
(c)
Larvae relative abundance
Adult relative abundance (10^3)

Figure 2.

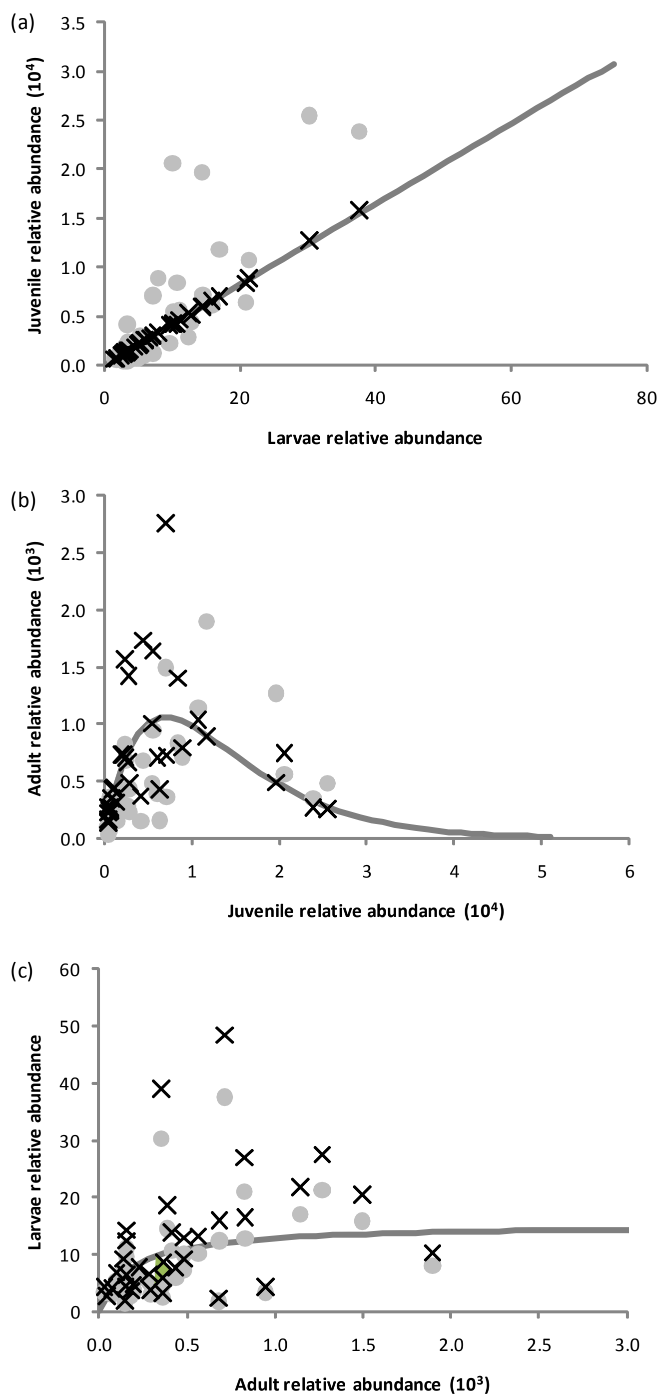
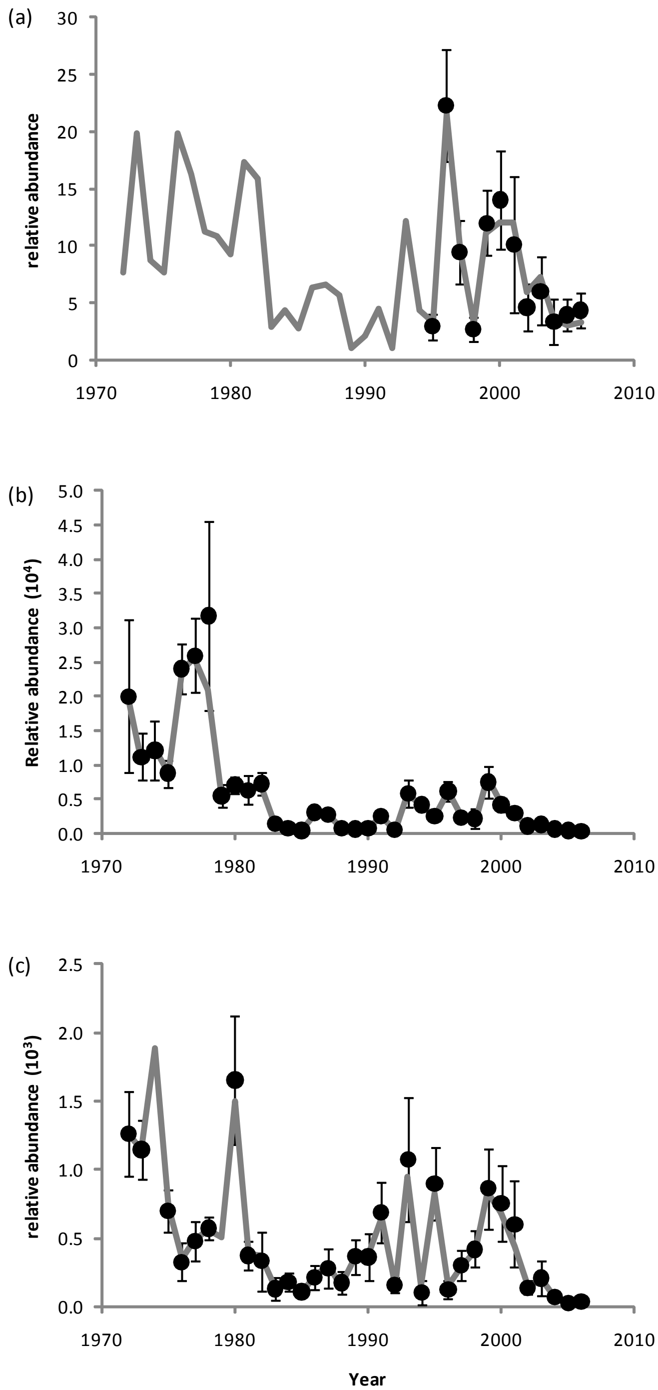

(a)
Juvenile relative abundance (10⁴)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
20
40
60
80
Larvae relative abundance
(b)
Adult relative abundance (10³)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
1
2
3
4
5
6
Juvenile relative abundance (10⁴)
(c)
Larvae relative abundance
60
50
40
30
20
10
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Adult relative abundance (10³)

Figure 3.



(a)
relative abundance
30
25
20
15
10
5
0
1970
1980
1990
2000
2010
(b)
Relative abundance (10^4)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1970
1980
1990
2000
2010
(c)
relative abundance (10^3)
2.5
2.0
1.5
1.0
0.5
0.0
1970
1980
1990
2000
2010
Year

Figure 4.

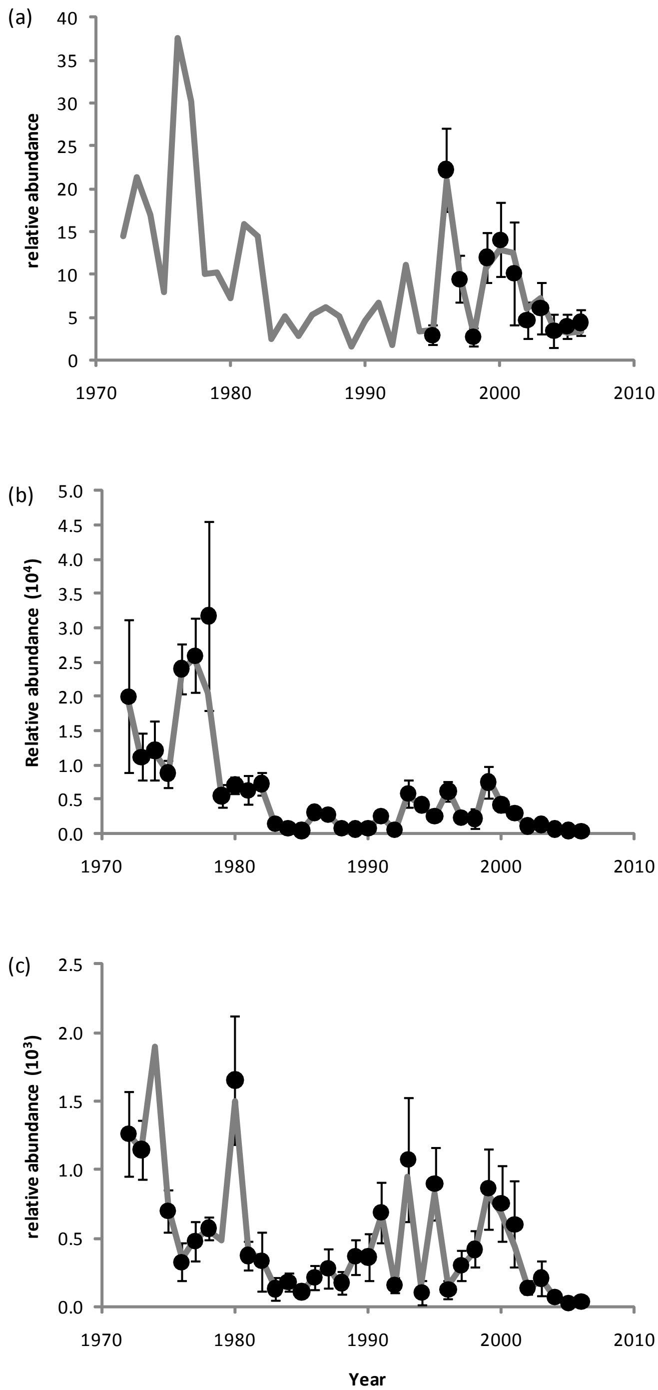

(a)
relative abundance
40
35
30
25
20
15
10
5
0
1970
1980
1990
2000
2010
(b)
Relative abundance (10⁴)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1970
1980
1990
2000
2010
(c)
relative abundance (10³)
2.5
2.0
1.5
1.0
0.5
0.0
1970
1980
1990
2000
2010
Year

Figure 5.

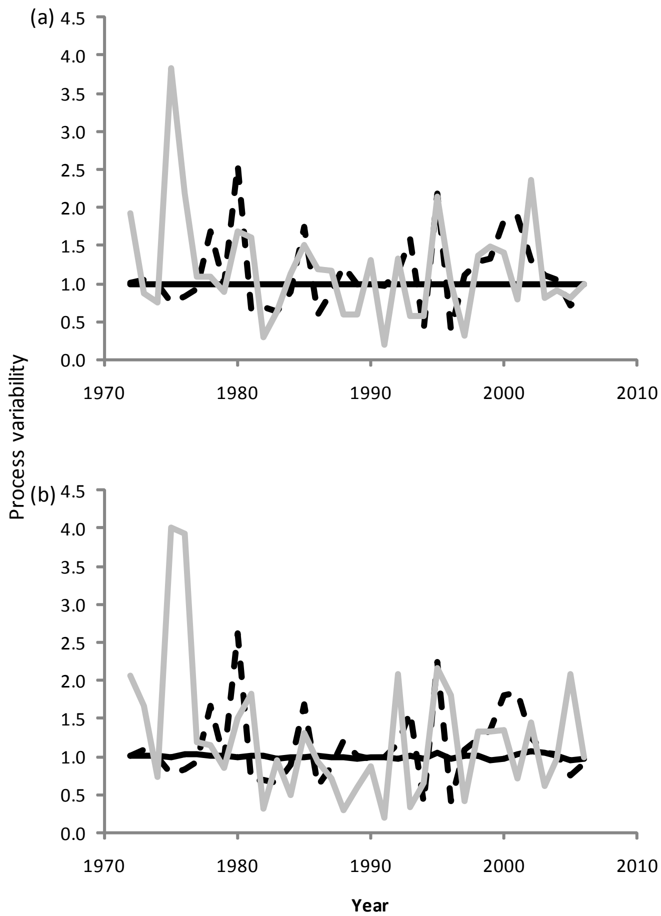

(a)
(b)
Process variability
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
1970
1980
1990
2000
2010
Year

Figure 6.

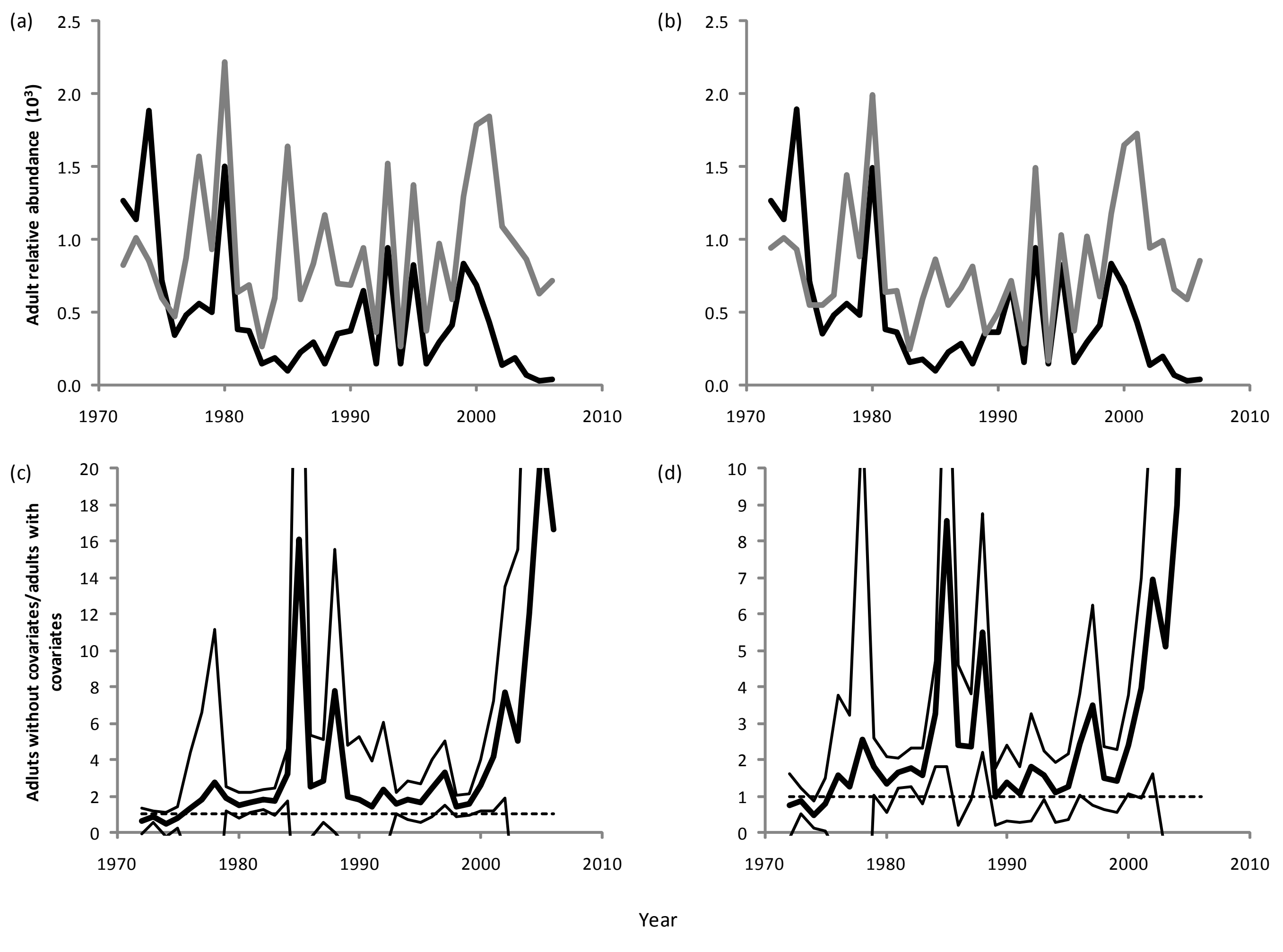

(a)
(b)
(c)
(d)
Adult relative abundance (10^3)
Adluts without covariates/adults with covariates
Year

Figure 7.

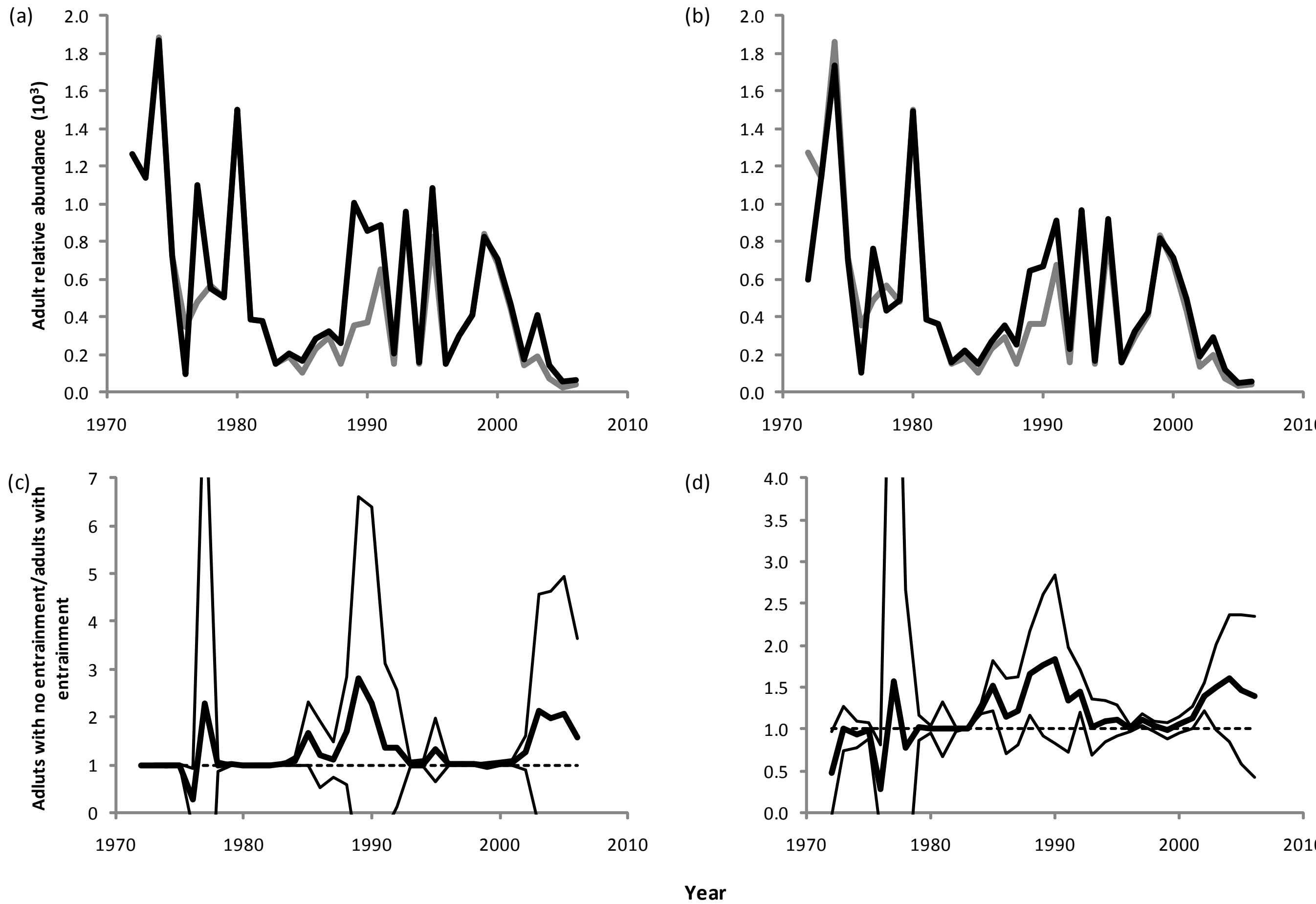

(a)
(b)
(c)
(d)
Adult relative abundance (10³)
Adluts with no entrainment/adults with entrainment
Year
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1970
1980
1990
2000
2010
7
6
5
4
3
2
1
0
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

Figure 8.

Supplementary material

The following tables provide the data used in the analysis, a complete set of results for all the covariates evaluated in the analysis, and correlation matrices for the factors and estimated parameters.

Table S1. Indices of abundance and standard errors used in the delta smelt application.

	20mm		STN		FMWT	
Year	value	SE	value	SE	value	SE
1972			20005	5577	1265	155
1973			11185	1722	1145	108.7
1974			12147	2175		
1975			8786	989	697	77.8
1976			24000	1802	328	67.7
1977			25965	2681	480	69.7
1978			31758	6867	572	41.2

1979	5484	853		
1980	7068	646	1654	235.6
1981	6300	1043	374	49.9
1982	7242	820	333	108.5
1983	1390	279	132	43.6
1984	779	147	182	35.2
1985	387	67	110	21.6
1986	3057	406	212	42.7
1987	2743	227	280	71
1988	764	129	174	40.7
1989	647	52	366	63.7
1990	747	125	364	83.3
1991	2486	334	689	108.8
1992	471	68	156	27.8
1993	5763	996	1078	226.6
1994	4156	380	102	45.4

1995	2.933692	0.563774	2490	307	899	132.6
1996	22.25453	2.437344	6162	701	127	31
1997	9.437214	1.371236	2362	353	303	55
1998	2.704639	0.526823	2209	694	420	67
1999	12.00716	1.428904	7478	1142	864	146.2
2000	14.02919	2.160034	4178	519	756	139.9
2001	10.10347	2.983169	2897	332	603	156.2
2002	4.63569	1.04671	1115	163	139	25.2
2003	6.043828	1.479269	1329	174	210	64.9
2004	3.380115	0.967356	649	113	74	19
2005	3.981609	0.693923	393	97	27	6.6
2006	4.372327	0.779492	352	117	41	11.9

Table S2. Untransformed covariate values. See Table 2 for definitions.

Year	SpDys	TpAJ	TpJul	EPAJ	EPJul	Preds1	StBass	DSLth	TpJS	EPJA	Secci	JEnt	AEnt	Preds2
1972	110	17.8	21.3	1243.77	4725	586	36498		21.8	4303	50	0.28136	0.02626	354
1973	104	18.6	21.3	754.234	1547	1041	27596		21.9	2082	26	0.1174	0.02626	793
1974	85	17.7	21.0	614.313	4202	850	32314		22.5	3799	44	0.0814	0.02626	446
1975	92	17.2	20.1	479.507	1520	735	41650	65.1	21.5	1545	44	0.06449	0.02626	280
1976	130	17.6	21.4	666.081	4125	19410	65427		21.9	2895	74	0.31567	0.0952	6118
1977	118	17.0	21.1	581.151	4194	22324	40655	65.6	21.5	3972	59	0.35274	0.02626	7095
1978	110	17.8	21.1	1457.95	2082	14726	28399	65.3	22.4	1391	13	0	0.02626	8423
1979	90	18.0	21.0	516.84	947	37712	25761		22.1	722	34	0.15945	0.02626	18631
1980	137	16.8	20.5	428.147	548	20360	20254	70.3	22.5	647	11	0.03108	0.02626	15120
1981	108	18.7	21.8	787.671	922	22248	20621	67.2	22.8	724	42	0.22261	0.02626	17070
1982	105	17.0	20.6	19.4272	636	30605	21560	66.2	21.4	670	31	0.00746	0.02626	23570
1983	102	17.3	20.7	271.066	530	28422	31059	62.2	22.2	544	28	0	0.02626	13957
1984	100	18.3	22.4	251.49	1560	29082	35459	69.5	22.8	1545	50	0.20125	0.02626	20444

1985	105	18.5	22.0	134.587	548	62483	46997	69.1	22.5	543	76	0.26546	0.06687	30364
1986	122	18.1	21.2	648.516	626	30255	22752	68.1	21.5	534	60	0	0.02626	22921
1987	102	19.0	20.6	534.328	392	42089	41144	64.8	21.3	519	65	0.26078	0.02626	26771
1988	125	17.8	22.4	119.215	364	36828	30207	69.5	23.1	360	46	0.3583	0.16922	26668
1989	108	17.9	21.1	383.708	2558	38551	29441	67.8	21.7	3641	67	0.27032	0.13226	24067
1990	100	18.4	22.0	200.219	3616	57128	32336	63.9	22.7	3837	46	0.36378	0.22385	26671
1991	108	17.2	21.3	150.931	2542	63209	39881	62.5	21.8	3059	87	0.3181	0.02626	23754
1992	99	19.2	21.3	531.604	2733	89736	44102	57.9	22.5	2828	82	0.28653	0.04369	42138
1993	112	17.8	21.5	602.607	1184	48487	27938	54.7	22.2	1425	23	0.06506	0.05702	25301
1994	102	17.8	21.1	1112	965	61942	32635	62.9	21.4	856	75	0.21454	0.02626	53729
1995	142	17.0	21.5	573.935	2366	59091	34966	58.5	22.0	1431	27	0	0.18	38412
1996	115	18.3	21.4	380.924	533	72056	44927	55.1	22.6	731	38	0.01	0.025	52547
1997	104	19.3	21.2	369.14	590	64436	56551	57.6	21.8	800	22	0.14	0.025	33056
1998	117	16.3	21.3	271.886	1002	25623	32979	59.3	22.6	842	30	0	0.01	21106
1999	112	17.3	21.3	751.657	1308	29853	42465	59.1	22.0	1091	56	0.07	0.03	21961
2000	118	18.9	20.8	411.035	825	74907	60639	59.3	22.2	1007	64	0.13	0.05	50114
2001	73	19.5	21.3	423.892	758	81186	48811	63.5	22.0	484	57	0.19	0.05	50992

2002	108	18.6	21.8	105.105	641	75565	32632	62.2	22.2	462	36	0.26	0.16	59540
2003	106	18.0	22.2	136.244	787	86509	40081	58.6	23.2	1525	35	0.17	0.22	56424
2004	108	19.1	21.3	153.943	354	109036	82253	62.0	22.3	1012	37	0.21	0.19	50151
2005	123	18.1	22.0	57.0556	849	119419	58943	59.6	22.8	466	49	0.03	0.09	68310
2006	95	17.8	22.6	121.846	1321	116848	41977	58.0	23.7	884	39	0	0.03	53328

Table S3a. AICc weights for each step in the two factor analysis for the model with Beverton-Holt survival from juvenile to adult. In the Stage column A=Adults, L=Larvae, and J=Juveniles. In the B/A column B=before density dependence and A=after density dependence. # = not included in AICc weights calculation because it was selected in previous step. * = not included in AICc weights calculation because a similar covariate was selected in previous step. The shaded cells indicate the two models chosen to retain in subsequent tests.

Run	Name	Stage	B/A	1st	2nd	3rd	4th	5th
1	SpDys	A	B	0.01	0.05	0.17	0.33	#
2	TpAJ	L	B	0.63	#	#	#	#
3	TpAJ	A	A	0.02	0.04	0.08	0.15	0.25
4	TpJul	L	A	0.31	0.68	#	#	#
5	EPAJ	L	B	0.56	#	#	#	#
6	EPAJ	A	A	0.01	0.00	0.00	0.00	0.00
7	EPJul	L	A	0.01	0.03	0.12	0.30	#
8	Pred1	J	A	0.13	0.43	#	#	#
9	Pred1	A	B	0.00	0.00	0.00	0.00	0.00

10	Pred1	A	A	0.00	0.00	0.00	0.00	0.00
11	StBass	J	A	0.01	0.06	0.08	0.17	0.25
12	StBass	A	B	0.00	0.00	0.00	0.00	0.00
13	StBass	A	A	0.00	0.00	0.00	0.00	0.00
14	DSLth	L	A	0.00	0.03	0.09	0.19	0.24
15	DSLth	J	A	0.00	0.03	0.00	0.00	0.00
16	DSLth	A	A	0.00	0.00	0.00	0.00	0.00
17	TpJS	J	A	0.00	0.02	0.06	0.00	0.00
18	EPJA	J	A	0.06	0.27	0.41	#	#
19	Secchi	A	B	0.01	0.08	0.23	#	#
20	Secchi	A	A	0.01	0.08	0.23	*	*
21	Jent	L	A	0.01	0.00	0.00	0.00	0.00
22	Aent	A	B	0.01	0.03	0.08	0.16	0.33
23	Pred2	L	B	0.18	0.06	0.10	0.18	0.25
24	Pred2	A	A	0.00	0.03	0.06	0.00	0.00

Table S3b. AICc weights for each step in the two factor analysis for the model with Beverton-Holt survival from juvenile to adult and a Beverton-Holt stock-recruitment relationship. In the Stage column A=Adults, L=Larvae, and J=Juveniles. In the B/A column B=before density dependence and A=after density dependence. # = not included in AICc weights calculation because it was selected in previous step. * = not included in AICc weights calculation because a similar covariate was selected in previous step. The shaded cells indicate the two models chosen to retain in subsequent tests.

Run	name	Stage	B/A	1st	2nd	3rd	4th	5th
1	SpDys	A	B	0.00	0.01	0.04	0.08	0.26
2	TpAJ	L	B	0.40	#	#	#	#
3	TpAJ	A	A	0.02	0.03	0.06	0.07	0.14
4	TpJul	L	A	0.05	0.71	#	#	#
5	EPAJ	L	B	0.89	#	#	#	#
6	EPAJ	A	A	0.04	0.03	0.11	0.13	0.17
7	EPJul	L	A	0.01	0.03	0.15	0.37	#
8	Pred1	J	A	0.09	0.32	#	#	#
9	Pred1	A	B	0.00	0.00	0.01	0.05	0.04
10	Pred1	A	A	0.01	0.04	0.10	0.22	0.23

11	StBass	J	A	0.01	0.06	0.07	0.09	0.15
12	StBass	A	B	0.00	0.00	0.00	0.00	0.00
13	StBass	A	A	0.00	0.00	0.00	0.00	0.00
14	DSLth	L	A	0.00	0.02	0.07	0.09	0.18
15	DSLth	J	A	0.00	0.02	0.00	0.00	0.00
16	DSLth	A	A	0.00	0.00	0.00	0.01	0.08
17	TpJS	J	A	0.00	0.02	0.05	0.00	0.00
18	EPJA	J	A	0.04	0.28	0.36	#	#
19	Secchi	A	B	0.01	0.06	0.24	#	#
20	Secchi	A	A	0.01	0.06	0.16	*	*
21	Jent	L	A	0.01	0.00	0.00	0.00	0.00
22	Aent	A	B	0.01	0.07	0.14	0.37	#
23	Pred2	L	B	0.34	0.10	0.11	0.13	0.19
24	Pred2	A	A	0.02	0.06	0.12	0.12	0.10

Table S3c. AICc weights for each step in the two factor analysis for the model with Ricker survival from juvenile to adult. In the Stage column A=Adults, L=Larvae, and J=Juveniles. In the B/A column B=before density dependence and A=after density dependence. # = not included in AICc weights calculation because it was selected in previous step. * = not included in AICc weights calculation because a similar covariate was selected in previous step. The shaded cells indicate the two models chosen to retain in subsequent tests.

Run	name	Stage	B/A	1st	2nd	3rd	4th	5th
1	SpDys	A	B	0.01	0.03	0.18	#	#
2	TpAJ	L	B	0.39	0.91	#	#	#
3	TpAJ	A	A	0.01	0.04	0.08	0.13	0.26
4	TpJul	L	A	0.17	0.50	#	#	#
5	EPAJ	L	B	0.44	#	#	#	#
6	EPAJ	A	A	0.00	0.00	0.00	0.00	0.00
7	EPJul	L	A	0.01	0.02	0.11	0.24	#
8	Pred1	J	A	0.02	0.16	0.38	#	#
9	Pred1	A	B	0.00	0.00	0.00	0.00	0.00
10	Pred1	A	A	0.00	0.00	0.00	0.00	0.00

11	StBass	J	A	0.01	0.03	0.09	0.00	0.00
12	StBass	A	B	0.00	0.00	0.00	0.00	0.00
13	StBass	A	A	0.00	0.00	0.00	0.00	0.00
14	DSLth	L	A	0.00	0.02	0.11	0.17	0.27
15	DSLth	J	A	0.00	0.04	0.17	0.15	0.26
16	DSLth	A	A	0.00	0.00	0.00	0.00	0.00
17	TpJS	J	A	0.00	0.00	0.00	0.00	0.00
18	EPJA	J	A	0.53	#	#	#	#
19	Secchi	A	B	0.01	0.04	0.18	0.26	#
20	Secchi	A	A	0.01	0.04	0.18	0.26	*
21	Jent	L	A	0.01	0.01	0.00	0.00	0.00
22	Aent	A	B	0.01	0.02	0.08	0.14	0.30
23	Pred2	L	B	0.37	0.09	0.11	0.18	0.26
24	Pred2	A	A	0.00	0.01	0.04	0.00	0.00

Table S3d. AICc weights for each step in the two factor analysis for the model with Ricker survival from juvenile to adult and a Beverton-Holt stock-recruitment relationship. In the Stage column A=Adults, L=Larvae, and J=Juveniles. In the B/A column B=before density dependence and A=after density dependence. # = not included in AICc weights calculation because it was selected in previous step. * = not included in AICc weights calculation because a similar covariate was selected in previous step. The shaded cells indicate the two models chosen to retain in subsequent tests.

Run	name	Stage	B/A	1st	2nd	3rd	4th	5th	6th	7th
1	SpDys	A	B	0.00	0.02	0.04	0.03	0.23	#	#
2	TpAJ	L	B	0.32	0.38	#	#	#	#	#
3	TpAJ	A	A	0.01	0.04	0.05	0.08	0.12	0.48	#
4	TpJul	L	A	0.04	0.09	0.61	#	#	#	#
5	EPAJ	L	B	0.78	#	#	#	#	#	#
6	EPAJ	A	A	0.03	0.02	0.07	0.19	0.18	0.00	0.00
7	EPJul	L	A	0.01	0.03	0.06	0.21	0.61	#	#
8	Pred1	J	A	0.01	0.13	0.30	#	#	#	#
9	Pred1	A	B	0.00	0.00	0.00	0.00	0.06	0.00	
10	Pred1	A	A	0.01	0.00	0.04	0.11	0.10	0.00	

11	StBass	J	A	0.00	0.04	0.08	0.00	0.00	0.00	0.00
12	StBass	A	B	0.00	0.00	0.00	0.00	0.00	0.17	0.00
13	StBass	A	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	DSLth	L	A	0.00	0.00	0.02	0.08	0.12	0.23	#
15	DSLth	J	A	0.00	0.04	0.09	0.09	0.10	0.20	0.54
16	DSLth	A	A	0.00	0.00	0.00	0.00	0.00	0.17	0.00
17	TpJS	J	A	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	EPJA	J	A	0.35	0.89	#	#	#	#	#
19	Secchi	A	B	0.01	0.09	0.17	0.37	#	#	#
20	Secchi	A	A	0.00	0.04	0.09	0.15	*	*	*
21	Jent	L	A	0.00	0.03	0.00	0.00	0.00	0.00	0.00
22	Aent	A	B	0.01	0.07	0.15	0.23	#	#	#
23	Pred2	L	B	0.39	#	#	#	#	#	#
24	Pred2	A	A	0.01	0.00	0.05	0.10	0.04	0.05	0.53

Table S4a. AICc values and covariates included for each step in the two factor analysis for the model with Beverton-Holt survival from juvenile to adult. y = covariate included in lowest AICc model, # = covariate selected in previous step, * = covariate not considered because it is similar to another covariate.

					test1		test2		test3		test4		test5	
					covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2
				AICc	841.06	833.44	827.58	824.00	823.01	823.30	824.61	825.95	828.28	831.08
				Δ	18.05	10.43	4.57	0.99	0.00	0.28	1.60	2.94	5.27	8.07
Run	Name	Stage	B/A											
1	SpDys	A	B								y	y	#	#
2	TpAJ	L	B			Y	#	#	#	#	#	#	#	#
3	TpAJ	A	A											y
4	TpJul	L	A				y	y	#	#	#	#	#	#
5	EPAJ	L	B			Y	#	#	#	#	#	#	#	#
6	EPAJ	A	A											
7	EPJul	L	A									y	#	#
8	Pred1	J	A					y	#	#	#	#	#	#
9	Pred1	A	B											
10	Pred1	A	A											
11	StBass	J	A											
12	StBass	A	B											

13	StBass	A	A										
14	DSLth	L	A										
15	DSLth	J	A										
16	DSLth	A	A										
17	TpJS	J	A										
18	EPJA	J	A					y	y	#	#	#	#
19	Secchi	A	B						y	#	#	#	#
20	Secchi	A	A						*	*	*	*	*
21	Jent	L	A										
22	Aent	A	B									y	y
23	Pred2	L	B	y									
24	Pred2	A	A										

Table S4b. AICc values and covariates included for each step in the two factor analysis for the model with Beverton-Holt survival from juvenile to adult and a Beverton-Holt stock-recruitment relationship. y = covariate included in the lowest AICc model, # = covariate selected in previous step, * = covariate not considered because it is similar to another covariate.

					test1		test2		test3		test4		test5	
					covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2
				AICc	832.46	824.68	818.25	815.18	813.92	814.32	814.17	811.85	812.33	814.75
				AICc-min(AICc)	20.60	12.83	6.40	3.33	2.06	2.46	2.32	0.00	0.48	2.90
Run	Name	Stage	B/A											
1	SpDys	A	B											y
2	TpAJ	L	B			y	#	#	#	#	#	#	#	#
3	TpAJ	A	A											y
4	TpJul	L	A				y	y	#	#	#	#	#	#
5	EPAJ	L	B		Y	y	#	#	#	#	#	#	#	#
6	EPAJ	A	A											
7	EPJul	L	A								y	y	#	#
8	Pred1	J	A					y	#	#	#	#	#	#
9	Pred1	A	B											
10	Pred1	A	A										y	
11	StBass	J	A											
12	StBass	A	B											
13	StBass	A	A											

14	DSLth	L	A						
15	DSLth	J	A						
16	DSLth	A	A						
17	TpJS	J	A						
18	EPJA	J	A	y	y	#	#	#	#
19	Secchi	A	B		y	#	#	#	#
20	Secchi	A	A			*	*	*	*
21	Jent	L	A						
22	Aent	A	B				y	#	#
23	Pred2	L	B						
24	Pred2	A	A						

Table S4c. AICc values and covariates included for each step in the two factor analysis for the model with Ricker survival from juvenile to adult. y = covariate included in lowest AICc model, # = covariate selected in previous step, * = covariate not considered because it is similar to another covariate.

				test1		test2		test3		test4		test5	
				covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2
			AICc	841.80	833.67	826.25	821.40	820.00	821.10	822.58	823.71	826.26	828.86
			Δ	21.81	13.68	6.25	1.40	0.00	1.11	2.58	3.72	6.26	8.86
Run	name	Stage	B/A										
1	SpDys	A	B						y	#	#	#	#
2	TpAJ	L	B			y	y	#	#	#	#	#	#
3	TpAJ	A	A										y
4	TpJul	L	A				y	#	#	#	#	#	#
5	EPAJ	L	B			#	#	#	#	#	#	#	#
6	EPAJ	A	A										
7	EPJul	L	A								y	#	#
8	Pred1	J	A					y	y	#	#	#	#
9	Pred1	A	B										
10	Pred1	A	A										
11	StBass	J	A										
12	StBass	A	B										

13	StBass	A	A										
14	DSLth	L	A										
15	DSLth	J	A										
16	DSLth	A	A										
17	TpJS	J	A										
18	EPJA	J	A		Y	#	#	#	#	#	#	#	#
19	Secchi	A	B							y	y	#	#
20	Secchi	A	A							*	*	*	*
21	Jent	L	A										
22	Aent	A	B									y	y
23	Pred2	L	B	y	Y								
24	Pred2	A	A										

Table S4d. AICc values and covariates included for each step in the two factor analysis for the model with Ricker survival from juvenile to adult and a Beverton-Holt stock-recruitment relationship. y = covariate included in lowest AICc model, # = covariate selected in previous step, * = covariate not considered because it is similar to another covariate. Additional covariates increased the AICc by more than 4 units and are not shown.

					test1		test2		test3		test4		test5		test6		test7	
					covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2	covar1	covar2
				AICc	833.16	824.93	817.96	814.72	811.60	810.20	810.72	810.38	808.47	809.23	810.86	813.39	817.03	820.83
				AICc-min(AICc)	24.68	16.46	9.49	6.25	3.12	1.73	2.25	1.91	0.00	0.75	2.38	4.92	8.55	12.36
Run	name	Stage	B/A															
1	SpDys	A	B											y	#	#	#	#
2	TpAJ	L	B			y		y	#	#	#	#	#	#	#	#	#	#
3	TpAJ	A	A												y	y	#	#
4	TpJul	L	A						y	y	#	#	#	#	#	#	#	#
5	EPAJ	L	B		Y	y	#	#	#	#	#	#	#	#	#	#	#	#
6	EPAJ	A	A															
7	EPJul	L	A										y	y	#	#	#	#
8	Pred1	J	A							y	#	#	#	#	#	#	#	#
9	Pred1	A	B															
10	Pred1	A	A															

11	StBass	J	A												
12	StBass	A	B												
13	StBass	A	A												
14	DSLth	L	A										y	#	#
15	DSLth	J	A											y	y
16	DSLth	A	A												
17	TpJS	J	A												
18	EPJA	J	A	y	y	#	#	#	#	#	#	#	#	#	#
19	Secchi	A	B					y	y	#	#	#	#	#	#
20	Secchi	A	A							*	*	*	*	*	*
21	Jent	L	A												
22	Aent	A	B						y	#	#	#	#	#	#
23	Pred2	L	B	#	#	#	#	#	#	#	#	#	#	#	#
24	Pred2	A	A												y

Table S5. Correlation matrix for the covariates used in the analysis. See table 2 for definitions.

	Year	SpDys	TpAJ	TpJul	EPAJ	EPJul	Preds1	StBass	DSLth	TpJS	EPJA	Secci	JEnt	AEnt	Preds2
Year	1.00														
SpDys	0.03	1.00													
TpAJ	0.28	-0.41	1.00												
TpJul	0.41	0.06	0.21	1.00											
EPAJ	-0.48	0.03	-0.04	-0.31	1.00										
EPJul	-0.47	0.01	-0.23	-0.02	0.38	1.00									
Preds1	0.87	-0.06	0.44	0.45	-0.51	-0.36	1.00								
StBass	0.44	0.01	0.40	0.08	-0.23	0.00	0.54	1.00							
DSLth	-0.67	0.03	-0.10	-0.08	0.03	0.01	-0.53	-0.40	1.00						
TpJS	0.36	0.01	0.08	0.73	-0.35	-0.14	0.40	0.04	-0.16	1.00					
EPJA	-0.42	-0.07	-0.15	-0.04	0.27	0.94	-0.31	0.00	0.02	-0.16	1.00				
Secci	0.04	-0.13	0.21	0.06	-0.03	0.28	0.17	0.30	0.15	-0.26	0.31	1.00			
JEnt	-0.13	-0.11	0.33	0.25	-0.05	0.38	0.03	0.19	0.32	-0.09	0.47	0.60	1.00		
AEnt	0.38	0.22	0.15	0.45	-0.38	0.03	0.40	0.23	-0.04	0.30	0.10	-0.04	0.35	1.00	
Preds2	0.90	0.00	0.41	0.41	-0.44	-0.49	0.93	0.40	-0.50	0.33	-0.46	0.12	-0.05	0.39	1.00

Table S6. Correlation matrix for the parameters estimated in the model for the lowest AICc model that has Ricker survival from juveniles to adults and a Beverton-Holt stock-recruitment relationship. Many parameters are estimated on the log scale. See table 2 for covariate definitions.

			Correlation																
Parameter	Value	SD	$\ln(a_L)$	$\ln(a_J)$	$Ln(b_J)$	$Ln(a_A)$	$Ln(b_A)$	$Ln(N_{init})$	$Ln(\sigma_L)$	$Ln(\sigma_J)$	$Ln(\sigma_A)$	TpAJ	TpJul	EPAJ	EPJul	Pred1	EPJA	Secchi	Aent
$\ln(a_L)$	6.12	0.09	1.00																
$\ln(a_J)$	-0.84	0.27	-0.02	1.00															
$Ln(b_J)$	-8.85	0.15	-0.03	0.74	1.00														
$Ln(a_A)$	-1.40	0.87	0.12	0.06	0.05	1.00													
$Ln(b_A)$	-3.95	1.01	0.19	0.06	0.06	0.98	1.00												
$Ln(N_{init})$	2.03	0.42	-0.55	0.01	-0.02	-0.14	-0.17	1.00											
$Ln(\sigma_L)$	-10.30	3891.30	0.00	0.00	0.00	0.00	0.00	0.00	1.00										
$Ln(\sigma_J)$	-0.74	0.16	-0.03	0.06	-0.12	-0.01	-0.02	-0.01	0.00	1.00									
$Ln(\sigma_A)$	-0.48	0.13	-0.03	0.03	0.03	0.08	0.02	0.07	0.00	-0.03	1.00								
TpAJ	-0.22	0.07	0.07	0.07	0.03	0.06	0.04	-0.38	0.00	0.03	-0.01	1.00							
TpJul	-0.32	0.09	-0.22	0.02	-0.02	-0.24	-0.27	-0.07	0.00	0.05	-0.08	0.16	1.00						
EPAJ	0.36	0.11	-0.05	-0.02	-0.06	-0.05	-0.03	-0.30	0.00	0.05	-0.08	0.14	0.46	1.00					
EPJul	0.33	0.13	0.51	0.02	0.00	0.19	0.20	-0.64	0.00	0.00	-0.02	0.44	-0.17	-0.35	1.00				
Pred1	-0.44	0.17	-0.01	-0.86	-0.53	-0.07	-0.07	-0.02	0.00	0.04	-0.01	-0.07	-0.03	0.03	-0.03	1.00			
EPJA	0.46	0.12	-0.01	0.22	0.42	0.04	0.04	0.15	0.00	-0.06	0.04	-0.02	-0.02	-0.04	-0.03	-0.06	1.00		
Secchi	-1.15	0.48	-0.27	-0.08	-0.06	-0.81	-0.80	0.25	0.00	0.01	-0.01	-0.13	0.25	0.10	-0.35	0.08	-0.04	1.00	
Aent	10.32	4.67	0.18	0.07	0.06	0.89	0.85	-0.17	0.00	-0.01	0.01	0.11	-0.15	-0.13	0.29	-0.07	0.04	-0.71	1.00

Table S7. Correlation matrix for the parameters estimated in the alternative model (the model that has the fewest covariates and the AIC is less than 2 AIC units greater than the lowest AIC model). Many parameters are estimated on the log scale. See table 2 for covariate definitions.

			Correlation													
Parameter	Value	SD	ln(a_L)	ln(a_J)	Ln(b_J)	Ln(a_A)	Ln(b_A)	Ln(N_{init})	Ln(σ_L)	Ln(σ_J)	Ln(σ_A)	TpAJ	TpJul	EPAJ	Pred1	EPJA
ln(a_L)	6.02	0.09	1.00													
ln(a_J)	-0.89	0.27	-0.08	1.00												
Ln(b_J)	-8.85	0.15	-0.07	0.74	1.00											
Ln(a_A)	-2.52	0.52	0.05	0.04	0.02	1.00										
Ln(b_A)	-5.25	0.83	0.19	0.03	0.02	0.95	1.00									
Ln(N_{init})	2.67	0.39	-0.45	0.07	0.00	-0.13	-0.20	1.00								
Ln(σ_L)	-2.32	1.50	0.35	-0.14	-0.11	0.11	0.16	-0.34	1.00							
Ln(σ_J)	-0.76	0.16	-0.03	0.05	-0.12	0.03	0.02	0.00	-0.02	1.00						
Ln(σ_A)	-0.34	0.13	-0.08	0.08	0.05	0.14	0.01	0.13	-0.18	0.00	1.00					
TpAJ	-0.31	0.07	-0.19	0.09	0.04	0.04	0.00	-0.11	-0.10	0.03	0.06	1.00				
TpJul	-0.30	0.10	-0.16	0.05	0.00	-0.16	-0.19	-0.20	-0.13	0.02	-0.05	0.27	1.00			
EPAJ	0.47	0.12	0.28	-0.04	-0.08	0.16	0.21	-0.76	0.27	0.03	-0.14	0.29	0.40	1.00		
Pred1	-0.40	0.17	0.04	-0.87	-0.54	-0.05	-0.03	-0.08	0.13	0.05	-0.06	-0.08	-0.07	0.05	1.00	
EPJA	0.46	0.12	-0.02	0.22	0.41	0.01	0.01	0.17	-0.06	-0.07	0.03	0.00	-0.01	-0.07	-0.07	1.00

Exhibit B

Evaluation of Fall X2 on delta smelt

Mark Maunder and Rick Deriso

October 2010

Introduction

The influence of Fall X2 on the population dynamics of delta smelt was evaluated using a state-space multi-stage lifecycle model .

Methods

Fall X2 was calculated as the average of the monthly average X2 for two periods:

1) October to December.
2) September to December.

The Alternative Model of Maunder and Deriso (submitted) was used to evaluate Fall X2. The model is run from 1972 to 2006 and includes the covariates TpAJ, TpJul, EPAJ, Pred1, and EPJA (see table 1). The model is run first without the inclusion of Fall X2. This is the same as the Alternative Model described in Maunder and Deriso (submitted). The model is then run including Fall X2 either before or after density dependence. The negative log-likelihood is recorded and used to evaluate the support in the data for Fall X2 given the model assumptions and the inclusion of the other covariates.

Results

The negative log-likelihood for the three model runs is

No Fall X2	388.56
Oct-Dec Fall X2 before density dependence	388.52
Oct-Dec Fall X2 after density dependence	388.11
Sept-Dec Fall X2 before density dependence	388.53
Sept-Dec Fall X2 after density dependence	388.15

The difference in the negative log-likelihood for a single parameter is small compared to the values needed for statistical significance based on standard statistical tests like AIC or the likelihood ratio test. Therefore, the analysis did not find any statistical support for Fall X2 impacting survival from Adults to larvae (i.e. between the FMWT and the 20mm).

To double check the results we regressed the adult survival process error from the Alternative Model against Fall X2 (p-value = 0.38), which also does not find any statistical support for Fall X2 impacting survival from Adults to larvae.

References

Maunder, M.N. and Deriso, R.B. (submitted). A state-space multi-stage lifecycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt. Can. J. Fish. Aquat. Sci.

Table 1. The variables used as candidates to account for the changes in delta smelt abundance. A = occurs between adult and larval stages, L = occurs between larval and juvenile stages, J = occurs between juvenile and adult stages. Norm = subtract mean and divide by standard deviation, Mean = divide by mean, Raw = not scaled. The covariate is attributed to after density dependence unless it is known to occur before density dependence. This is because density dependence generally reduces the influence of the covariate.

Run	Name	Covar	Stage	B(efore)/ A(fter)	Sign	Description	Data scaling	Justification
2	TpAJ	2	L	B	- or +	Average water temperature Apr-Jun in delta smelt habitat	Norm	Temperature affects growth rate and survival of early life stages.
4	TpJul	3	L	A	-	Average water temperature July in delta smelt habitat	Norm	Higher water temperatures can be lethal. Could also include August temperature.
5	EPAJ	4	L	B	+	Minimum Eurytemera and psydodyoptimus density April-Jun	Norm	Measures height of food “gap” in spring, as Eury falls from spring maximum and Pseu rises from ~0.
8	Pred1	6	J	A	-	Sep-Dec abundance other predators	Mean	Predation is a source of direct mortality, measured as the product of relative density from beach seine data with the square of average sechi depth
18	EPJA	10	J	A	+	Average eurytemera and psydodyoptimus density July-August	Norm	Measures food availability in summer between STN and FMWT surveys, identified as problem by Bennett based on smelt condition.

Exhibit C

Exploratory analysis of set two covariates in the delta smelt life-cycle model

Rick Deriso and Mark Maunder

December 2010

A second set of covariates was provided to us. This second set is composed of the covariates listed in Table 1 below. An exploratory analysis was made utilizing the stage structured life cycle model described in Maunder and Deriso[1] (2010) using the abundance indices described in that paper for years 1972-2006. The analysis procedure applied here is a forward step-wise process involving the following steps:

1. Fit the model using the state space approach to abundance indices only.
2. Record the AIC score from the model fit,
3. Calculate a correlation matrix between all covariates in Table 1 and process errors calculated from the model fit.
4. Choose the covariate which has the highest correlation with any of the process errors.
5. If the highest correlation exceeds 0.3 go to step 6; otherwise the selection process is completed.
6. Rerun the model with the additional covariate added.
7. If the AIC score is improved then retain the additional covariate .
8. Iterate again starting at step 2 with the additional covariate retained.

AIC scores from the iterations and covariates added to the model are listed in Table 2. The final model contained the covariates: secchi depth in the fall, average Eurytemora plus Pseudo-diaptomus density for January-March, and largemouth bass abundance. The final AIC score was 837.40 which is substantially worse than the 808.63 AIC score for the “alternative model” described in Maunder and Deriso (2010). The difference in AIC scores between those two models exceeds 10. Paraphrasing Burnham and Anderson[2], models that are 10 or more AIC units above the best model have essentially no support.

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[1] Maunder, M and R. Deriso 2010 A state-space multi-stage lifecycle model to evaluate population impacts in the presence of density dependence: illustrated with application to delta smelt (in review CJFAS).

[2] Burnham, K. P. and Anderson, D.A. 2004. Multimodel inference, understanding AIC and BIC in model selection. Socio. Methods & Res. 33(2): 261-304.

	Table 1: additional covariates Additional 4M Variables					NCEAS Variables								Additional Variables of Interest Stations D4, D6, D7, D8 NCEAS Phyto Data		
	average Eurytemora+ Pseudo-diaptomus density, Apr-June, adjusted for delta smelt distribution #/m3	average Eurytemora+ Pseudo-diaptomus density, January-March #/m3	kimmerer adjusted % adult entrainment	kimmerer adjusted % larval-juvenile entrainment	**adjusted kimmerer total annual % entrainment**	cal_sp_ls: • Average biomass (mg C m-3) of calanoid copepodites and adults during Spring (March-May) in the low salinity zone (0.5-10 ppt)	cal_sum_ls: • Average biomass (mg C m-3) of calanoid copepodites and adults during Summer (June-September) in the low salinity zone (0.5-10 ppt)	zoo_sp_fw: • Average biomass, March through May, freshwater cladocera, rotifer	is_biomass: Total biomass of inland (mississipi) silverside	lb_biomass: Total biomass of largemouth bass	x2_sp: Average March-May position of the 2ppt isohaline (X2) measured in kilometers	x2_fall: • Average (September - December) position of the 2ppt isohaline (X2) measured in kilometers upstream from the Golden Gate	secchi: Average secchi depth (meters) for the Fall midwater trawl survey	Jan-Mar Diatom Densities	April - June Diatom Densities	July - Sept Diatom Densities

Year	#/M3	#/M3				mg-C/M3	mg-C/M3	mg-C/M3	Natural?	Natural?	KM	KM	M	#/ml	#/ml	#/ml
abbreviation:	Eury1	Eury2	adult entrainment	larval-juvenile entrainment	entrainment	cal_sp_ls	cal_sum_ls	zoo_sp_fw	is_biomass	lb_biomass	x2_sp	x2_fall	secchi	Jan-Mar Diatom Densities	April - June Diatom Densities	July - Sept Diatom Densities
1972	2298	346	0.05	0.19	0.23	15.91	27.62	64.14			74.44	71.24	0.52			
1973	1997	767	0.04	0.07	0.11	15.64	14.33	23.07			64.39	66.68	0.44			
1974	2606	1586	0.05	0.05	0.09	43.87	21.68	35.44			57.39	65.80				
1975	998	184	0.04	0.05	0.09	13.17	12.34	19.72			59.37	68.23	0.56	358.75	2530.46	2068.29
1976	1021	570	0.06	0.21	0.26	5.95	11.37	47.75	32.91	313.09	81.06	89.60	0.74	619.70	1125.66	517.07
1977	1022	1193	0.04	0.22	0.26	9.76	15.03	17.02	47.78	58.08	91.74	93.18	0.61	70.29	207.23	308.87
1978	3341	465	0.08	0.00	0.08	32.32	18.51	8.81	424.12	34.83	57.80	76.72	0.52	147.65	583.27	2937.10
1979	1140	513	0.06	0.11	0.16	14.38	14.35	8.70	6575.48	500.72	67.69	80.75		149.76	919.91	2416.06
1980	713	573	0.04	0.00	0.04	24.51	15.94	14.78	1642.72	19.49	63.17	76.49	0.58	153.75	672.10	2751.62
1981	1006	516	0.06	0.14	0.20	15.31	7.16	8.66	2374.67	661.32	74.40	79.28	0.56	210.49	1536.27	2003.91
1982	1065	530	0.07	0.00	0.07	28.48	17.43	5.29	2366.06	554.68	53.07	65.79	0.60	423.27	923.49	467.76
1983	594	25	0.02	0.00	0.02	26.96	22.00	6.90	1526.43	1752.82	48.55	60.24	0.59	180.17	991.44	625.37
1984	581	116	0.02	0.12	0.14	9.35	17.01	3.81	3081.38	309.53	68.62	69.55	0.69	218.63	312.68	728.33
1985	327	193	0.06	0.18	0.23	5.15	10.52	7.90	2274.95	160.09	75.41	86.34	0.70	177.95	319.04	472.30
1986	1511	0	0.02	0.00	0.02	24.73	13.45	7.03	3564.22	1925.04	58.28	79.02	0.47	94.06	1178.29	2252.35
1987	1184	449	0.03	0.17	0.20	13.19	4.18	5.27	2420.32	97.69	76.16	89.61	0.72	307.60	502.07	53.39
1988	1068	24	0.06	0.24	0.28	0.98	3.81	6.61	1568.51	20.07	84.33	90.80	0.78	171.60	737.22	241.50
1989	2909	117	0.05	0.18	0.22	4.50	13.99	4.53	2146.42	81.51	73.02	87.39	0.78	99.14	155.58	109.31
1990	3645	234	0.05	0.23	0.27	2.44	9.68	5.64	638.22	71.75	88.28	90.94	0.86	45.76	114.40	205.91
1991	1513	47	0.02	0.22	0.23	0.99	7.75	3.47	3868.74	68.33	81.76	89.41	0.95	220.21	95.33	53.39
1992	6219	63	0.02	0.18	0.20	8.52	8.34	13.06	7327.81	670.39	79.43	87.67	0.79	62.40	129.65	53.39
1993	4074	125	0.08	0.05	0.12	11.66	7.94	6.94	4673.62	1967.88	59.59	82.02	0.77	99.14	1019.40	211.63
1994	2888	28	0.00	0.14	0.14	1.27	5.63	11.48	5348.02	1258.02	76.43	86.07	0.84	38.13	88.66	71.69
1995	2046	52	0.06	0.00	**0.06**		7.71	9.15	10437.27	1774.76	49.43	74.06	0.84	45.76	655.88	183.03
1996	1684	62	0.01	0.01	**0.02**	7.35	4.12	5.81	9812.94	1558.94	55.57	78.04	0.82	131.56	88.66	74.36
1997	1924	66	0.01	0.08	**0.09**	2.63	4.36	4.30	10430.47	1092.31	65.49	81.65	0.73	183.03	57.20	34.32
1998	3971	82	0.00	0.00	**0.00**	11.30	7.43	6.12	8032.85	970.12	49.80	68.73	0.70	65.52	188.75	27.46
1999	1710	101	0.01	0.04	**0.05**	8.38	6.59	7.84	7495.04	1198.65	58.37	83.36	0.91	139.36	260.25	62.92
2000	2842	76	0.02	0.08	**0.10**	11.37	4.83	4.25	13553.38	1886.48	59.32	84.98	0.89	48.62	394.67	34.32
2001	1838	46	0.02	0.11	**0.13**	4.50	2.93	5.67	16433.04	2603.29	72.41	83.62	0.63	80.08	28.60	22.88

2002	578	86	0.06	0.16	**0.21**	2.17	3.46	9.62	15455.87	2789.94	73.01	84.65	0.94	108.68	120.12	11.44
2003	1411	94	0.08	0.10	**0.18**	4.32	5.16	10.98	13411.06	4782.09	67.36	83.65	0.89	629.18	165.88	154.44
2004	824	59	0.07	0.13	**0.19**	4.80	3.66	8.09	12355.00	3220.05	64.09	83.65	1.00	85.80	108.68	34.32
2005	726	49	0.03	0.02	**0.05**	4.78	3.71	2.94	13142.71	2937.44	63.21	82.18	0.96	34.32	148.72	12.48
2006	3264	153	0.01	0.00	**0.01**	14.63	6.92	4.81	12794.12	4655.76	48.53	82.52	1.13	177.32	74.36	45.76

Table 2: Stepwise results of exploratory analysis

Model version	AIC
Base model no covariates	853.38
add Sechi depth	844.95
add Eury 2	839.64
add lb_biomass	837.40

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UNITED STATES DISTRICT COURT

EASTERN DISTRICT OF CALIFORNIA

THE DELTA SMELT CASES SAN LUIS & DELTA-MENDOTA WATER AUTHORITY, *et al.* v. SALAZAR, *et al.* (Case No. 1:09-cv-407)	1:09-cv-407 OWW GSA 1:09-cv-422 OWW GSA 1:09-cv-631 OWW GSA 1:09-cv-892 OWW GSA
STATE WATER CONTRACTORS v. SALAZAR, *et al.* (Case No. 1:09-cv-422)	Partially Consolidated With: 1:09-cv-480 OWW GSA
COALITION FOR A SUSTAINABLE DELTA, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-480)	**REPLY DECLARATION OF DR. RICHARD B. DERISO IN SUPPORT OF PLAINTIFF'S MOTION FOR INJUNCTIVE RELIEF**
METROPOLITAN WATER DISTRICT v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-631)	Date: July 26-29, 2011 Time: 8:30 a.m. Ctrm: 3 Judge: Hon. Oliver W. Wanger
STEWART & JASPER ORCHARDS, *et al.* v. UNITED STATES FISH AND WILDLIFE SERVICE, *et al.* (Case No. 1:09-cv-892)	

I, DR. RICHARD B. DERISO, declare:

1. My declaration is set forth in the following manner.

INTRODUCTION

2. In this declaration I will respond to the declaration of Mr. Matthew L. Nobriga ("Nobriga Decl.") in support of Defendants' Opposition to Plaintiff's Motion for Injunctive Relief.[1]

3. My declaration responds first to Mr. Nobriga's defense of the habitat analysis in Feyrer (2007) and Feyrer (2011); second, to his discussion of density-dependence in the smelt population; and finally, to his specific criticisms of the peer-reviewed quantitative life-cycle model that I have produced with Dr. Mark Maunder.[2]

I. The Habitat Modeling in Feyrer (2007) and Feyrer (2011) Does Not Provide a Useful Basis for Determining the Effect of Habitat on Delta Smelt Populations

4. As Mr. Nobriga explains in Paragraph 7 of his declaration, in Feyrer (2007), Mr. Feyrer used general additive modeling to evaluate the relationship between three habitat variables (salinity, turbidity, and temperature), which he collectively termed "EQ," and the presence/absence of delta smelt at the sites of the Fall Midwater Trawl. Mr. Feyrer found a correlation between EQ and smelt presence/absence, but the deviance accounted for by the EQ variables was fairly weak, equating to only 26% of the total deviance in the model.

5. Mr. Nobriga is correct that Feyrer (2007) has "been criticized during this litigation because their analysis did not explain very high proportions of variability in delta smelt catch." (Nobriga Decl. ¶ 8.) He suggests that this *could* be because Mr. Feyrer based his analysis on smelt presence/absence data rather than the actual fish counts in the FMWT, a conclusion he

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[1] In their opposition brief, Defendants rely extensively on the declaration of Dr. Christina Swanson, which was filed as Doc. 800 in this case. I have responded to Dr. Swanson's criticisms in my previous reply declaration, Doc. 814, which I hereby incorporate by reference in this declaration.

[2] The final published version of the Maunder & Deriso (2011) article is available online at http://www.nrcresearchpress.com/doi/abs/10.1139/f2011-071.

bases on the fact that Kimmerer (2009) used fish count data and the "more distinct peaks [of count data] give the statistical routine a clearer signal to find." (*Id.*) Fair enough, this is a possibility, but where is the analysis? It could be that Mr. Feyrer's use of presence/absence data caused a weaker statistical signal from EQ, but it is more likely that the weak correlation derives from the actual weakness of these variables to explain changes in smelt presence/absence. This is the kind of question that should be resolved by statistical analysis, not speculation.

6. Mr. Nobriga also neglects to mention an important point. Kimmerer (2009) did, in fact, perform a similar statistical analysis to that in Feyrer (2007), but used fish counts instead of presence/absence. And Dr. Kimmmerer found a similar correlation between his habitat index and changes in fish counts. But he also examined whether changes in spring X2 had any correlation with subsequent smelt abundance, and he found that "abundance of delta smelt did not vary with X2 . . . Despite the evident increase in the amount of habitat, delta smelt abundance appears to be regulated by other factors so far unidentified."[3] After Kimmerer (2009), the real question for Mr. Feyrer, and for FWS, is whether changing fall X2 will benefit the smelt. Neither Mr. Feyrer nor Mr. Nobriga want to answer that question.

7. In Paragraph 9, Mr. Nobriga again asserts that there might be other statistical analyses that he could perform that might "explain much more variation in delta smelt habitat use." But he does not want to perform those analyses because "the result would generally be the same and we would no doubt be accused of inappropriately 'customizing' our analysis." (Nobriga Decl. ¶ 9.) Frankly, in the course of this litigation I have provided a number of statistical analyses and I have been accused of much worse than inappropriately "customizing" the analysis. But open debate and criticism is an essential part of the scientific process, and no scientist can just accept on faith that an analysis would *probably* explain more of the variation in the data if

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[3] In fact, the only significant correlation between X2 and delta smelt abundance shown in Kimmerer (2009) was for the relationship between log-abundance in the Summer Townet Survey and spring X2 in years when delta smelt were more abundant (1959-1981). The correlation was *positive*: the further upstream X2 was located, the higher the abundance of delta smelt. Needless to say, this is the opposite of the hypothesized relationship proposed by Mr. Feyrer in his papers.

that analysis were performed. Either one can produce an acceptable statistical analysis that proves one's point, or one cannot.

8. In Paragraph 10, Mr. Nobriga puts great emphasis on the fact that the analyses in Feyrer (2007) and Feyrer (2011) were "reporting *concurrent* associations of fish catches and water quality." (Nobriga Decl. ¶ 10) (emphasis added.) "Thus, they show that some of the variation in delta smelt catch is explained by environmental conditions that occurred during the sampling." (*Id.*) However, the fact that the environmental data was collected "concurrently" does not mean that it therefore "explains" the variation in the smelt catch.[4] That "explanation" either comes through a strong statistical correlation or it does not. Similarly, Mr. Nobriga asserts that "when a water quality variable has trended over the long-term in a direction not favorable for delta smelt, it is reasonable to expect that some of the lower catch could be related to that trend even if other factors are demonstrably influencing the delta smelt abundance indices at the same time." (*Id.*) This is undeniable—the environmental variables *could* be related to trends in abundance—but this is easily resolved by conducting the proper statistical analysis; namely by comparing the environmental variable to the population growth rate. If one factor is "demonstrably" influencing changes in delta smelt abundance then the results are worth noting. On the other hand, if a factor cannot be demonstrated to affect changes in abundance, then in what way is it "reasonable" to assume that the second factor has an influence despite the fact that it cannot be detected? One may believe that the factor is important at a qualitative level, but one cannot prove it.

9. I agree with Mr. Nobriga that the attempt to link the results of a generalized additive model with delta smelt abundance is inherently circular. (Nobriga Decl. ¶ 11.) This was one of the flaws with Feyrer (2011), which sought and predictably found a correlation between its habitat index and smelt abundance as measured by the FMWT. The way to break out of that circularity would be to analyze the effect of the habitat index or X2 on the *population growth rate*

[4] I will discuss Mr. Nobriga's insistence on the concurrent collection of prey data in the third section of this declaration.

not raw abundance. But for reasons that continue to be inexplicable to me, that analysis has not been performed.

II. Density-dependence in the Delta Smelt Population

10. In Paragraphs 14-21, Mr. Nobriga provides an extended discussion of the role of density-dependence in the smelt population, very little of which I disagree with. As Mr. Nobriga acknowledges, Maunder & Deriso (2011) found that it was unclear whether and to what degree density-dependence occurs between generations. I cannot comment on Mr. Nobriga's hypotheses regarding step changes in population that have changed patterns in density dependence because they are presented without any substantive analysis. But it would not surprise me if Mr. Nobriga is correct that the smelt population is currently density-independent. (Nobriga Decl. ¶ 17.) My article came to a similar conclusion: "At the recent levels of abundance, density dependence is probably not having a substantial impact on the population, and survival is impacted mainly by density-independent factors." Kimmerer (2009) also suggested that one of the explanations for why spring X2 does not have an effect on smelt abundance may be that the population is "at a low enough abundance to preclude density dependence, which may be necessary for abundance to track habitat quality."

11. Nor, ultimately, do I disagree that the smelt carrying capacity has declined. (Nobriga Decl. ¶ 20.) However, I suspect that I do disagree with Mr. Nobriga on two key points. Mr. Nobriga asserts that "[t]he mechanism causing carrying capacity to decline is likely due to the long-term accumulation of deleterious habitat changes—both physical and biological—during the summer-fall." (*Id.*) Mr. Nobriga seems to believe that there is no way to separate out these factors to determine which of them is having the most effect on the smelt population. My quantitative life-cycle analysis found that there was a strong influence of food supply on changes delta smelt abundance. In other words, food supply is likely one of the important factors limiting the smelt carrying capacity. On the other hand, my model found no evidence that the location of X2 has any effect on smelt abundance. Therefore it is unlikely that the location of X2 is an important factor limiting smelt carrying capacity. Kimmerer (2009) also found that the location of spring X2 is not affecting smelt abundance (except for the positive relationship noted in

footnote 3 above). Notably, neither Mac Nally et al. (2010) nor Thomson et al. (2010) found any evidence for an effect of fall or spring X2 on delta smelt abundance in their life-cycle analyses. This is why it is useful to develop quantitative life-cycle models: they allow us to test which factors are most important. And this is why it is inexplicable that FWS continues to believe that manipulation of X2 is an effective method of benefiting the smelt.

12. My second, related concern is that if Mr. Nobriga is correct that the smelt are not currently density-dependent then it is highly unlikely that an action designed simply to increase the volume of their habitat will provide any benefit in the foreseeable future. As a scientist, I have not seen any data-based analysis that would justify such an action. This is the same point made by Kimmerer (2009), which theorized that smelt abundance may only "track habitat quality" when abundance levels are sufficient to cause density dependence. If Mr. Nobriga is correct that smelt are presently density-independent, then there is sufficient habitat already that increases in adults will translate directly into increases in juveniles, allowing for a population rebound.

13. Finally, I strongly disagree with Mr. Nobriga's implication in Paragraph 21 that abiotic factors somehow have to be "appropriate" before a biotic factor such as productivity begins to matter. First, there is no basis in ecological theory for suggesting that abiotic factors have priority. On the contrary, all species require both biotic and abiotic factors to survive, and some of those factors will necessarily be more limiting than others on the population. What is most important is determining which factors are most limiting. Second, Mr. Nobriga's analysis in Figure 2 does nothing to address the question here, because it does not consider either salinity or X2. His analysis seems to provide some support for a relationship between turbidity and the presence of smelt, which is consistent with analyses that I have performed in the past. Finally, his example illustrates the slipperiness of the abiotic/biotic concept. One theory for why turbidity is important to smelt is that smelt are better hidden from predators when the water is less clear. Is turbidity an abiotic factor? Or is turbidity a proxy for predation risk, which is a biotic factor? As I said above, the best way to sort these out is to use a quantitative life-cycle model to test the influence of variables without creating arbitrary distinctions.

III. Delta Smelt Quantitative Life Cycle Models

14. In Paragraphs 22-42, Mr. Nobriga criticizes a number of specific details regarding the quantitative life-cycle model that Dr. Maunder and I developed in Maunder & Deriso (2011). I will respond to those points below, but before turning to those details I will make a few general points about Mr. Nobriga's critique.

15. First, it is not a legitimate criticism in this context to imply that quantitative life-cycle modeling is somehow unhelpful for the task of understanding smelt population dynamics because modeling is based on "correlations" rather than "equations that explicitly describe delta smelt vital rates in terms of environmental variation that were developed under controlled conditions." (Nobriga Decl. ¶ 22.) Controlled studies of that sort are unimaginable in the Delta, and Mr. Nobriga does not point to any studies that should have been included in an analysis. Moreover, the only other option to quantitative life-cycle modeling that Mr. Nobriga presents is Mr. Feyrer's model, which is also entirely based on correlative relationships. It is a given that conditions in the Delta are sufficiently complicated that it will be difficult to tease out cause-and-effect relationships; however, statistical modeling based on correlations is unquestionably the best tool available to do so.

16. In addition, Mr. Nobriga attempts to undermine the results of my and Dr. Maunder's modeling work by implying that the available life-cycle models, including those in Mac Nally et al. (2010) and Thomson et al. (2010), all reach different conclusions and that therefore this is all simply a matter of scientific disagreement among experts: "If there is a 'big picture' conclusion to be gleaned from these studies, it is that the results depend *very strongly on how the model is set up and what covariates are considered*." (Nobriga Decl. ¶ 23.) But this is not the case for several important reasons.

17. First, as I mentioned above, the question that is being presented here by Mr. Nobriga and FWS is not *which* quantitative life-cycle model to use—Mr. Nobriga is not suggesting that FWS should make *any* use of life-cycle modeling to understand the effect of X2.

The question is whether to make use of quantitative life-cycle modeling, which is the standard scientific technique for evaluating covariates in a complicated ecosystem, or to use an ad hoc "habitat index" which is based on a number of statistical flaws that have been identified not just by me and Dr. Burnham, but by the NRC and other independent reviewers. The fact that the recently developed quantitative life-cycle models do not reach identical conclusions does not mean that it is scientifically justified to continue to rely on outdated and erroneous correlative analyses.

18. Second, the simple fact that analyses reach different conclusions based on how the model is set up and which covariates are considered does mean that those models cannot be compared and evaluated against each other. This is Dr. Burnham's area of expertise, but it is well-established in modern statistics that there are statistical methodologies such as AIC that allow for an evaluation of the weight of the evidence between models. I have always been willing to subject my modeling work to these sorts of analyses, and I believe that there is very strong evidence that the model presented in Maunder & Deriso (2011) is a powerful tool for understanding and evaluating the relationship between covariates in the Delta.

19. Finally, it is remarkable that Mr. Nobriga correctly states that all of the available life-cycle models "have been used to assess whether fall X2 has been an important correlate of delta smelt population dynamic trends," (Nobriga Decl. ¶ 24), but then fails to share the result of that assessment: namely that *none* of the available life-cycle models have found that X2 has been an important correlate of delta smelt population dynamic trends. (*See* Nobriga Decl. Exh. B.) As a statistician, the fact that three different life-cycle models, each of which took different approaches to data and covariates, all reached the same conclusion regarding X2 strongly indicates that no matter how you turn the data, X2 does not drive changes in smelt abundance. There is no scientific disagreement here.

20. Turning to Mr. Nobriga's specific criticisms of two out of the many covariates I analyzed, I will note first that I made use of the covariates that were developed in Manly (2010),[5] which are further elaborated in a peer-reviewed paper by Miller et al. (2011) that is currently in press at *Reviews in Fisheries Science*.[6] Due to the complexity of pulling together data sets, it is standard practice in the field of statistical modeling to rely on data sets developed by other scientists, especially those published in peer-reviewed journals. I have reviewed all of the data in Manly (2010), but I cannot account for every detail of every covariate—I suspect that the same is true of the modelers using the NCEAS data. For example, there is a standard and well-accepted correlation between air temperature and water temperature, and modelers regularly use that data interchangeably. To the extent that Mr. Nobriga is concerned about the use of air temperature rather than water temperature, the covariate could easily be traded out for future analysis.

21. Mr. Nobriga's criticism of my use of the EPJA variable, which is a variable that is based on counts of two smelt prey species weighted by regional delta smelt catch, is more profound and also more off-base. Mr. Nobriga criticizes the fact that the EPJA covariate weights zooplankton density by delta smelt catch, a technique which he concedes "is a good idea in principle" and one that he has used himself. (Nobriga Decl. ¶ 31.) However, in this case, Mr. Nobriga believes that the weighting is inappropriate because the predator and prey data were not collected "concurrently"—at the exact same moment.

22. There are two problems with this logic. First, while it is true that in an ideal world one would like all data to be collected concurrently in order to minimize the risk of any confounding factors, the fact is that such ideal data are rarely available. Here, for example, zooplankton data is not collected concurrently with the FMWT, as Mr. Nobriga acknowledges. (Nobriga Decl. ¶ 12.) According to Mr. Nobriga's logic, it would be impossible to model the

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[5] Manly , B.F.J. 2010b. Initial analyses of delta smelt abundance changes from Fall to Summer, Summer to Fall, and Fall to Fall. Western EcoSystems Technology, Inc. 2003 Central Avenue, Cheyenne, Wyoming, 82001, unpublished report.

[6] Miller et al., An investigation of factors affecting the decline of delta smelt (*Hypomesus transpacificus*) in the Sacramento-San Joaquin Estuary, *Reviews in Fisheries Science*, in press.

effects of any covariate on delta smelt unless it happened that there was a forty-year history of collecting it concurrently with the FMWT, which would severely limit the range of possible inquiry regarding the habitat factors that affect smelt abundance.

23. Second, what Mr. Nobriga is demanding, in return for excluding all consideration of a highly significant covariate, is a needless level of precision. As Mr. Nobriga admits, the EPJA variable matches the prey counts with "the regional delta smelt catch estimate collected nearest in time and space to the zooplankton sample." (Nobriga ¶ 31.) It is undoubtedly true that smelt and their prey are always moving "due to hydrodynamics and their own swimming behavior" but Mr. Nobriga presents no evidence or analysis that this movement is so extreme that weighting prey measurements based on smelt density produces misleading estimates. Nor does he present any evidence that taking zooplankton and smelt samples concurrently would have any substantial effect on the utility of the comparison. In other words, Mr. Nobriga would like to throw out the possibility of using weighted prey data, which he admits is a "good idea," based upon his unsupported assertion that the use of non-concurrently collected data is illegitimate.

24. Which leads to a larger problem with Mr. Nobriga's criticisms of the data set that I and Dr. Maunder used. Mr. Nobriga implies that other life-cycle modeling efforts have used "raw data," while I used data that was "contrived." (Nobriga Decl. ¶ 41.) The implication is that somehow that "raw" data is more honest, and more useful than the data that I used in my analysis. But this is not the case.

25. For example, the "raw" IEP data was collected over a wide range of Delta habitat and was designed to capture data for a large number of Delta species, not just Delta smelt. For example, the prey density data was collected all the way through the low salinity zone (0.5-10 ppt), without regard to where delta smelt actually reside. Thus, using this "raw" data by itself, as did the Mac Nally et al. (2010) and Thomson et al. (2010) life-cycle models, means that one floods the analysis with data that has not been tailored to the species in question. It is no surprise that the other models did not select Cal.s, for example, as a significant predictor of smelt abundance when that analysis contained data from large regions of the system where no smelt reside. The EPJA covariate is carefully tailored to analyze delta smelt by focusing on the regions

where they actually live. And the results are powerful: once you look at prey density where smelt actually live rather than over the entire system, the correlation is very strong. The EPJA variable is not "contrived," it is refined out of the raw data dump that is the IEP data. There is nothing "indefensible" about refining the available data set so that it is capable of answering important questions about the species.

26. In this regard, the issue is similar to the concern that I raised previously regarding FWS's use of raw salvage data to analyze the effect of OMR flow on smelt entrainment. As I explained in that case, FWS's insistence on simply using the raw data led to scientific error. In order to make proper use of the salvage data in the analysis, one had to transform the data by normalizing it to a measure of abundance. There, as here, it was possible to debate the details of the transformation of the data, but it was not reasonable to debate whether it should be done. With regards to prey density, and other factors, I believe that it is essential to use data that has been tailored to the biological reality of delta smelt populations when one is analyzing delta smelt. It is the use of a raw data set filled with biologically irrelevant samples that is "indefensible."

CONCLUSION

27. Ultimately, Mr. Nobriga's questioning of the precise details of individual covariates in the Maunder & Deriso (2011) quantitative life-cycle model illustrates why it is so useful to develop quantitative life-cycle models to understand a system like the Delta. Unlike a conceptual model, the assumptions in a quantitative life-cycle model are made clear, each covariate can be examined, tweaked or replaced, and the conclusions reached by the model are independently verifiable. Our model is not the final word on the delta smelt—it can undoubtedly be improved, and I welcome input from Mr. Nobriga and others—but it is a start towards answering the complicated questions regarding the Delta ecosystem.

28. However, I strongly believe that the results of my and Dr. Maunder's model, as well as the life-cycle models of Mac Nally et al. (2010) and Thomson et al. (2010) and the habitat analysis of Kimmerer (2009), are sufficient to answer the question of whether the location of X2 is a significant factor in the survival of delta smelt. It is not. Mr. Nobriga believes that it is a

"false choice" between the use of rigorous quantitative life-cycle analyses and the use of Mr. Feyrer's model, and yet he does not provide a scientific explanation for why it is imperative or even appropriate to continue relying on the results of Mr. Feyrer's model in the face of overwhelming scientific evidence to contrary. The real choice here is between the standard scientific process, in which hypotheses are rigorously tested and invalidated if they are unsupported by the evidence, and no science at all.

I declare under penalty of perjury under the laws of the State of California and the United States that the foregoing is true and correct and that this Declaration was executed on July ____, 2011 at La Jolla, California.

DR. RICHARD B. DERISO

CERTIFICATE OF SERVICE

I hereby certify that on July 15, 2011, I electronically filed the foregoing with the Court by using the Court's CM/ECF system.

Participants in the case who are registered CM/ECF users will be served by the Court's CM/ECF system.

I further certify that the court-appointed experts are not registered CM/ECF users. I have emailed the foregoing document to the following:

REPLY DECLARATION OF DR. RICHARD B. DERISO IN SUPPORT OF PLAINTIFF'S MOTION FO RINJUNCTIVE RELIEF

SERVICE LIST

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I declare under penalty of perjury under the laws of the State of California the foregoing is true and correct and that this declaration was executed on July 15, 2011, at San Francisco, California.

/s/ Teresa M. Mendoza

tmendoza@mofo.com

September 19, 2013

Re: Independent Panel Review of the Bay Delta Conservation Plan

Dear Interested Stakeholder:

The attached report was prepared by an independent panel of experts convened by Dr. Jeff Mount for American Rivers and The Nature Conservancy to assist in our deliberations regarding the Bay Delta Conservation Plan. Dr. Mount assembled a balanced, interdisciplinary, and objective group of experts with long experience in the San Francisco Bay-Delta estuary to conduct this review of BDCP, which will now join a growing library of independent reviews of efforts to resolve the Delta crisis.

The opinions, analyses, and recommendations provided in the report are solely those of the authors. Our organizations will use the information in the report along with our own analysis of BDCP to develop a proposal for increasing the probability that BDCP will substantially improve environmental conditions in the Delta. This report does not represent the position of American Rivers or the Nature Conservancy.

American Rivers and The Nature Conservancy have been active participants in the BDCP planning process for the last seven years. Our organizations have not taken a formal position in support of the proposed project described in the administrative draft of the BDCP, but we are fully committed to continue our work in good faith to develop a conservation plan for the Delta ecosystem that advances the co-equal goals of ecosystem restoration and water supply reliability. The status quo condition in the Delta is unacceptable, and without action, will result in the inexorable decline of the Delta ecosystem and the species it supports.

Please direct questions regarding the report to Leo Winternitz or John Cain at lwinternitz@TNC.ORG and jcain@americanrivers.org. Thank you for your consideration.

Sincerely:

Leo Winternitz
Senior Advisor - Water Program
The Nature Conservancy

John Cain
Conservation Director
American Rivers

Panel Review of the Draft Bay Delta Conservation Plan:

Prepared for The Nature Conservancy and American Rivers

Jeffrey Mount, Ph.D. (Chair)
William Fleenor, Ph.D.
Brian Gray, J.D.
Bruce Herbold, Ph.D.
Wim Kimmerer, Ph.D.

Financial support provided by the S.D. Bechtel, Jr. Foundation

Technical support provided by NewFields, Inc.

September 2013

Saracino & Mount, LLC

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Preface

The Bay-Delta Conservation Plan is more than 15,000 pages long and covers a wide range of issues ranging from water supply, new facility construction, aquatic and terrestrial ecosystem management, governance and costs. Few outside of the handful of people deeply involved in BDCP actually know what is in the document due to its imposing size. This is particularly true for the various stakeholder groups who lack either the staff or the technical capacity to review the document and to evaluate the complex analyses that underpin it.

Saracino & Mount, LLC, was asked to assemble a panel of independent experts to review portions of the Plan to help guide decision-making by two non-governmental organizations: The Nature Conservancy and American Rivers. Guided by a narrow set of questions about how the Plan would impact water supply and endangered fishes, the panel reviewed the Plan documents and conducted analyses of data provided by the project consultants. The following document is a summary of our results.

It is important that this analysis not be over-interpreted. We do not endorse or reject the Plan. We only assess effectiveness of various conservation measures, guided by narrowly targeted questions. In addition, we make a handful of modest proposals to improve the performance of the Plan, particularly for issues of concern to the two non-governmental organizations. Thus, the scope of this review is quite limited.

The authors wish to thank the S.D. Bechtel, Jr. Foundation for its generous support. The staff of The Nature Conservancy and American Rivers provided abundant time and energy as we scoped this review. Jennifer Pierre, Armin Munevar, Chandra Chillmakuri, and Laura King-Moon provided voluminous data, answered our many questions and addressed our concerns. Spreck Rosecrans and Drs. Peter Moyle and Jay Lund provided comment on portions of the manuscript, although their comments do not constitute formal peer review. All errors of omission or commission are our own.

Jeff Mount, Panel Chair

Table of Contents

Executive Summary

Two non-governmental organizations, The Nature Conservancy (TNC) and American Rivers (AR), are evaluating their options for engagement with the Bay Delta Conservation Plan (BDCP). If approved, the Plan would become a Habitat Conservation Plan (HCP) under the federal Endangered Species Act and a Natural Communities Conservation Plan (NCCP) under California law. The purpose of the Plan is to allow for construction of new water diversion facilities in the Sacramento-San Joaquin Delta while also protecting aquatic and terrestrial species that may be adversely affected by the project and accompanying changes in the State Water Project (SWP) and Central Valley Project (CVP) operations. The Plan also includes habitat restoration and a commitment to assist in the conservation and recovery of species that are listed for protection under the federal and state Endangered Species Acts.

With financial support from the S.D. Bechtel, Jr. Foundation, Saracino and Mount, LLC, convened an independent panel of experts, with technical support from NewFields, Inc., to evaluate portions of the Plan. The panel, working jointly with TNC and AR, developed a series of technical and legal questions about the Plan. This report provides answers to these questions, along with limited recommendations on how to improve BDCP.

To simplify analysis, this review focuses on conditions for federally listed fishes during the Early Long Term (ELT), a decade after a permit would be issued (approximately year 2025). These are described in detail in the BDCP Effects Analysis and accompanying Environmental Impact Statement/Environmental Impact Report. We compared the performance of three different scenarios: a No Action Alternative (NAA) where no new North Delta diversion facility is constructed, a High Outflow Scenario (HOS) where the facilities are operated in a way that allows for occasional high spring and fall outflows, and a Low Outflow Scenario (LOS) with lower spring and fall outflows. The review also emphasizes in-Delta and Sacramento River watershed conditions during the ELT, with less attention to San Joaquin River conditions and fishes.

Although multiple data sources were used in this analysis, most hydrologic data came from CALSIM simulations conducted by BDCP consultants. The Panel strongly cautions about the conclusions drawn from these simulations. Flow simulations have three compounding uncertainties that can lead to significant error: (1) uncertainty in system understanding and future conditions, (2) model uncertainties (particularly the relationships between 1-, 2-, and 3-dimensional models), and (3) behavioral/regulatory uncertainty where the models cannot capture the scope of human behavior in operating the projects under various conditions. These uncertainties, which are not described in BDCP documents well, makes all of our conclusions contingent on the projects *actually being operated as simulated.*

Do Operations Shift Delta Exports from Dry to Wet Years?

The BDCP calls for increasing exports in wet years and reducing them in dry years, taking advantage of the increased operational flexibility provided by two points of diversion. This would reduce stress on Delta ecosystems during drier periods. Our analysis of simulation data suggests that while there is some increase in flexibility, export operations are highly constrained by upstream consumptive uses, regulations that cover reservoir operations, and flow and water quality standards. This greatly limits the anticipated benefit associated with operation of the dual facilities. Despite these limitations, as modeled, there is an increase in exports in wet years. In most dry years there are no substantial changes over NAA conditions. However, significant improvements in outflow and Old and Middle River (OMR) conditions occur in some dry years. We were unable to identify the regulatory or operational requirements that would lead to this.

Are Impacts of the North Delta Facility Fully Assessed and Mitigated?

The Plan identifies multiple near- and far-field effects of the new North Delta facility. Based on our review of the Effects Analysis, the Plan appears to have properly identified the most significant effects and uses standard models to assess them. Outmigrating juvenile winter-run and spring-run Chinook salmon will be most heavily affected, leading, in the absence of mitigation, to significant losses. The Plan identifies multiple mitigation strategies, including pulse flow management, predator control, entrainment reduction, non-physical barriers, real-time operations and development of alternative migration pathways (Yolo Bypass). With the exception of benefits from diverting juveniles onto the Yolo Bypass, all of these mitigation approaches have high uncertainties. Done well and successfully, however, they appear to offset the losses associated with operation of the North Delta facility. The HOS appears most protective of conditions upstream of the Delta and adjacent to the new facility. However, mitigation actions are unlikely to contribute significantly to recovery of these species. Additionally, successful mitigation is likely to occur only if there is a robust adaptive management and real-time operations program. The Plan provides neither.

Are In-Delta Conditions Significantly Improved for Smelt?

We evaluated the modeling results in the Plan and conducted our own modeling to evaluate how changes in conditions would affect delta and longfin smelt. As noted, we are concerned that anomalously positive (or less negative) OMR flows and high Delta outflows that are modeled during some drier years would not actually occur in real operations. However, if these changes were to occur we find modest to significant improvement in in-Delta conditions for smelt, particularly delta smelt. Improvements in OMR flows under HOS and LOS result in substantial decreases in entrainment, leading to significant increases in long-term survival percentages for delta smelt. However, increases in spring and fall outflow under HOS lead to small increases in longfin smelt abundance and modest improvements in delta smelt recruitment.

Will Pelagic Fishes Benefit from Floodplain and Tidal Marsh Restoration?

The Plan properly identifies food limitation as a significant stressor on smelt populations in the Delta. The Plan proposes to address this issue by restoring physical habitat to help subsidize pelagic food webs. Based on simple modeling and comparison with other systems, we find that restored floodplains and tidal marshes are unlikely to make a significant contribution to smelt rearing habitat conditions. Tidal marshes can be sinks or sources of food, with most appearing to be sinks for zooplankton. The Plan appears to be too optimistic about the benefits of tidal marsh and floodplain restoration. However, there is likely to be benefit where fishes have direct access to productivity, such as in Cache Slough. In addition, although benefits for listed pelagic fishes are low, there are broad benefits of restoration for many aquatic and terrestrial species covered by the Plan.

Does the Plan Provide an Effective Governance Structure?

We reviewed the proposed BDCP governance structure to evaluate its likely effectiveness in meeting the Plan's goals and objectives. Implementation of BDCP would be overseen by an Authorized Entity Group (AEG) comprising the California Department of Water Resources (DWR), the U.S. Bureau of Reclamation (USBR), and the state and federal water contractors if they are issued incidental take permits pursuant to the BDCP. A Permit Oversight Group (POG), consisting of the U.S. Fish and Wildlife Service (USFS), the National Marine Fisheries Service (NMFS), and the California Department of Fish and Wildlife (CDFW), would monitor implementation of the Plan and compliance with the biological objectives and conservation requirements. The draft BDCP includes a 50-year "no surprises" guarantee, as well as other regulatory assurances. We found that, when examined in detail, the draft BDCP blurs the lines between implementation and regulation and grants the permittees unusual decision authority. Additionally, the regulatory assurances in the Plan, especially the "no-surprises" policy, place undue financial responsibilities on the state and federal governments if certain modifications to the Plan become necessary during its 50-year term. Given the complexity of the Delta ecosystem, predicted changes in hydrology, anticipated changes in the Delta not included in the Plan, and significant scientific uncertainties, Plan modifications are likely to be needed in the future.

Is There a Robust Science and Adaptive Management Plan for BDCP?

The Plan is committed to adaptive management in order to address the high uncertainties. Most of the unresolved issues in the Plan are to be resolved at a future date through adaptive management. A "decision tree" approach is proposed to resolve conflicts over starting operations. We found that the governance structure, whereby the AEG may exercise veto authority over changes to the biological objectives and conservation measures, is likely to create disincentives for adaptive management. In addition, a proposed consensus-based Adaptive Management Team made up of POG, AEG, and scientific community members creates conflicting relationships between decision-makers and providers of key information. The limited information available about the science program suggests that BDCP proposes to develop a wholly new science program that is not integrated, but should be, with existing programs. Finally, our review of the "decision tree" process indicates that it is unlikely to achieve the goal of significantly reducing uncertainties before the North Delta facility is constructed and ready for operation.

Recommendations

Based on answers to these six questions, the Panel formulated a list of nine recommendations for improving BDCP.

- All parties need to recognize the model uncertainties in BDCP and factor that into decision-making. It is unlikely that actual operations will follow simulated operations.

- Given the high uncertainty over mitigation for the North Delta facility, all mitigation efforts should be in-place and tested *before* the facility is completed. This includes completion of the Fremont Weir modifications on the Yolo Bypass as well as large scale, significant experiments in real-time flow management, predator control and non-physical barriers.

- The improvements in long-term survival percentages for delta smelt in response to changes in OMR need to be more rigorously evaluated, particularly in light of uncertainties over operations. If further examination supports these findings, operational rules should be developed that insure that the anomalous, significantly improved drier-period OMR and outflow conditions occur.

- The limited benefit derived from changes in outflow under HOS requires a second look at options for significant increases in outflow, including finding sources of water outside the direct control of BDCP.

- Although we find that marsh and floodplain restoration is unlikely to create the benefits for pelagic fishes described in the Plan, this can only be resolved through experimental restoration projects. These projects need to be designed and implemented rapidly to resolve this issue.

- Substantial revision of BDCP's governance structure is needed. This includes giving full regulatory authority to the POG, while limiting their involvement in implementation.

- To address high uncertainties about project performance and future conditions, instead of a 50-year permit, there should be renewable "no surprises" guarantees issued every ten years based on conditions at the time and prior performance.

- An adaptive management program needs to be developed that has the capacity and authority to conduct adaptive management experiments and effectively use outcomes to revise and improve future actions..

- A well-funded BDCP science program needs to be developed that is integrated with existing Delta science programs. The best opportunity for integration lies with the current efforts to update the Delta Science Program.

Chapter 1: The Bay Delta Conservation Plan and Charge to the Panel

Introduction

The Bay Delta Conservation Plan (BDCP) is being developed to meet endangered species act permit requirements for operations of the Federal Central Valley Project (CVP) and the State Water Project (SWP) within the Sacramento-San Joaquin Delta. The Plan includes proposals for new points of diversion in the North Delta, new operations criteria, extensive floodplain and tidal marsh restoration, and new governance, oversight and adaptive management programs. The Plan applicants are seeking Habitat Conservation Plan (HCP)/Natural Communities Conservation Plan (NCCP) permits that will guide water exports and habitat management for 50 years.

The Bay Delta Conservation Plan is the most complex HCP/NCCP permit application ever attempted. Development of the Plan has been funded principally by state and federal water contractors and has been on-going for more than 5 years. In Spring 2013, select chapters of the Administrative Draft of BDCP were serially released for public review[1]. An Administrative Draft of the EIS/EIR for the Plan was released in May of 2013[2].

At the request of The Nature Conservancy California and American Rivers—two non-governmental organizations engaged in the BDCP process—an independent panel of five experts (Text Box 1.1) was assembled to assist in technical review of BDCP documents. The panel was asked to answer a suite of questions about the Plan to help inform decisionmaking by American Rivers and The Nature Conservancy. The panel was assembled and managed by Saracino & Mount, LLC, under contract from the S.D. Bechtel, Jr. Foundation Water Program. NewFields, Inc. provided support for the panel, including data retrieval, analysis and presentation. This report summarizes the conclusions of the work of this panel.

Guiding Questions

Two planning meetings were held between Saracino & Mount, LLC and staff of American Rivers and The Nature Conservancy. An initial list of more than 40 questions were developed that were germane to decisions that the organizations

[1] This report assumes that the reader is familiar with the Sacramento-San Joaquin Delta and on-going efforts to manage water supply and ecosystems to meet the co-equal goals prescribed in the 2009 Delta Reform Act. A summary of conditions in the Delta and other issues can be found at: http://baydeltaconservationplan.com/Home.aspx

[2] http://baydeltaconservationplan.com/Library/DocumentsLandingPage/EIREISDocuments.aspx

needed to make about future engagement with BDCP. These questions were distilled into the following six:

- *Q.1 Do operations of the dual facilities meet the broader goal of taking advantage of wet and above average years for exports while reducing pressure on below average, dry and critically dry years? What substantive changes in operations (and responses, see below) are there both seasonally and interannually?*
- *Q.2 Based on operations criteria, does the Plan properly identify ecological impacts likely to occur adjacent to and in the bypass reach downstream of the new North Delta diversion facilities? If there will be direct and indirect harm to listed species by the facilities, does the Plan prescribe sufficient mitigation measures?*
- *Q.3 Are changes in operations and points of diversion prescribed in the Plan sufficient to significantly improve in-Delta conditions for covered species? The focus is on listed species, including delta and longfin smelt, steelhead, winter and spring run Chinook, and green sturgeon.*
- *Q.4 Are covered pelagic fish like longfin smelt and delta smelt likely to benefit from restoration of floodplain and tidal marsh habitat at the scale proposed by the Plan? Given the current state of knowledge, and assuming that all Plan commitments are met, are these efforts likely to result in relaxed X2 and spring outflow standards?*
- *Q.5 Does the Plan provide achievable, clear and measureable goals and objectives, as well as governance that is transparent and resilient to political and special interest influence?*
- *Q.6 Is there a robust science and adaptive management plan for BDCP? As described, is the proposed "decision tree" likely to resolve major issues regarding Fall X2 and Spring Outflow prior to initial operations?*

Text Box 1.1: Members of the Review Panel.

Jeffrey Mount, Ph.D. (chair), geomorphologist, Professor Emeritus UC Davis, former Chair of the Delta Independent Science Board, and Partner, Saracino & Mount, LLC

William Fleenor, Ph.D. hydrologist and water quality specialist, Research Scientist, UC Davis Center for Watershed Sciences

Brian Gray, J.D. Professor, environmental law, UC Hastings.

Bruce Herbold, Ph.D. retired US Environmental Protection Agency, former Coordinator for the Interagency Ecological Program

Wim Kimmerer, Ph.D. food web ecologist, Researcher, San Francisco State University, Tiburon Center.

Using these questions as guide, the panel reviewed selected chapters within the Plan. The focus of the review was on the biological goals and objectives for species of fish listed as threatened or endangered (BDCP Chapters 1, 2), the conservation measures proposed to meet the biological objectives (BDCP Chapter 3 and appendixes, see Text Box 1.2), and the analysis of the effects of the project on Delta fish species and communities (BDCP Chapter 5 and appendixes). The panel also examined governance, adaptive management and science programs proposed in the

Plan, including the "decision tree" intended to resolve technical disagreements about initial operations (BDCP Chapters 3, 5, 6, 7, 8, 9, 10).

In addition to reviewing BDCP documents and literature, the panel held two meetings with the consultants who prepared the Plan for the project applicants. The consultants answered questions about analyses contained within the Plan and provided or directed panel members to pertinent sources of modeling data.

Text Box 1.2: Conservation Measures Considered by the Panel

There are 22 different conservation measures in BDCP. Since the questions asked were narrowly defined, the Panel focused only on five of the measures. These include:

Conservation Measure 1: Operations and Facilities. This covers the design, implementation and operation of a new North Delta point of diversion and the operation of all SWP and CVP facilities to improve conditions for listed species.

Conservation Measure 2: Yolo Bypass Fisheries Enhancement. The Plan proposes to increase winter flooding in the Yolo Bypass to improve rearing habitat for salmon as well as improve Delta food webs.

Conservation Measure 4: Tidal Natural Communities Restoration. This measure seeks to restore 55,000 acres of tidal freshwater and brackish marsh, with an additional 10,000 acres of transitional habitat. This will improve rearing habitat for several listed species and improve food webs for pelagic fishes.

Conservation Measure 5: Seasonally Inundated Floodplain Restoration. The Plan seeks to restore 10,000 acres of seasonal floodplain outside of the Yolo Bypass. This supports juvenile salmonids and overall food web productivity of the Delta.

Conservation Measure 6: Channel Margin Enhancement. The goal of the Plan is to improve conditions for rearing salmonids along channels of the Delta with close levees. This measure will improve 20 linear miles of channel by creating mudflat, riparian and wetland habitat through levee setbacks.

Basis of Comparison

The Bay Delta Conservation Plan seeks a permit for operation of the SWP and CVP at a future date when new facilities will be constructed. As written, the preferred alternative is to construct a new point of diversion in the North Delta on the Sacramento River near Freeport, with the goal of completion in 2025. This diversion is to have three screened intakes that will divert water into forebays and a pair of tunnels capable of transmitting a maximum of 9000 cfs by gravity feed. These tunnels will link to existing SWP and CVP export facilities located in the South Delta. Permit authority for the construction and combined operations of these facilities—typically referred to as dual facilities—are the foundation of the plan. Construction and operations are paired with extensive conservation measures (see below) to mitigate for impacts of the project and to conserve and recover listed species and their biological communities.

One of the many controversies surrounding the Plan is the establishment of an environmental baseline for comparison of alternatives and analysis of the effects of the project on listed species. The requirements of the Biological Opinions (BiOps) issued by the U.S. Fish and Wildlife Service (USFWS) in 2008 and the National Marine Fisheries Service (NMFS) in 2009 constitute the baseline for the Plan. There is considerable debate between the fish agencies (NMFS and USFWS principally) and the permitees over the provisions of these BiOps, particularly in regard to requirements for high Delta outflows to support longfin smelt in the spring and high outflows to achieve Fall X2 (low salinity zone) provisions to support delta smelt. For this reason, there are two Existing Biological Conditions (EBC) considered by the Plan (Table 1.1): EBC1 includes high spring outflow provisions and EBC2, includes both high spring outflow and the new Fall X2 provisions.

A central requirement of the Plan, and the source of much of its complexity, is to analyze conditions over the 50-year life of the project. The Plan divides future conditions into two classes: Early Long Term (ELT), which captures the initial operating conditions of the project once a new diversion facility has been constructed (approximately 2025), and Late Long Term (LLT) which accounts for full completion of all conservation measures, including restoration of more than 55,000 acres of tidal marsh and floodplain (approximately 2060). Climate change, particularly changes in runoff and sea level, and changes in water demand are incorporated in these projections.

The controversy over spring and fall outflow needs for conservation and recovery of listed species propagates into the assessments of future conditions. Without-project EBC1 and EBC2 are considered for both ELT and LLT. Evaluated starting operations (ESO) of the preferred project and alternatives are presented for ELT and LLT conditions. Two additional future scenarios are evaluated that purport to provide bookends to project operations that dictate future water exports. The first is a High Outflow Scenario (HOS), which is similar to the outflow standards in EBC2 (high spring and fall outflow). The second is a Low Outflow Scenario (LOS), which has reduced outflow standards for both spring and fall. Both the LOS and HOS are considered in the ELT and LLT, with the latter including completion of habitat restoration. The Plan proposes a "decision tree process" be undertaken during construction of the facility that will reduce uncertainties and guide initial project operations, presumably within the bounds of the HOS and LOS (reviewed in Chapter 9).

For the purposes of this review, we simplified our comparison of operations and restoration scenarios to just three. Using simulation data provided by BDCP consultants we examined the HOS and LOS scenarios for ELT. We then used a no-project alternative, NAA ELT, that commonly appears throughout BDCP documentation, particularly in the EIR/EIS. NAA prescribes a high fall outflow to maintain X2 standards for smelt and D-1641 salinity and flow standards required by the State Water Resources Control Board for the remainder of the year.

Table 1.1. Definitions of existing baseline conditions and project conditions simulated in BDCP.

Conditions		Description
Existing Biological Conditions	EBC1	Current operations based on BiOps, excluding management of outflows to the Fall X2 provisions of USFWS 2008 BiOp.
	EBC2	Current operations based on BiOps, including management of outflows to meet USFWS Fall X2 provisions from 2008 BiOp.
Projected Future Conditions without the BDCP	EBC2_ELT	EBC2 projected into year 15 (2025) accounting for climate change expected at that time.
	EBC2_LLT	EBC2 projected into year 50 (2060) accounting for climate change expected at that time.
Projected Future Conditions with the BDCP	ESO_ELT	Evaluated starting operations in year 15 assuming new intake facility operational and restoration not fully implemented
	ESO_LLT	Evaluated starting operations in year 50 assuming new intake facility operational and restoration fully implemented.
	HOS_ELT	High-outflow operations during spring and fall in year 15 assuming new intake facility operational and restoration not fully implemented.
	HOS_LLT	High-outflow operations during spring and fall in year 50 assuming new intake facility operational and restoration fully implemented.
	LOS_ELT	Low-outflow operations during spring and fall in year 15 assuming new intake facility operational and restoration not fully implemented.
	LOS_LLT	Low-outflow operations during spring and fall in year 50 assuming new intake facility operational and restoration fully implemented.

It should be noted that the Panel chose not to review LLT scenarios and conditions beyond the question of whether restoration of marsh is likely to benefit listed fishes.

Although it is necessary and useful to consider how the project might operate over the long-term, especially under climate change, the Panel felt that exceptionally high uncertainties made it difficult to offer precise answers within the LLT framework. These uncertainties are associated with our understanding of the Delta, with the models used to simulate future conditions, and with the array of events (biological invasions, floods, droughts, earthquakes, policy changes, lawsuits, etc.) that are likely to occur.

A Note About Hydrologic Modeling Tools and Uncertainties

The basis for the BDCP analysis is hydrologic simulation modeling that provides flow, water elevations, temperature and salinity at various locations throughout the Delta and its upstream areas. Much of the Effects Analysis for aquatic species and all of the export projections are based on outputs from these hydrologic models. BDCP is one of the most complex modeling efforts of its kind and certainly the most complex ever attempted in the Delta. This is a heroic modeling effort.

There are three general categories of uncertainty in the hydrologic model results:

Model uncertainties. This includes how the model simulates hydrology and the hydrologic results of operations, including salinity, temperatures and other water quality parameters. The currently available modeling tools are less than ideal to simulate such a long-term record with dramatic changes in conditions such as sea level rise and introduced sub-tidal and inter-tidal land. The principal issues are summarized in Text Box 1.3.

Future condition uncertainties. There is extensive effort in BDCP to estimate future conditions in the Delta, including sea level rise and changes in temperature and runoff. This is the most comprehensive approach to date. These are described well in Appendix 5A of the Plan and highlight high levels of uncertainty.

Regulatory and behavioral uncertainty. BDCP models assume that flow and water quality standards will remain static during the life of the project. In addition, the models assume uniform behavior of system operators, ignoring real-time operations and adaptations. All of these are highly unlikely to occur.

The hydrologic model results of BDCP are presented as if they are a unique solution. Given the compounding uncertainties, BDCP model results should be considered as scenarios rather than specific outcomes. This issue is often lost in the public debates over BDCP. As discussed later in this report, the model uncertainties significantly impact our confidence in some of our results, particularly our analysis of the response of pelagic fishes to changes in South Delta operations.

Text Box 1.3: Hydrologic Model Uncertainty.

To adapt existing tools to model future conditions under BDCP consultants developed dispersion coefficients with the 3-dimensional UnTRIM model developed by Michael MacWilliams for sea level rise. A similar process was then followed with a 2-dimensional model developed by Research Management Associates to estimate the additional dispersion for the proposed new open tidal areas. Parameters developed from the multi-dimensional efforts were then incorporated into the 1-dimensional DSM2 planning model developed by DWR to simulate a part of the long-term record incorporating sea level rise and tidally restored acreage. The boundary conditions for the DSM2 model, which operates at time steps as short as 15 minutes, was provided by CALSIM, the 1-dimensional system-wide water operations optimization model. CALSIM output occurs on monthly time steps and had to be disaggregated to provide boundary conditions for DSM2. All the results, including the DSM2 results and artificial neural network salinity results, were then used to train the CALSIM model. The CALSIM model was then used to simulate the entire 82-year record that formed the basis for the Effects Analysis. All of these model exchanges, particularly between 1-, 2-, and 3-dimentional models, create error or model bias. To date, there is no assessment of these model biases and how they impact BDCP results.

Organization of This Report

This report is organized into nine chapters followed by a summary of answers to the guiding questions. Chapters 2-9 include:

- *Chapter 2, Overview of the Law Governing BDCP.* Although not specifically requested by TNC and AR, we found it helpful to review key provisions of the HCP/NCCP laws that set standards for recovery of populations of covered fishes.
- *Chapter 3, Water Supply Operations.* This chapter examines how BDCP performs in meeting the goal of increasing water supply reliability. This includes assessment of changes in export volumes, both seasonally and within different year types.
- *Chapter 4, Environmental Flow Performance: Upstream and Inflows.* The new facilities and their operation are supposed to improve flow conditions impacted by the SWP and CVP. This chapter describes flows regulated by project dams, flows past and through the new North Delta facilities, and the overall inflow regime of the estuary.
- *Chapter 5, In-Delta Effects on Pelagic Fishes.* The changes in flow conditions outlined in the previous chapter translate to changes in ecological conditions for listed fish species. This chapter evaluates the likely response of delta smelt and longfin smelt to these changes

- *Chapter 6, Estimated Effects of BDCP Flows on Smelt.* This chapter examines the magnitude of changes in outflow and the likely response of delta and longfin smelt.
- *Chapter 7, Likely Response of Listed Fishes to Habitat Restoration.* A fundamental hypothesis of BDCP is that restoration of physical habitat, particularly tidal marsh, will improve food web conditions for pelagic fishes, aiding their recovery. This chapter evaluates this hypothesis.
- *Chapter 8, Governance and Terms of BDCP*. The 50-year permit for the project, coupled with governance and oversight, are examined in this chapter.
- *Chapter 9, Science and Adaptive Management*. The Plan makes extensive mention of the use of adaptive management supported by robust science to address major uncertainties. The Plan's objectives in this regard are reviewed.
- *Chapter 10*, Summary and Conclusions. This chapter provides a summary of answers to the six questions presented to the panel by American Rivers and The Nature Conservancy. In addition, where appropriate, recommendations are offered for ways to improve the performance of BDCP.

Conclusion

This report is, by design, narrowly focused on a limited set of issues of concern to The Nature Conservancy and American Rivers. It is not intended to serve as a broad review of BDCP, nor is it directed toward a wide audience. In addition, the panel specifically steered away from endorsing or rejecting BDCP, and makes no recommendation on the critical question of whether American Rivers and The Nature Conservancy should support BDCP, support it with modifications, or reject/oppose it. Rather, the observations, analyses and recommendations are solely intended to inform this decision.

Chapter 2: An Overview of the Law Governing the BDCP

Introduction

This chapter provides a brief overview of the law that governs the creation and implementation of the Bay Delta Conservation Plan. It also addresses an important question that has arisen during the BDCP negotiations: May the California Department of Fish and Wildlife (CDFW) approve the BDCP as a natural community conservation plan if the BDCP does not provide for full recovery of the endangered and threatened species covered by the Plan?

Habitat Conservation Planning and Natural Community Conservation Planning Under Federal and California Law

The BDCP is a Habitat Conservation Plan (HCP) authorized by section 10(a) of the federal Endangered Species Act (ESA), 16 U.S.C. § 1539(a), and a Natural Community Conservation Plan (NCCP) authorized by the California Natural Community Conservation Planning Act (NCCPA), California Fish and Game Code §§ 2800-2835. Section 10(a) of the federal ESA allows the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) to issue permits that authorize the taking of endangered or threatened species "if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" and the proposed activity is governed by an approved HCP. *Id.* § 1539(a)(1)(B) & (2). Similarly, under the NCCPA the California Department of Fish and Wildlife (CDFW) may "authorize by permit the taking of any covered species . . . whose conservation and management is provided for in a natural community conservation plan approved by the department." California Fish & Game Code § 2835.[1]

If approved by the three fish and wildlife agencies, the BDCP will be a legally binding document that defines the terms and conditions under which the U.S. Bureau of Reclamation (USBR) and the California Department of Water Resources (DWR) may construct and operate the proposed new water diversion and transport facilities described in the draft Plan.[2] The BDCP also will serve as "a comprehensive

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[1] The NCCPA defines "covered species" to include species that are listed for protection under the California Endangered Species Act, California Fish & Game Code §§ 2050-2115.5, and nonlisted species that are "conserved and managed under [another] approved natural community conservation plan and that may be authorized for take." *Id.* § 2805(e).

[2] The complete statutory requirements governing the contents and approval of the BDCP as an HCP and NCCP are set forth respectively in section 10(a)(2)(A) & (B) of the federal Endangered Species Act, 16 U.S.C. § 1539(a)(2)(A) & (B), and sections 2810 and 2820 of the California Fish and Game Code.

conservation strategy for the Sacramento–San Joaquin River Delta (Delta) designed to restore and protect ecosystem health, water supply, and water quality within a stable regulatory framework" (BDCP 1-1)[3].

The BDCP will include "regulatory assurances" that protect the permittees from the financial cost of changes to the BDCP or other regulatory changes needed to protect the species or their habitat[4]. As authorized by federal and state law, these regulatory assurances provide that, if changed circumstances arise that are either unforeseen or not provided for in the Plan, then the fish and wildlife agencies will not require the permittees to devote additional land, water, or financial resources beyond the levels set forth in the BDCP without the consent of the plan participants. Nor will the federal and state regulators impose additional restrictions on project operations without compensating the permittees for the lost water or additional costs.[5]

Both statutes also authorize the fish and wildlife agencies to suspend or revoke the incidental take permits for noncompliance with the terms and conditions of the BDCP or where implementation of the Plan will place the covered species in jeopardy of extinction.[6]

We consider the regulatory assurances, revocation authority, and other aspects of BDCP governance in Chapter 8.

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[3] In addition, the BDCP will be the basis for a biological assessment that USBR will submit to the USFWS and NMFS prior to consultation under section 7 of the Endangered Species Act. BDCP 1-6. The BDCP thus will help to inform the federal fish and wildlife agencies' analysis of the new facilities and changes in coordinated CVP/SWP operations proposed in the draft Plan. The agencies then will decide whether the BDCP "is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [the species' critical habitat]." 16 U.S.C. § 1536(a)(2). If the agencies determine that the BDCP *is* likely to jeopardize a listed species or adversely affect critical habitat, the biological opinion that they issue to the Bureau will include "reasonable and prudent alternatives" designed to avoid these consequences, as well as incidental take authorization governing CVP operations. *Id.* § 1536(b)(3) & (4).

[4] The regulatory assurances will apply to all entities that are issued incidental take permits under the BDCP, including DWR and the CVP and SWP contractors if the contractors become permittees. The "no surprises" assurance will not apply, however, to the Bureau of Reclamation. BDCP 6-29.

[5] The USFWS and NMFS adopted the federal "no surprises" policy by rulemaking in 1998. The substantive requirements of these rules may be found at 50 C.F.R. § 17.22(b)(5) & (6) and 50 C.F.R. § 222.307(g), respectively. The state "no surprises" guarantees are set forth in the NCCPA itself. California Fish & Game Code § 2820(f).

[6] The federal suspension and revocation rules are set forth in the Endangered Species Act, 16 U.S.C. § 1539(a)(2)(C), and in the ESA regulations, 50 C.F.R. § 17.22(b)(8). The state law counterparts may be found in California Fish & Game Code § 2820(b)(3).

Conservation and Recovery Requirements Under Federal and State Law

The federal Endangered Species Act and the California Natural Communities Conservation Planning Act differ in their respective conservation and recovery standards. The federal statute provides that the fish and wildlife agencies may not approve the BDCP unless they determine that the incidental take authorized by the permit and HCP "will not appreciably reduce the likelihood of the survival and recovery of the species in the wild." 16 U.S.C. § 1539(a)(2)(B)(iv).

In contrast, the NCCPA states that Department of Fish and Wildlife may approve the BDCP only if it finds *inter alia* that the Plan

> provides for the protection of habitat, natural communities, and species diversity on a landscape or ecosystem level through the creation and long-term management of habitat reserves or other measures that provide equivalent *conservation* of covered species appropriate for land, aquatic, and marine habitats within the plan area.

California Fish & Game Code § 2820(a)(3) (emphasis added). The Act defines "conservation" as "the use of methods and procedures within the plan area that are necessary *to bring any covered species to the point at which the measures provided pursuant to [the California Endangered Species Act] are not necessary.*" *Id.* § 2805(d) (emphasis added).

In other words, the federal Endangered Species Act requires only that habitat conservation plans ensure that the permitted activities do no significant harm to the listed species or to their critical habitats. The California Natural Communities Conservation Planning Act, by comparison, regards proposed projects such as the BDCP as opportunities for more coordinated and cohesive planning to improve the condition of covered species and their habitat, rather than simply being a means to authorize the permitted activities while maintaining the *status quo ante.*

The draft BDCP describes its biological goals and objectives in two different ways. At the "landscape level," the goals include restoration or creation of "ecological processes and conditions that sustain and reestablish natural communities and native species" (BDCP 3.3-5). At the "species level," however, the biological goals refer to *progress toward* the landscape level goal of reestablished and sustainable natural communities and native species.

Thus, the primary biological goals for the Delta Smelt and Longfin Smelt are "increased end of year fecundity and improved survival of adult and juvenile . . . smelt to support increase abundance and long-term population viability" (BDCP 3.3-13 & 3.3-16). Similarly, the principal biological goal for Sacramento Winter-Run Chinook Salmon is "improved survival (to contribute to increased abundance) of immigrating and emigrating . . . salmon through the Plan Area," (BDCP 3.3-16), and for other species of salmon and steelhead the goal is "increased . . . abundance" (BDCP 3.3-17 to 3.3-19).

The draft BDCP explains that the process of developing these species level biological goals "did not assume that the BDCP would be solely responsible for recovery of these species, and so the designated biological goals and objectives did not necessarily match the recovery goals, but instead represented the BDCP's potential to *contribute to recovery* within the Plan Area (BDCP 3.A-14: emphasis added). This decision has become a focal point of debate over the essential purposes and mandates of the NCCPA.

In a July 10, 2013, letter to the Director of CDFW, three environmental organizations challenged the BDCP's proposed adoption of biological goals that do not provide for full recovery of the species, arguing that this "contribution to recovery" standard violates California law:

> Under the plain text of the NCCPA, conservation means recovery, and a Plan is required to contain measures that are sufficient to achieve recovery within the plan area.

The Natural Community Conservation Planning Act is the Foundation for a Successful Bay Delta Conservation Plan, Letter to Charlton H. Bonham, Director of the California Department of Fish and Wildlife, from the Defenders of Wildlife, Natural Resources Defense Council, and the Bay Institute, July 10, 2013, at 5 (citing Fish & Game Code § 2805(c)).

As described in detail in the chapters that follow, the limitations on project operations and other conservation measures set forth in the draft BDCP would not meet the conservation standard proposed by the July 10th letter—*viz.* full recovery of the listed species—though they are likely to contribute to species recovery. The letter thus raises a critical legal question that will have to be resolved by the Director of CDFW, in consultation with the Department's General Counsel and the Attorney General, before the Department decides whether to approve the BDCP.

The answer to this question is not free from doubt, as the Legislature defined the purposes of the NCCPA in terms that stand in some tension to one another. For example, section 2801(i) declares that the "purpose of natural community conservation planning is to *sustain and restore* those species and their habitat . . . that are necessary to maintain the continued viability of those biological communities impacted by human changes to the landscape." California Fish and Game Code § 2801(i) (emphasis added). In contrast, section 2801(g) states that "[n]atural community conservation planning is a mechanism that can provide an early planning framework for proposed development projects . . . in order to avoid, minimize, and compensate *for project impacts to wildlife.*" *Id.* § 2801(g) (emphasis added).

A careful and integrated reading of the text of the substantive provisions of the statute, however, should lead to the conclusion that the Act authorizes the CDFW to approve the BDCP if it concludes that the Plan would protect listed species from the adverse effects of the projects authorized by the Plan (including full mitigation of those effects) *and* would promote the recovery of listed species. Stated differently, we do not believe that the Legislature intended to prohibit the Department from approving the BDCP unless it concludes that the Plan—in isolation both from other existing sources of the species' decline and from other state and federal actions to protect listed species—will achieve full recovery of the species. We reach this conclusion for several reasons.

First, the interpretation of the statute proposed in the July 10th letter is based entirely on the section of the Act that defines the term "conservation." If the Legislature actually intended to require the CDFW to determine that an NCCP would be likely to achieve full recovery of listed species, it would have included this requirement in Section 2820, which governs the Department's approval of proposed NCCPs.

Section 2820(a) lists ten separate findings that are prerequisite to CDFW approval, and section 2820(b) contains nine terms that must be included in the implementation agreements that accompany the NCCPs. None of these mandatory findings and terms includes the requirement proposed in the July 10th letter. We do not believe that the Legislature somehow intended to add a twentieth requirement to these lists—that the NCCP and implementation plan must provide for full species recovery—by implication from the definitions section of the Act.

Second, there are two provisions in section 2820 that expressly link the required conservation measures to the effects of the project authorized by an NCCP. Section 2820(a) states that the CDFW may approve an NCCP only if it finds that the plan

> contains *specific conservation measures that meet the biological needs of covered species and that are based upon* the best available scientific information regarding the status of covered species and *the impacts of permitted activities on those species*. [*Id.* § 2820(a)(6) (emphasis added).]

Section 2820(b) stipulates that implementation agreements must include provisions

> to ensure that *implementation of* mitigation and *conservation measures on a plan basis is roughly proportional in time and extent to the impact on habitat or covered species authorized under the plan*. These provisions shall identify the *conservation measures* . . . that will be maintained or carried out in *rough proportion to the impact on habitat or covered species.* [*Id.* § 2820(b)(9) emphasis added).]

This pairing of conservation and recovery with references to the "impacts of permitted activities," together with the "rough proportionality" limitation on conservation measures, suggests that the Legislature intended to authorize NCCPs as a means of contributing to other state and federal efforts to recover species, but not significantly in excess of the burdens that the project covered by the plan would impose on the species.[7]

Third, there is nothing in the text or legislative history of the NCCPA to indicate that the Legislature intended to force the state to bear programmatic and financial responsibility for full species recovery each time the CDFW approves an NCCP.[8] Conservation measures required to achieve full recovery may extend far beyond the scope of an individual NCCP. Indeed, a requirement of full recovery would be particularly problematic for plans such as the BDCP that involve multiple species (some of which only partly inhabit the program area), multiple sources of stress, and diverse land and water management and regulatory agencies that each have independent obligations to contribute to species conservation and recovery. We do not believe that the Legislature would have assigned such a Herculean obligation to the Department, or imposed such a potentially large financial burden on state taxpayers, without saying so explicitly in the text of the statute.

Finally, an interpretation of the statute that would require the CDFW to make a determination that all proposed NCCPs provide for full recovery of listed species would likely have the unintended and pernicious consequence of deterring the Department from approving future plans. The CDFW might conclude that the scope of the necessary species recovery effort extends beyond the scope of the proposed project and hence beyond the capabilities of the project restrictions and conservation measures that would be included in the individual NCCP. Or it might be reluctant to approve an NCCP in situations where the costs of full recovery of the listed species covered by the plan—which the state would have to bear—significantly exceed the project mitigation costs that may be placed on the project proponents.

Again, these factors are especially pronounced in contexts such as the Delta ecosystem where there are multiple species (some of whose habitat is only partly

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[7] The July 10th letter acknowledges that the NCCPA contains this "rough proportionality" limitation, but argues that "the concept of 'rough proportionality' is applied only to mitigation measures and not to a plan's conservation measures." Letter to Director Bonham at 7. The text of the Act belies this interpretation, however, as four of the five statutory references expressly apply the "rough proportionality" limitation to the conservation requirements. *See* California Fish & Game Code §§ 2805(g)(3)(C), 2820(b)(3)(B), § 2820(b)(9) & § 2820(c).

[8] The July 10th letter recognizes that the entities that receive incidental take permits under the BDCP may not be required to bear all of the costs of recovery of the various listed species: "[W]hen dividing up the costs of the plan's conservation strategy, the individual developers are only responsible for paying for 'mitigation' and the 'conservation' increment above mitigation is the responsibility of the state." Letter to Director Bonham at 7. Thus, if the costs of recovery exceed the mitigation costs that lawfully may be assigned to the permitted entities, the state must make up the difference: "The BDCP cannot limit its conservation measures to address only those impacts from the covered activities and avoid providing conservation measures sufficient to recover covered species." *Id.* at 8.

within the project area), multiple stressors (many of which are not plan participants), overlapping and sometimes conflicting habitat requirements, and tremendous uncertainty both about the needs of the species and the likelihood of success of recovery strategies. The interpretation of the NCCPA set forth in the July 10th letter therefore poses a significant policy risk of deterring otherwise salutary applications of natural resources conservation planning.

Conclusion

We conclude that the draft BDCP's establishment of biological goals and conservation measures that are based on the Plan's "potential to contribute to recovery" of the covered species complies with the Natural Communities Conservation Planning Act. We also believe that the CDFW may approve the Plan if it determines that the BDCP will ensure the survival of the listed species, fully mitigate the adverse effects of the project on all covered species and their habitat, and further the more general state and federal efforts to recover the species and to restore the favorable conditions of their habitat.

Chapter 3: Water Supply Operations

Introduction

The construction of a new North Delta diversion facility, and the coordinated operation of the North and South Delta facilities constitute the first and most prominent conservation measure (CM#1) of the BDCP. While ostensibly a conservation measure, the new facilities are principally an effort to improve the reliability of exports from the Delta. Their operations, in conjunction with all other conservation measures, are intended to mitigate for impacts of the CVP and SWP, avoid jeopardy and/or to contribute to the recovery of covered species (Chapter 2).

A basic premise of BDCP is that the construction of the new North Delta diversion facility will simultaneously improve water supply reliability while reducing ecosystem impacts. This stems from the increased operational flexibility associated with two points of diversion located in different portions of the Delta. A presumed benefit of this flexibility is the capacity to take advantage of periods of high inflow for exports, allowing for reductions in exports during dry periods when impacts on the ecosystem may be largest. This is consistent with the co-equal goals expressed in the 2009 Delta Reform Act.

This chapter examines the water supply operations proposed under BDCP to evaluate 1) if there are significant changes in supply reliability associated with the project and 2) how these changes apportion exports in wet vs. dry periods. This description is foundational for the assessment of ecological and species-specific consequences of BDCP as described in subsequent chapters.

Proposed Facilities and Operations

There are lengthy descriptions of the design and operation of new and existing water export facilities in the Administrative Drafts of the EIR/EIS and BDCP. The reader is referred to these documents for information. The centerpiece of the plan is the 9000 cfs capacity diversion in the North Delta that conveys water to the SWP and CVP export facilities in the South Delta through two tunnels.

Regulatory Constraints

The operational criteria for the export facilities are both complex and highly constrained (Appendix A). As outlined below, these constraints *significantly reduce the operational flexibility of the facilities*. The current regulatory constraints include but are not limited to:

- SWRCB water rights decision D-1641: this includes standards for minimum monthly Delta outflow, salinity objectives at multiple Delta locations, location of X2 (the position of the 2 ppt salinity near the channel bottom), a maximum export/import ratio objective[1], closures of the Delta Cross Channel (DCC), placement of a barrier at the head of Old River, and flow standards for the San Joaquin River below Vernalis. These standards vary depending upon months of the year and water year type.

- Remanded 2008 USFWS Biological Opinion (BiOp): prescribes restrictions for magnitude and timing of reverse flows in Old and Middle River (OMR) in the South Delta, to protect delta smelt. These vary depending upon time of year, water temperature, flows on the San Joaquin River, and proximity of smelt. This BiOp also calls for higher spring and fall outflows that exceed D-1641 standards. These outflow standards vary on water year type.
- Remanded 2009 NMFS BiOp: has different restrictions on OMR flows than the USFWS BiOp. Reductions in reverse OMR flows are scheduled to protect outmigrating salmonids. These vary depending on temperature and inflow. This BiOp increased San Joaquin River flows and set export/San Joaquin River flow ratios that are more restrictive than D-1641.

There are other regulatory constraints beyond D-1641 and the two remanded BiOps; however, compliance with these regulations appears to dominate water supply export modeling. Additional constraints are based on proposed operating rules for both the North and South Delta facilities. The most significant include:

- Maintenance of minimum flows downstream of the North Delta facility (called "Bypass Flows")
- Restrictions aimed to reduce reverse flows at the confluence between the Sacramento River and Georgiana Slough
- A tiered, three-level pumping regime for December through June that seeks to protect the initial winter flood pulse and spring pulses that affect juvenile salmon outmigration
- Flows with sufficient velocity to reduce impingement of salmonids at diversion screens
- Increased restrictions for reverse Old and Middle River (OMR) flows associated with South Delta exports.

Infrastructure and Inflow Constraints

Infrastructure design and capacity forms another array of constraints. For the purposes of BDCP simulation modeling, south of Delta storage was limited to space within San Luis Reservoir. Operations during wet and above average conditions are often constrained by available space to store water in this facility. Expanding potential storage, particularly groundwater storage, would have created considerably more flexibility in exports, particularly during wet years.

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[1] BDCP treats the export/import ratio in two ways: 1) counting as "import" all inflows from the San Joaquin and Sacramento Rivers and Delta's tributaries or 2) counting inflows as above, but counting flows below the North Delta facility as inflow. The latter approach seeks to exclude North Delta exports from D-1641 export/import restrictions. From an ecosystem perspective, this makes no sense since the North Delta exports are, in effect, exports from the legal Delta.

The size of the North Delta facility is also a constraint, principally during periods of sustained high flow on the Sacramento River in wet years. The preferred project has shifted from an initial facility size of 15,000 cfs to 9,000 cfs in the current plan. The export, economic and environmental performance of the 9,000 cfs facility is compared to 14 alternatives in Chapter 3 and 5 of the Draft EIS/EIR. These alternatives vary facility size, location and operations in the comparison. A narrative is presented in the EIS/EIR that describes the rationale for rejecting the 14 alternatives and selecting the preferred project[2].

Exports are also naturally constrained by the timing and volume of inflows, with strong seasonal and interannual variation. One of the larger export challenges faced by BDCP is its location at the bottom of the system where flows enter the Delta. Upstream water management and consumptive use dominate inflows to the Delta over most years (Figure 3.1). These abstractions, which consume roughly ¼ of water that would naturally flow to the Delta, are beyond the control of BDCP, yet are the greatest operational influence on Delta inflows. Under BDCP, exports would be roughly equivalent to upstream consumptive use.

In addition, there are important restrictions on reservoir operations that constrain exports. The USACE has congressionally authorized rule curves that dictate Fall, Winter and Spring operations to maintain flood reserves. More importantly, there are BiOps that dictate flow and temperature requirements to meet the life history needs of covered salmon, steelhead and sturgeon below the dams. Meeting these standards, particularly in drier years and under a warming climate, limits the amount and timing of inflows to the Delta. Oroville Reservoir, which has fewer restrictions on flows, becomes the most important for supporting Delta inflows as a result, particularly during drought conditions (see below).

Consequences of Constraints

The above discussion is intended to highlight a conundrum that is not discussed much outside of the BDCP community of experts and is not examined in the Plan: export operations and operations to support conservation are *highly* constrained. These regulatory, operational and infrastructure constraints limit the ability of BDCP to adaptively manage operations to support co-equal export *and* ecosystem objectives. For this reason, the anticipated management associated with the new diversion facility is not fully realized.

[2] It is beyond the scope of this review to examine facility size in detail. In general, the analyses offered in the EIR/EIS conclude that the 9000 cfs facility provides the optimal balance of cost and flexibility. The additional capacity of the 15,000 cfs facility is rarely used in the operations that they modeled, leading to a very modest increase (<250 taf) in overall exports. The EIS/EIR did examine smaller facilities with capacities of 6000 and 3000 cfs. However, the operating criteria used to evaluate these two alternatives are not comparable to those of the preferred alternative, making the comparison moot.

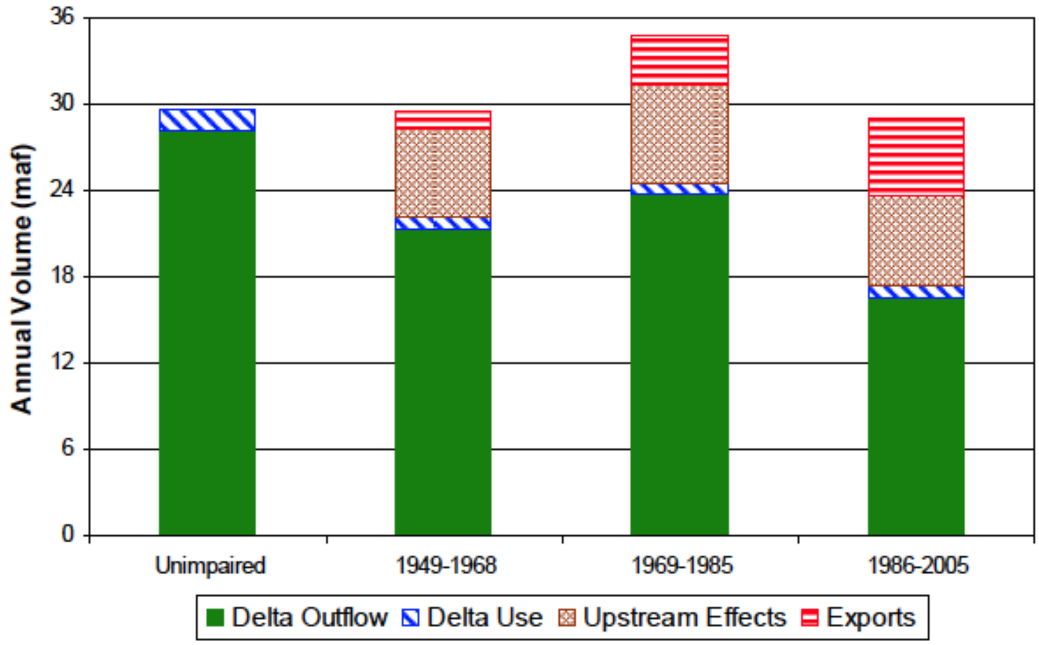

Figure 3.1 Proportional Delta water use. Exports constitute roughly 18% of the total unimpaired flow of the Delta in the 1986-2005 hydrology, with upstream consumptive use approximately 24%. From Fleenor et al. (2010).

This also highlights how flow management in BDCP was developed using system models. As described in Appendix 5C of the Plan, the models sought to meet the requirements of D-1641, the remanded BiOps, reservoir and diversion facility constraints, and south of Delta storage. The objective function was then to maximize Delta exports within those constraints. Although this seems logical, it highlights how CM1 is not a conservation measure, per se. Rather than doing a bottom-up assessment of ecosystem flow needs, as is typically done when setting environmental flows, the modeling sought to meet current regulatory requirements and flow constraints sought by fish agencies. This illustrates one of the key points made by Lund et al. (2010) and Moyle et al. (2012) that multi-objective management of the Delta is likely to require a comprehensive re-evaluation of flow and water quality standards.

Export Reliability

A goal of the BDCP project and the current Delta Plan is to improve reliability of water derived from the Delta for consumptive uses[3]. Using model simulations provided by BDCP consultants, we have evaluated how well BDCP meets the goal of improving export reliability. The most commonly discussed aspect of BDCP—

[3] In actuality, the most reliable system would provide a given amount of water each year with the smallest deviation from that amount. Instead, BDCP attempts to produce the most water in any given year under the given regulatory and operational constraints. This produces a more *resilient* water supply systems, whereby the greatest volume is made available, even under the event of catastrophic salinity intrusion into the Delta. The terms resilient and reliable are used interchangeably in BDCP and other documents.

average annual export—is summarized in Figure 3.2, and compares the no-project alternative, NAA with the high outflow scenario, HOS and low outflow scenario, LOS (defined in Chapter 1). This modeling suggests that the HOS and NAA would provide roughly equal average exports, with the LOS providing approximately 700 taf more. However, these figures are an average over an 82-year simulation period and offer little information about reliability.

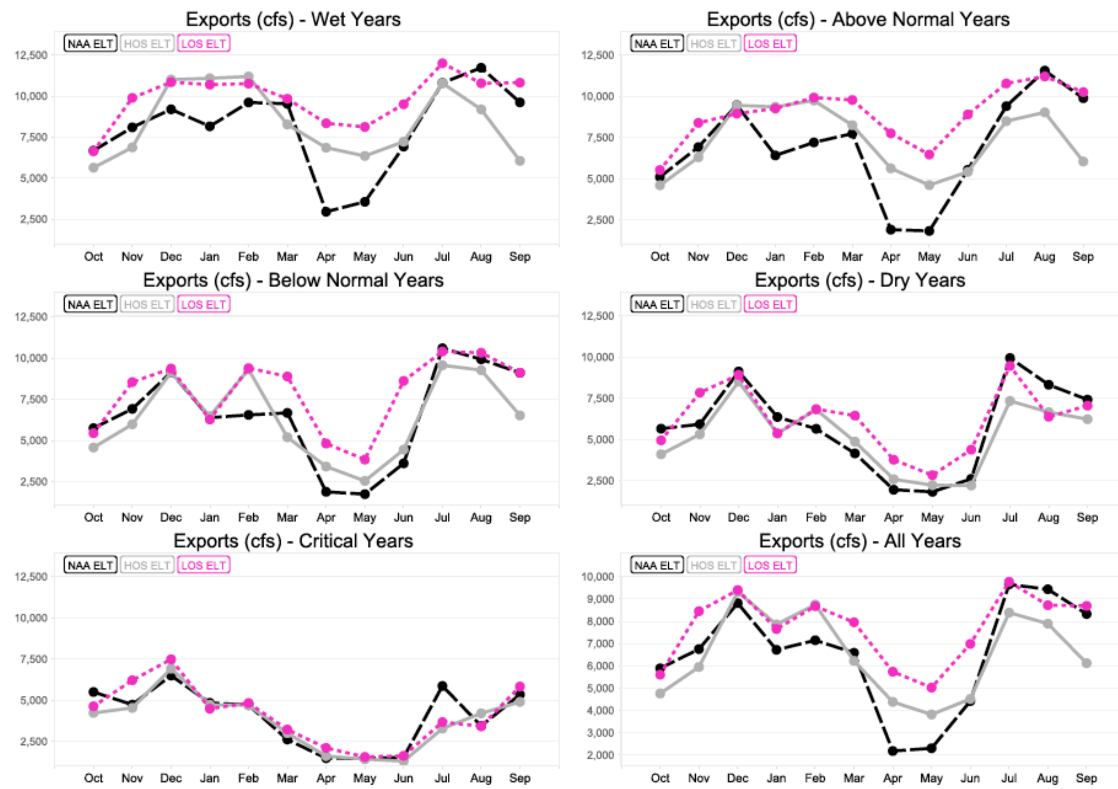

Figure 3.2: Monthly averaged exports for NAA, LOS and HOS under ELT conditions. Based on BDCP CALSIM data.

Exceedance curves (Figure 3.3) give a better indication of reliability. This approach provides the probability that a given export volume will be equaled or exceeded in any given year. For example, for the 50% exceedance probability (meaning one out of every two years), the NAA performs slightly better than the HOS, but much worse than the LOS. Overall, the LOS performs significantly better than NAA in six out of ten years and better than the HOS in eight out of ten. The HOS is outperformed by the NAA in five out of ten years (drier) and appears to only provide significant water supply benefits over the NAA in one out of ten years (wettest). The conclusion is that export reliability for the HOS and NAA are not substantially different, while reliability for the LOS is markedly higher.

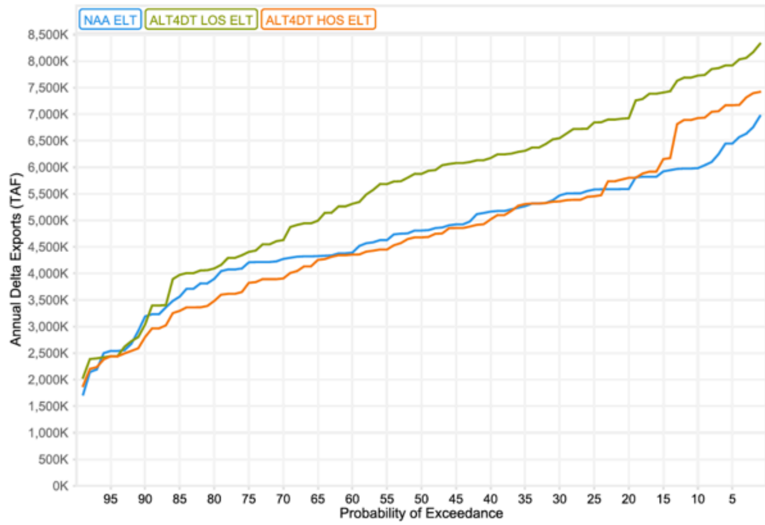

Figure 3.3: Exceedance probabilities for NAA, LOS and HOS exports under ELT conditions. Note that LOS produces higher exports for all probabilities, suggesting that it is the most reliable/resilient of the scenarios.

Water supply reliability curves for SWP and CVP customers are presented in Chapter 5 of the Draft EIS/EIR. These curves indicate that south-of-Delta municipal and farm users would realize considerable increases in overall reliability of supply under the LOS, compared to the NAA and HOS, particularly in above average and wet years. North-of-Delta users of CVP water would likely see a decrease in reliability over the long term, principally due to climate change.

Export Timing

A goal of BDCP and the Delta Plan is to shift exports to wetter years and to reduce pressure on drier years. A comparison of the average exports of NAA, LOS and HOS for all five year-types is presented in Figure 3.2. Based on the modeling data provided, there appears to be a significant increase in LOS exports in above average and wet years as compared to the NAA, with HOS intermediate between the two. This increase is accomplished through increased use of the North Delta facility during winter and spring periods when OMR restrictions most strongly impact South Delta operations.

Below average, dry and critical dry year performance of BDCP is mixed (Figure 3.2). For LOS, overall exports during the drier years are higher than the NAA, while HOS exports are roughly the same as NAA. Exports, on average, for both the LOS and HOS tend to be higher than the NAA in the winter and early spring, and lower during the summer. This minimal change in exports during dry years stems, in comparison to wet years, from the constraints on North Delta facility operations. As is illustrated below, during dry periods the North Delta facility is used very little, creating pressure on South Delta facilities.

In sum, although there are many regulatory and infrastructure constraints, BDCP does make use of the dual points of diversion to create modest increases in wet year exports and, depending on which export scenario is evaluated, equal to or greater exports in drier years. *BDCP therefore does not achieve the broader goal of reducing pressure on the Delta during dry years by shifting exports to wet years*.

Drought Performance

In the draft Plan and EIR/EIS, export performance of BDCP is summarized by presenting averages, typically linked to water year-types based on the Sacramento 40-30-30 index. Averaging fails to fully reflect how the system might be operated, however, because the complex rules governing operation can create significant year-to-year variability in exports (although see concerns over model uncertainties described in Chapter 1). This issue is particularly acute during multi-year droughts, when carryover storage in reservoirs is greatly reduced and demand increases significantly. To better illustrate how this system might perform we examined time series of model outputs during drought periods.

There were two six-year droughts during the 20th Century that fall within the time period used for hydrologic simulations: water years 1929-34 and 1987-92. We focused on the 1987-92 period of record for evaluation because it has historical export data for comparison and facilities that are comparable to today. As shown in Figure 3.4, overall export timing and magnitude during the six-year drought were roughly the same for the NAA, LOS and HOS, with LOS performing marginally better for exports throughout the drought[4]. The significant exception to this pattern is in the one year in that sequence, 1989, where modest inflows to the Delta occurred in the winter. Once bypass flow criteria were met, the flexibility created by the North Delta facility was able to take advantage of these inflows during a period of high restrictions on South Delta pumping to protect smelt.

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[4] Figure 3.4 highlights one of the issues not discussed in BDCP documentation. The environmental baseline for the BDCP assessment was determined to be the remanded BiOps, with provisions of one of the BiOps (high fall X2 flows in above normal and wet years) yet to be enacted. By choosing this as a baseline, the plan does not provide a comparison with how the project was actually operated under historic conditions. This administrative decision to only compare proposed operations with the remanded BiOps masks the striking differences between historic export operations and those proposed under BDCP.

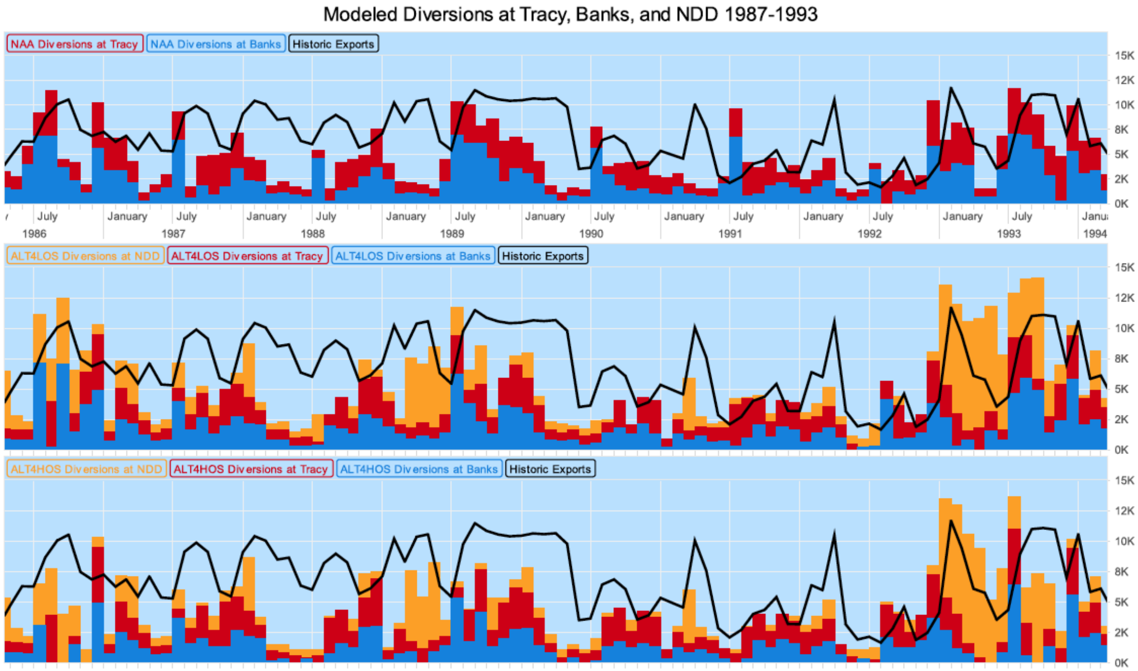

Figure 3.4: Exports for NAA, LOS and HOS under ELT conditions simulated for the 1987-92 drought, with historical exports are plotted for comparison. Important to note that ELT conditions take into account minor changes in climate and sea level rise by 2025 and cannot be compared specifically with historic conditions. In addition, historic conditions reflect human behavior; simulated conditions are guided by algorithms that do not account for human behavior.

Role of Reservoirs in Drought Management

Reservoir storage and operations play a critical role in drought management in California and greatly influence the timing and magnitude of Delta exports. The CALSIM modeling conducted for BDCP manages reservoirs within operational constraints described above and in detail in Chapter 3 of the Plan. The Plan makes it clear that the plan area does not include these reservoirs. Existing and future BiOps will govern their operations, not the terms of the HCP/NCCP permit. Despite this, the plan does envision significant changes to the operations of Oroville Reservoir under BDCP.

The 1987-92 simulated operations of the three most important reservoirs—Shasta, Oroville and Folsom—are shown in Figure 3.5. These simulations have important biological implications that are covered in later chapters. For water supply reliability, there are several important observations:

- As noted by the BDCP documentation, the NAA puts a great deal of pressure on upstream reservoirs to meet flow requirements, with Oroville providing most of the operational flexibility. In comparison to historic operations, the NAA significantly reduces storage, and thus carryover, in Shasta and

Oroville, but has limited impact on Folsom, with the exception of the last two years of drought.

- Under NAA all three reservoirs are at or near dead pool for the last two years of the drought cycle. Had water-year 1989 been closer in runoff to the other drought years, dead pool conditions would have occurred for the last three years of the six-year drought. Although a statement of the obvious, dead pool limits flexibility in managing water supply and ecosystem needs, both immediately downstream and in the Delta. This is likely to be of greatest concern for managing flow and temperature needs of winter- and spring-run Chinook salmon, particularly under warming climate conditions. Changes in flow releases to meet the needs of listed salmon are highly likely to impact export operations during dry periods. BDCP recognizes this as a concern but does not analyze the likely effects.
- A surprising result of the simulations is that HOS drought operating procedures are more protective of reservoir storage than either NAA or LOS. In an extended drought, storage is more aggressively allocated to either outflow (NAA) or exports (LOS), with both increasing the risk of creating dead pool conditions. This suggests that HOS operating criteria designed to protect smelt, may also do a better job of protecting upstream conditions for salmonids and sturgeon by increasing carryover storage. This, in turn may inadvertently improve water supply resiliency during drought.

It is important to note that a time series analysis of one extended drought within a single simulation record does not give guidance on how the system is likely to perform in all future droughts. Each drought is different, with different storage (reservoir and groundwater) conditions at the start, different precipitation and temperature patterns, and different regulatory or operational responses. To test the above observations more thoroughly, a range of six-year drought scenarios, should be simulated and analyzed. Given that most climate models prescribe an increase in frequency and duration of drought, this anecdotal assessment highlights an issue that is likely to occur during the life of the project and have significant impacts on supply as well as ecosystem management.

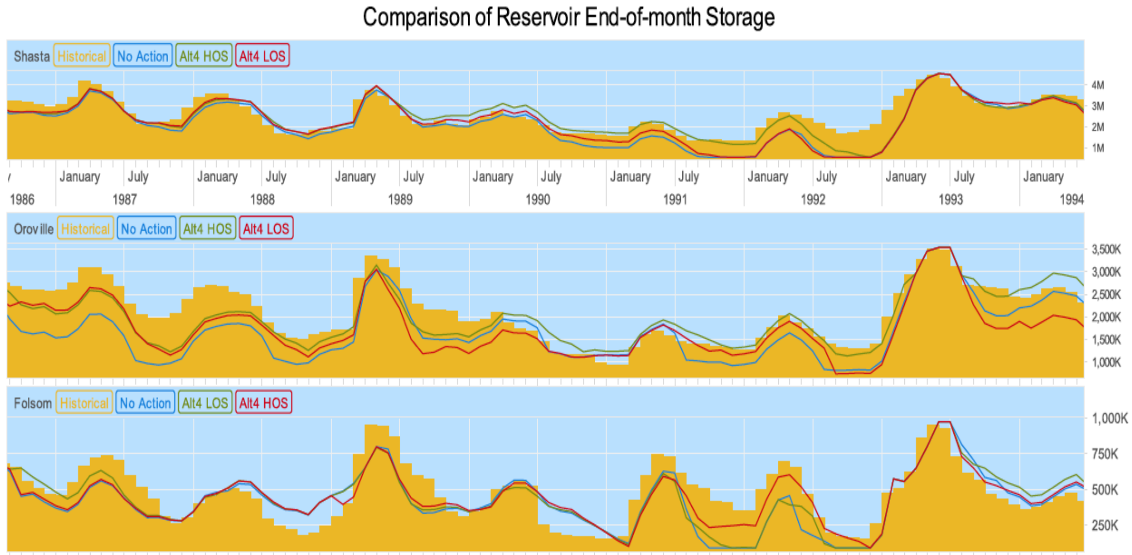

Figure 3.5: End of month storage for HOS, LOS and NAA under ELT conditions simulated for the 1987-92 drought. Historical storage (yellow histogram bars)is plotted for comparison. During the latter stages of the drought, dead pool conditions occur on all three reservoirs. Note that ELT conditions take into account minor changes in climate and sea level rise by 2025 and cannot be compared directly with historical conditions.

Conclusions

The project described in the Draft BDCP and the accompanying Draft EIR/EIR seeks to improve water supply reliability for water exported from the Delta while improving conditions for covered species. An underlying premise for the effort is that adding a second point of diversion, the North Delta facility, operated in conjunction with existing South Delta facilities will allow for more flexible export operations that better support environmental goals and objectives. In concept, this approach appears reasonable and should provide significant flexibility. In practice, however, regulatory and infrastructure constraints, coupled with high upstream consumptive uses of water, severely limits flexibility in operations. These highly constrained operations limit the effectiveness of BDCP in improving water supply reliability.

One of the objectives of BDCP that is in line with those of the Delta Plan is to increase exports during wet periods and decrease them during dry periods when impacts on the ecosystem are greatest. In comparison to the no project alternative, the new facility appears to achieve the former to a modest degree, but it does not significantly reduce pressure on the Delta during drier periods.

The proposed system is particularly vulnerable to extended drought periods (3-6 years). The NAA and LOS lead to dead pool conditions in upstream reservoirs after 3-4 years of drought. This decreases water supply reliability during dry periods and, as discussed in later chapters, places at risk species dependent upon reservoir releases, particularly cold water pool releases. This problem is likely to be particularly acute as climate changes. The surprising result from the model outputs is that the high outflow scenario, principally designed to improve conditions for smelt in the Delta, leads to improved carryover in upstream reservoirs that, in turn, improves year to year water supply reliability and allows for greater flexibility to manage reservoir-dependent species.

The hydrologic modeling effort for BDCP is unprecedented and heroic. However, the tools available for this modeling do not match the information demands. In addition, the plan documents do not do an adequate job of quantifying model uncertainties, particularly those caused by exchanges between 1-, 2- and 3-dimensional models, uncertainties over future conditions, and regulatory behavioral uncertainties . New tools will be needed going forward.

Chapter 4: Environmental Flow Performance: Upstream and Inflows

Introduction

The focus of the BDCP is principally on the legal Delta and adjacent Suisun Bay and Marsh, where export operations have the most direct impact on covered species. As discussed in Chapter 3, upstream management, including reservoir operations, consumptive uses of water, and flood management, play a critical role in inflow timing and volume. In this chapter, we examine how conservation measures #1 (water operations) and #2 (Yolo Bypass fisheries) meet conservation objectives that impact listed aquatic species.

The focus of this chapter is on the environmental performance of proposed flow changes in the Sacramento watershed, including the Sacramento, Feather and American Rivers, and inflows to the Delta through the Yolo Bypass and the Sacramento River. Although inflow from the San Joaquin River is important and a determinant of conditions in the South Delta, BDCP does not envision significant changes in flows. For this reason, our analysis is focused only on the Sacramento watershed.

Performance, as used here, is how well actions proposed by BDCP are likely to meet the goals and objectives of the plan. Although there are many issues discussed in the Plan for the Sacramento system and covered species, there are three central flow performance concerns: changes in reservoir release timing and magnitude and its impact on anadromous fishes; modifications to Fremont Weir and its benefits for floodplain habitat for outmigrating salmonids; and near- and far-field effects of North Delta diversion operations.

Impaired Flow in an Impaired System

One of the objectives of BDCP and the Delta Plan—and a concern of many NGOs--is to produce a flow regime with attributes that better support the life history stages of covered aquatic and riparian species. This objective is supported by a large body of national and international literature that has demonstrated how creating more natural flow regimes in highly regulated systems improves conditions for native species (see recent summary by Arthington, 2012). This issue has been at the forefront of controversial efforts by the SWRCB to develop a basin plan that addresses flows (Fleenor et al., 2010).

A flow regime that mimics natural seasonal variation is also considered by the scientific community in the Delta to be fundamental to better species management (Hanak et al., 2013). Restoring appropriate seasonal and intra-annual variability involves re-establishing flow timing, magnitude, duration, frequency and rates of change that drive key ecosystem attributes that, in turn, support native species (Figure 4.1).

Although restoring elements of the natural flow regime is a worthwhile goal, it should be made clear that in the Delta and its tributaries there is little that remains natural (Bay Institute, 1998; Whipple et al., 2012). Added to these physical changes are profound shifts in biological conditions, including a Delta ecosystem dominated by non-native plants and animals (Lund et al., 2008; Baxter et al., 2010). For this reason, restoring a more naturally variable flow regime in an altered Delta and its watershed, while necessary for improving conditions for covered species, is unlikely to lead, by itself, to their recovery (Mount et al., 2012).

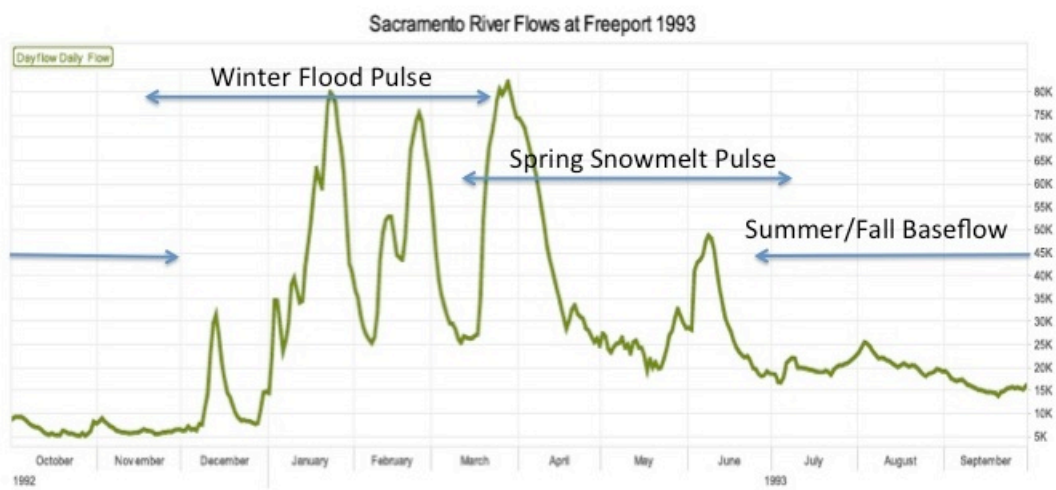

Figure 4.1: Unimpaired Sacramento River flow at Freeport for WY 1992-3 based on DAYFLOW data (DWR). This illustrates the range of natural seasonal variability in flow. Reproduction or migration of aquatic and riparian species are tied to timing, magnitude, frequency, duration and rate of change of flows. Flows, particularly winter and spring flood pulses, are necessary for geomorphic processes that support various life history stages. Flow regulation and land reclamation have significantly altered flow regime (see text for discussion).

In this chapter we sought to evaluate BDCP's potential impact on flow regimes upstream and into the Delta. It is infeasible—if not inappropriate--to reconstruct natural flow in the Central Valley given the significant changes in the landscape. Instead, we use *unimpaired flow* (DWR 2007) as a proxy for a more naturally distributed flow regime[1]. Unimpaired flow is the volume of water that would flow by a given point if no upstream impoundments or diversions were in place. Estimating

[1] We focus here principally on the rivers that feed into the Delta rather than the Delta per se. An assessment of changes in outflow that occurs in response to changes in operations is contained in Appendix B.

unimpaired flow is complicated and imprecise, yet is important in setting flow and water quality targets, particularly by the SWRCB. It involves aggregating unimpaired and unregulated runoff from multiple basins that flow to the Delta. Unimpaired flow ignores surface water-groundwater interactions and storage or conveyance of flow in channels, floodplains and wetlands. For this reason, it is not a useful proxy for flow regime on daily time steps, but can be used as an imperfect proxy for annual and monthly flows. We follow that convention in this analysis.

This simplified approach should not be over-interpreted. It is used to assess whether BDCP meets the overall goal of improving ecological conditions by creating a more natural seasonally variable flow regime. It does not address all issues of concern for listed fishes, such as winter- and spring-run Chinook salmon whose primary limitation is due to loss of upstream spawning and rearing habitat and high temperatures in existing channel habitat (Williams, 2006, 2009).

Main Rivers of the Sacramento Valley

Multiple biological goals and objectives of BDCP are associated with flow conditions on the Sacramento River and its two main tributaries, the Feather and American Rivers. All anadromous fishes covered by BDCP rely directly on these river systems for spawning, rearing and migration. As noted in Chapter 1, we focus here principally on winter- and spring-run Chinook since the BiOps that cover their life history needs have the greatest impact on water operations.

With the exception of proposed changes to the Fremont Weir and the Yolo Bypass (CM#2), BDCP does not envision making significant investments in improving physical habitat upstream of the Delta, or addressing other stressors such as hatcheries, contaminants or harvest procedures (see summary in Williams, 2006, 2009). For this reason, most of the impact of BDCP on the Sacramento River and its tributaries upstream of the North Delta facilities will be associated with changes in flow releases from the three major reservoirs: Shasta, Oroville and Folsom.

Simulated average flow conditions affected by changes in reservoir operations under BDCP are summarized in Figure 4.2A-C, including Sacramento River at Red Bluff, Feather River below Oroville Reservoir, and American River below Folsom. These flows, along with all other tributaries, aggregate to form the Freeport flow (Figure 4.2D) and the Yolo Bypass. These results include NAA, LOS and HOS flow scenarios and unimpaired flow under the five year-types based on the Sacramento River wetness index.

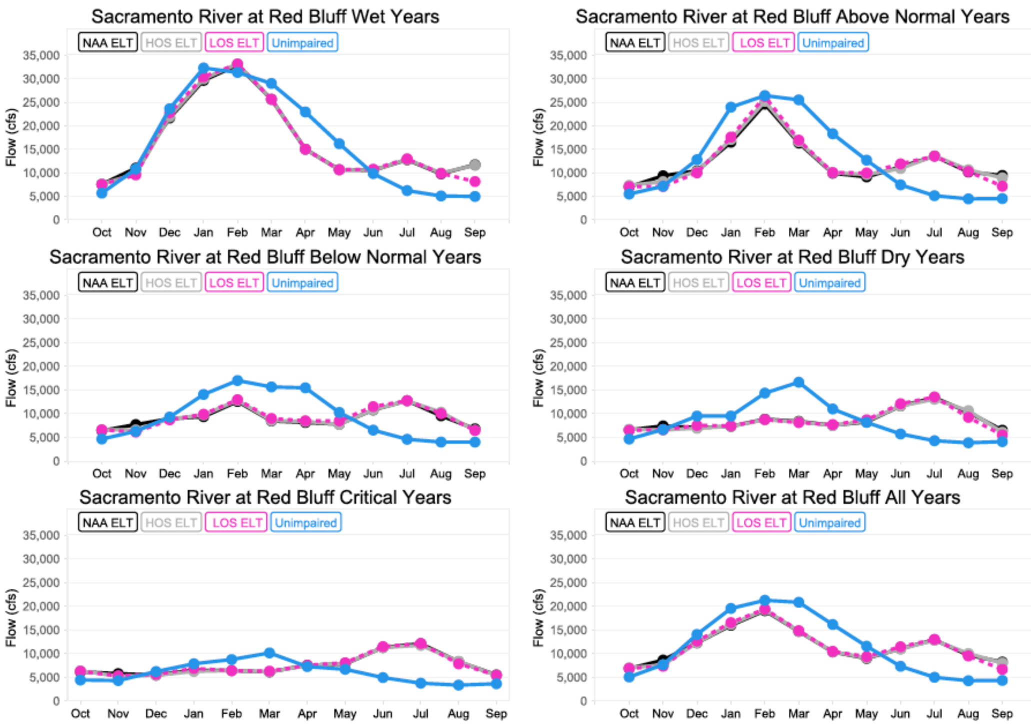

Figure 4.2A: Sacramento River at Red Bluff.

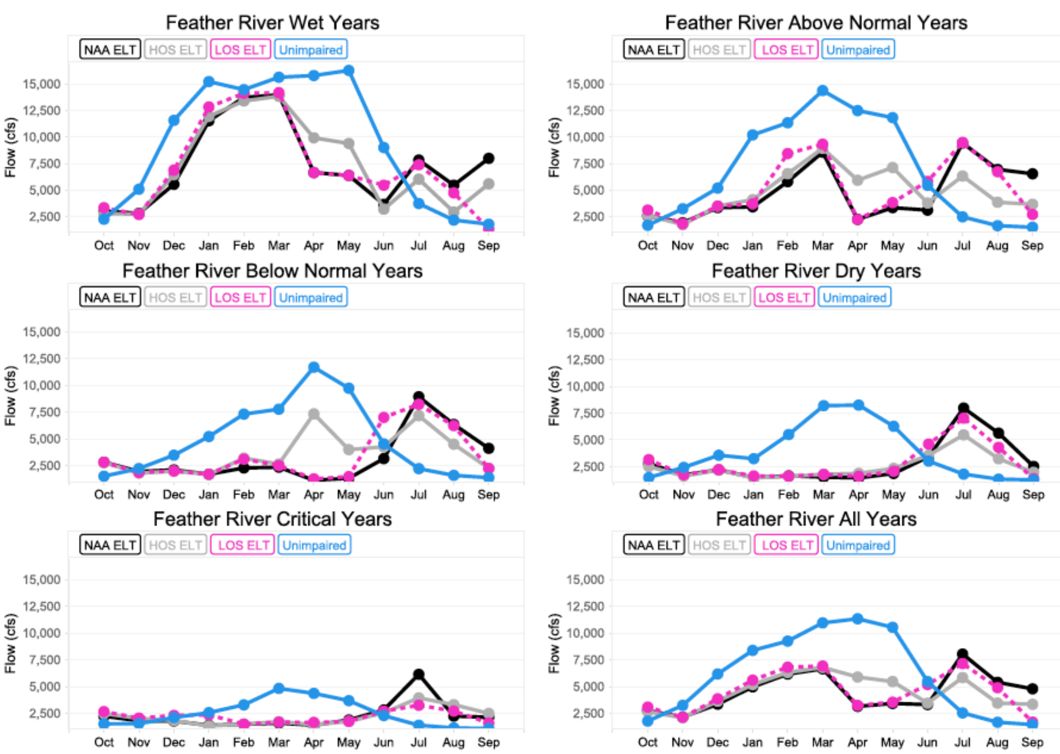

Figure 4.2B: Feather River.

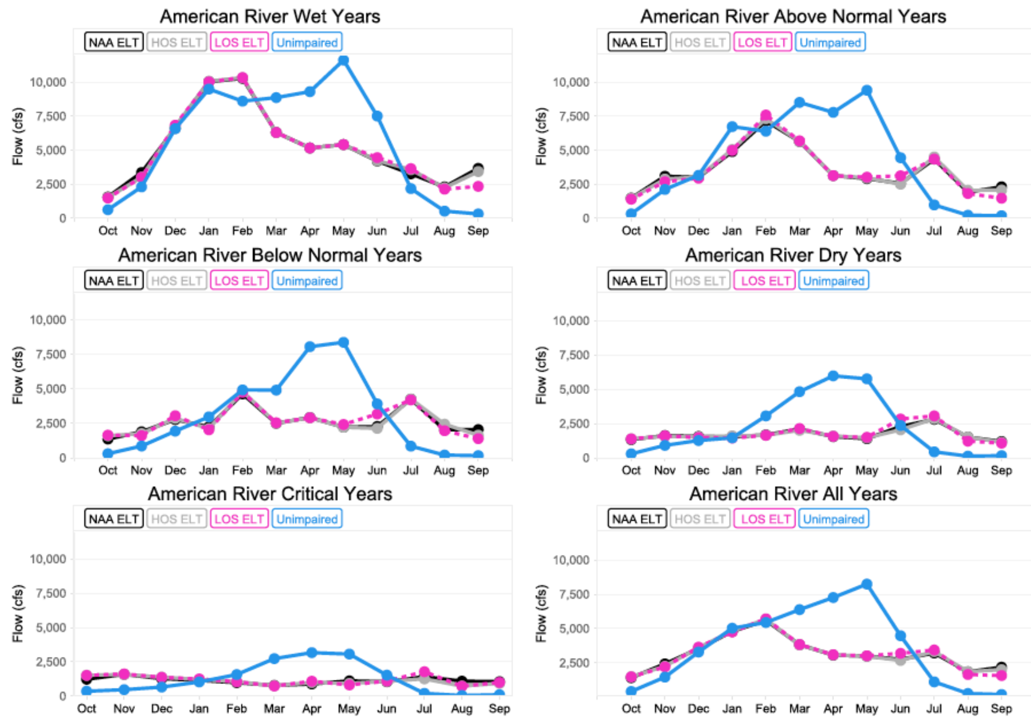

Figure 4.2C: American River.

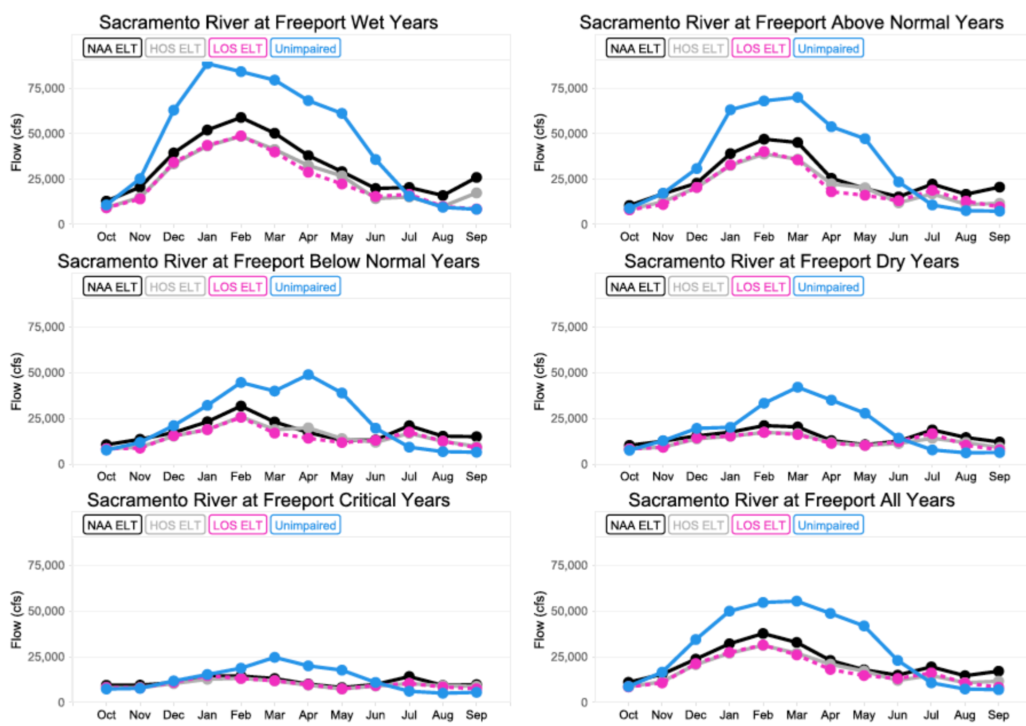

Figure 4.2D: Flow at Freeport. Figures 4.2A-D. Monthly averages sorted by water year types for HOS, LOS, NAA and unimpaired flow. Unimpaired flow is based on current conditions and HOS, LOS and NAA are ELT conditions. See text for discussion. Data from BDCP CALSIM simulations.

As noted in Chapter 3, the constraints on reservoir operations are significant due to temperature and downstream flow requirements, based mostly on the 2009 BiOp. For this reason, the differences between scenarios are not large. However, a comparison of the impaired and unimpaired flow data allows for several general conclusions about the impact of BDCP on key attributes of Sacramento Valley flow regimes:

Winter Flood Pulse. With the exception of the American River, the winter flood pulse is significantly reduced over unimpaired conditions in the Sacramento Valley. The magnitude of this reduction reflects the size and operations of upstream impoundments relative to the total runoff of the watershed. The most dramatic impairment of winter flood pulses occurs on the Feather River where the pulse is virtually eliminated in most years. There are no substantive differences between LOS, HOS and NAA operations for winter flood pulses. The winter flood pulse is marginally higher under NAA at Freeport, but this reflects more frequent flows down the Yolo Bypass.

Spring Snowmelt Pulse. The rise and gradual recession of flow in the spring is, next to low baseflow conditions in the late summer, the most predictable element of the Sacramento Valley flow regime and is of high biological significance. As shown in Figures 4.2A-D, the spring snowmelt pulse is highly impaired due to impoundments and flow diversions. With the exception of the Feather River, there are no substantive differences between HOS, LOS and NAA impacts on the spring snowmelt pulse in the Sacramento Valley. On the Feather, HOS flow operations designed to improve spring outflow in the Delta, lead to significant improvement in spring conditions in all but dry and critical year types.

Summer/Fall Baseflow. The timing and magnitude of reservoir releases dominates the summer/fall flow regime of the basin (Figure 4.2A-D). These releases are to meet the complex array of temperature and flow requirements downstream of the dams, irrigation demands upstream of the Delta, inflows to meet export demands, and outflows to meet water quality and habitat standards. Summer/fall baseflow flow regimes are highly altered with flows three to five times higher than unimpaired flows. With the exception of the Feather River, BDCP does not change summer/fall baseflow conditions. Under HOS and LOS simulations, the summer flows on the Feather are reduced, creating marginal improvement in flow regime.

Main Rivers Summary. The plan area for BDCP is, by design, limited in scope. The same applies to its conservation measures. The project Plan documents make it clear that operations of the CVP and SWP reservoirs are governed by BiOps or FERC licenses, and not BDCP. In addition, they note limited flexibility in reservoir operation due to cold water pool management, particularly on Shasta and Folsom Reservoirs. In this way, the reservoirs are in effect another constraint on BDCP (Chapter 3), rather than an asset for management.

Yet operations of these reservoirs greatly impact winter- and spring-run Chinook habitat downstream. As shown above, these operations contribute to the significant impairment of flows of the Sacramento River and its major tributaries and are a challenge when trying to meet the biological objectives of BDCP. Additionally, these dams block access to holding, spawning and rearing habitat that has far-reaching effects on winter- and spring-run Chinook salmon populations (Williams, 2006, 2009). These dams also support mitigation hatcheries whose operations may be contributing to harm of native salmon (Moyle et al., 2011).

It is unclear to us how to disentangle the relationship between the impacts of BDCP—a project designed to meet CVP and SWP water supply needs and an array of associated biological goals and objectives—and operations of SWP and CVP reservoirs. It seems logical to include these reservoirs in BDCP and operate them, along with the new facilities, under a single HCP/NCCP. The modest improvement in Feather River flows not withstanding, the result of this administrative separation is, in effect, to maintain the status quo for the highly impaired flows of the Sacramento system.

Yolo Bypass Flows

One of the more prominent conservation measures (CM#2) of BDCP is the modification of the Fremont Weir to promote increases in the frequency of winter and early spring inundation of the Yolo Bypass. A well-established and growing body of evidence, involving monitoring data, field experimentation and, to a lesser extent, life cycle models indicate high benefit of floodplain habitat to foraging juvenile salmon (see BDPC documentation for a full summary). This stems from the use of high value, off-channel habitat by juveniles, who, under optimal bioenergetic conditions and low predation pressures grow at high rates, increasing their survivorship through the Delta. Fish that either forage on the Yolo Bypass and/or use it as a migration corridor will not be impacted by near-field effects of the proposed North Delta diversion facilities. Fish using the Bypass are also less likely to enter the interior of the Delta where predation pressures are high. Finally, juveniles that use the Bypass leave the Delta later in the season, increasing the likelihood of arriving at the ocean during higher upwelling periods with better food availability.

Currently flow onto the Yolo Bypass from the Sacramento River only occurs when the Verona gauge exceeds 55,000 cfs. Modifications to the Fremont Weir would allow 1,000 cfs to flow onto the floodplain when flow at Verona exceeds 25,000 cfs. Flow through the Weir would climb to 6000 cfs when the river approaches 55,000 cfs. Above 55,000 cfs flow into the Bypass would be similar to NAA conditions. In addition to allowing flood flows, the weir would be modified to allow 100 cfs attraction flows to a fish ladder to improve upstream passage of adult salmon, steelhead and sturgeon (passage issues not evaluated here).

The average annual flow of the Yolo Bypass is approximately 1.5 maf. Under NAA, HOS and LOS, this amount would not differ significantly since the majority of flow volume on the Bypass occurs when the Sacramento overtops Fremont Weir and the

Sacramento Weir (Figure 4.3). However, the timing, frequency, and duration of floodplain inundation—key elements of the natural flow regime--would change substantially with the proposed modification of Fremont Weir.

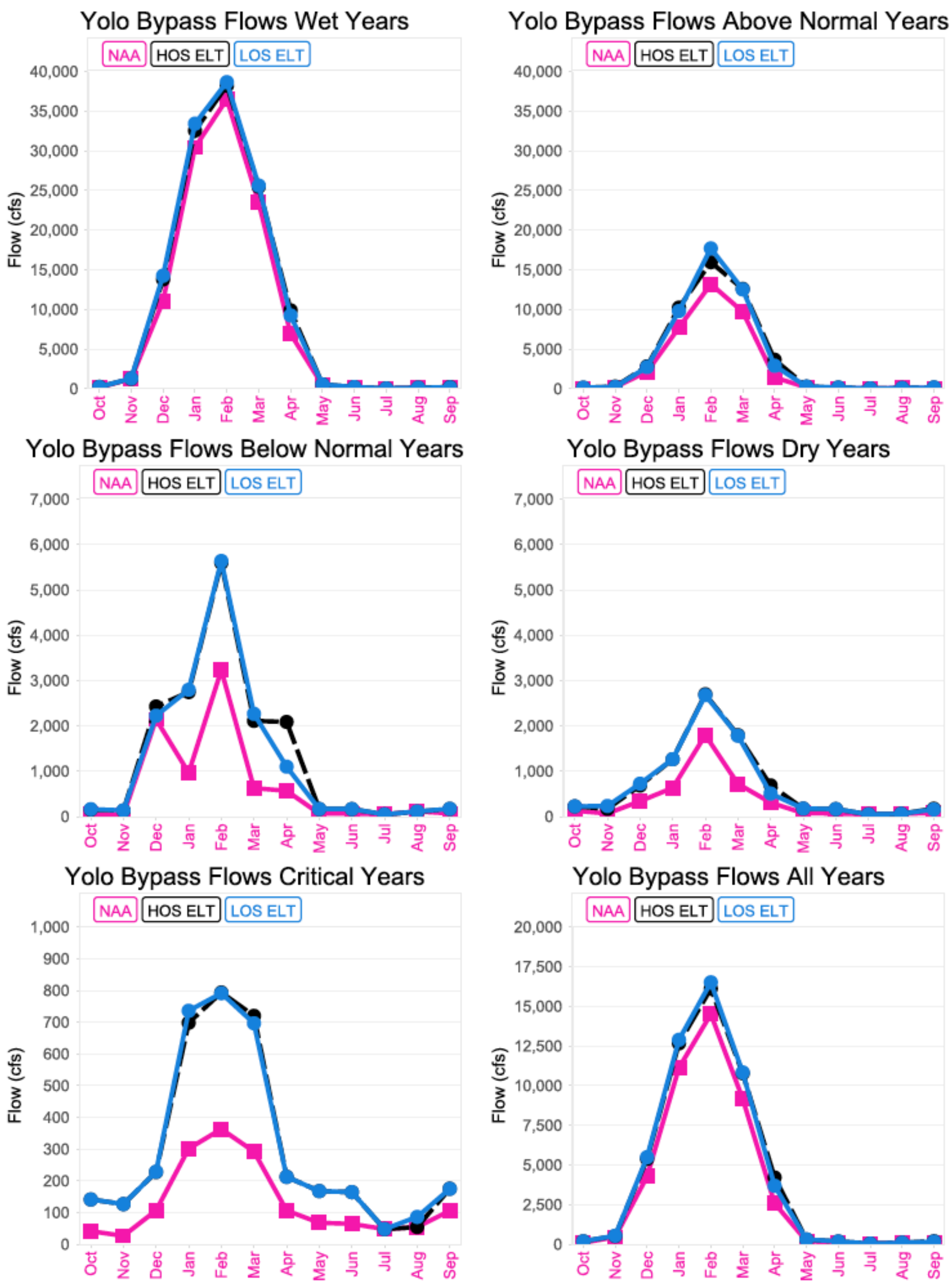

Figure 4.3: Average monthly flows for the Yolo Bypass under HOS, LOS and NAA under ELT conditions for different year types. Note changes in scale.

Flood Frequency. The frequency of inundation of the Bypass increases significantly under BDCP. Under current conditions there is a roughly 40% annual probability of flooding on the Yolo Bypass. Under BDCP this increases to more than 70% annual probability (BDCP statistics). The largest change occurs in drier years (Figure 4.3).

Flood Duration. Multiple studies have shown that flood duration, which allows for nutrient cycling and primary production, is essential for supporting juvenile salmonid foraging (Sommer et al., 2001; Williams, 2006, 2009). Modifications to Fremont Weir increase flood durations with high habitat benefits. Under current operations, flood durations aggregate to an average of 25 days per year. This would not change under NAA in the ELT. Under both HOS and LOS ELT this would increase more than three-fold to an average of 81 days per year.

Flood Timing. In addition to more frequent, longer-lasting flooding conditions, modifications to the Fremont Weir would expand the flood season, particularly in drier years (Figure 4.3). This expansion helps divert early migrants, such as winter-run Chinook salmon and later migrants, such as spring-run and fall-run Chinook, onto the floodplain. For example, based on BDCP data, we estimate that days of flooding above 1000 cfs on the Bypass will more than double in January and triple in April.

Yolo Bypass performance for listed salmon

Although CM#2 achieves the broader objective of improving the amount and quality of floodplain habitat, principally by restoring a more natural flow regime, it's effectiveness in supporting federally listed species of salmon (the focus of this review) is somewhat limited. The BDCP consultants modeled the overall benefits of the Yolo Bypass flows to out-migrating and foraging juveniles. For winter-run Chinook salmon, the benefits were modest with an estimate 1-8% increase in escapement. The limited benefit of the Yolo Bypass is, according to the BDCP model results, due to the small percentage of juveniles likely to be diverted onto the floodplain. This stems from the fact that most migration begins in December and January coincident with the first pulse flows of the season and does not coincide with peak inundation periods of the Bypass.

Greater benefit, albeit still limited, occurs for spring-run Chinook salmon. The bulk of juvenile out-migration takes place during the optimal months for floodplain inundation: February through March. However, two factors reduce the effectiveness of Yolo Bypass for spring-run according to BDCP documents. The majority of spring-run Chinook salmon come from hatcheries in the Feather River. Juveniles leaving the Feather are only diverted onto the Yolo Bypass during rare high flow events, leaving the Sacramento River as their principal migration route to the Delta. Naturally spawned fish in Butte Creek use the Sutter Bypass as their principal migration route. Like Feather River fish, they too only move access the Yolo Bypass during rare high flow events. Naturally spawned spring-run in Battle, Clear, Mill and Deer Creek pass Fremont Weir on their out-migration paths and will benefit most from likely access to the Bypass.

Second, according to BDCP models, most spring-run juveniles reach the Delta, and presumably the Yolo Bypass, as yearling smolts. In this stage, they are presumed by BDCP consultants to not take full advantage of the high quality foraging conditions of the Bypass, but use it principally as a migration corridor. BDCP consultants estimate that 90% of spring-run Chinook in the Yolo Bypass are migrants, rather than foraging fish. The BDCP consultants readily note that this proportion reflects the split between migrants and foraging characteristics in hatchery fish and may not be indicative of proportions of wild fish. Our consultation with several salmon biologists suggests that the distinction between foragers and migrants is arbitrary and likely does not reflect actual behavior of juveniles on the Bypass. In addition, there is emerging evidence that a high percentage of naturally spawned fish move out as fry and migrate during high winter flows (*pers. comm*., P.B. Moyle, 2013).

The BDCP consultants used several approaches to model the effect of the Yolo Bypass on survivorship. They acknowledge that current modeling tools are not well-suited to this kind of analysis. They developed a simple bioenergetic model for floodplain rearing, but told the panel that they felt it did not fully capture the benefits of the Bypass, and that their estimates of survivorship were conservatively low. Despite these limitations the BDCP models along with a growing body of literature suggest that spring-run juveniles as well as winter-run juveniles that access the Bypass are likely to have significantly higher survival rates to Chipps Island and presumably higher adult escapement[2].

Yolo Bypass Summary

CM#2 has high potential to benefit a range of covered species. Its benefit for winter- and spring-run Chinook is muted due to outmigration timing (winter-run) or the structural difficulty in diverting Feather River and Butte Creek fish (spring-run) onto the Bypass. Yet even with these concerns, there are likely to be improvements in survivorship associated with an alternative migration corridor with high value foraging habitat. There is an adaptive management program being developed for the Yolo Bypass that will be incorporated into BDCP. This effort would benefit BDCP objectives by conducting experiments and modeling that test ways to improve access of listed salmon onto the Bypass. This can include modifications to the Fremont Weir or pulse flow releases that improve winter-run diversion. Along with modification of Fremont Weir, this program may also want to consider the potential for using the Sacramento Weir to divert Feather River and Butte Creek fish. Regardless, as outlined below, a more aggressive approach to developing an alternative migration corridor for winter- and spring-run Chinook is likely to be necessary to mitigate the effects of the new North Delta facility.

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[2] The focus of this chapter is on spring- and winter-run Chinook. There is very significant benefit to other covered species, particularly fall-run Chinook and Sacramento splittail that can take advantage of Yolo Bypass flooding more readily.

North Delta Facility Impacts and Mitigation

The new point of diversion along the Sacramento River is likely to impact all covered fish that either use the main channel of the Sacramento for migration or rearing, or are indirectly affected by downstream changes in flow volume and timing. These impacts are some of the most difficult to assess due to uncertainties about design and operation of the facilities (no comparable facility exists to calibrate models) and the relationship between downstream actions, such as tidal marsh restoration, and flows. This section assesses BDCP's evaluation of near-field (adjacent to the facility) and far-field (downstream from the facility) effects.

Near Field Effects

The preferred project involves the construction of three screened intakes along the left bank of the Sacramento River in the vicinity of the town of Hood. Each screen will be capable of withdrawing up to 3000 cfs. In our view, the BDCP consultants have properly identified the two main sources of near field effects of the facility on out-migrating salmonids: losses due to impingement on the intake screens and losses due to predation near the diversion. However, we are uncertain about the effectiveness of proposed mitigation for these effects.

To mitigate for impingement potential, the consultants propose real-time management of pumping regimes relative to channel flow in order to maintain approach and sweeping velocities that reduce contact with intake screens. This real-time management would be informed by upstream monitoring of outmigrants. This issue remains a high uncertainty for operations of the facility ("low certainty" in the parlance of BDCP). Conceptually, a good adaptive management and research program coupled with real-time management could reduce impacts. However, as of this writing, the specifics of this program are not provided by BDCP (see discussion in Chapters 8, 9 this report) and we are unable to evaluate how effective it might be.

A greater near field effect of the facility is the high likelihood of concentration of predators near the facility, with resulting losses of migrants and foragers due to predation. Predators take advantage of concentrated prey and velocity refugia at physical structures throughout the Delta (Vogel, 2008) and will presumably do the same at the North Delta intake facilities. The BDCP consultants use various modeling approaches to estimate potential predation losses, including comparison with estimates of losses at known structures such as diversion screens of the Glenn-Colusa Irrigation District. Estimated predation losses for juvenile winter run Chinook that pass the facility vary from as low as 1% to as high as 12% (we did not find statistics for spring-run Chinook salmon losses). The higher predation loss values would have significant population-level impacts on winter-run Chinook and would fail to meet objectives of BDCP. The consultants acknowledge high levels of uncertainty about predation effects at the facility. The solution, as with most issues with high uncertainty in BDCP, is to defer this to adaptive management of the project, including unspecified predator control programs and real time management of flows. Based on our experience in the Delta, we consider this to be a significant, unresolved management issue.

Far Field Effects

The North Delta facility is expected to provide an average of roughly half of the exports from the Delta. As outlined in Chapter 3, operations of the facility are highly constrained by flow and water quality regulations, upstream water use, reservoir operations and hydrology. The simulated operations of the North Delta facility are summarized in Figure 4.4, including a measure of the proportion of channel flow that is diverted.

There are significant seasonal and interannual variations in operation of the North Delta facility that will drive far field effects[3]. During wet and above average water years, pumping regimes are most aggressive, particularly during the summer and early fall when 25% to as much as 39% of channel flow is diverted. Diversions, as a percentage of channel flow, decline dramatically in below normal, dry and critical years. In addition, pumping regimes are highly protective of channel flow in December, reflecting the restrictions on exports to protect initial pulse flows for winter-run Chinook. As expected, the HOS scenario, designed to improve Delta outflow, results in the most protective pumping regime for bypass flows at the North Delta facility.

BDCP documents acknowledge that the reductions in bypass flow create multiple far field effects that impact listed salmon. These include reduced attraction flows for migrating adult salmon, increased losses of juvenile salmon migrants and foragers due to longer transit times to the Delta, and diversion into the interior Delta where predation and/or entrainment losses are high. These operations also affect total Delta outflow[4].

The BDCP consultants use multiple modeling approaches to address the far field effects of the North Delta facility. The main model used is the Delta Passage Model (DPM) that tracks smolt survival through the Delta. This model and others summarized in Appendix 5C of the Effects Analysis all draw the same conclusion: there is an increase in losses of winter- and spring-run Chinook salmon migrants associated with reduced flows in the bypass reach from Hood to Rio Vista. The magnitude of this impact varies depending upon year type (wetter years have reduced losses) and magnitude of flow reduction associated with pumping (up to 35% decreases in flows during some migration periods). These results are not surprising since there is a long-established relationship between transit time and

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[3] We did not evaluate the effects of size of the facility and its level of use. However, it is worth noting in Figure 4.4 how often average monthly exports approach facility capacity. Using a monthly average greater than 8000 cfs as an indicator of periodic use of full capacity, this only occurs in February and March in wet years and March of above average years. This is roughly 5% of the total months, suggesting that operational and regulatory constraints, rather than facility size, determine export volumes.

[4] Appendix B presents a summary of Delta outflow and the magnitude of impairment of flows from the Sacramento Valley. The latter uses a simplified impairment index.

survivorship for smolts leaving the Sacramento River (Newman, 2003; Perry et al., 2010).

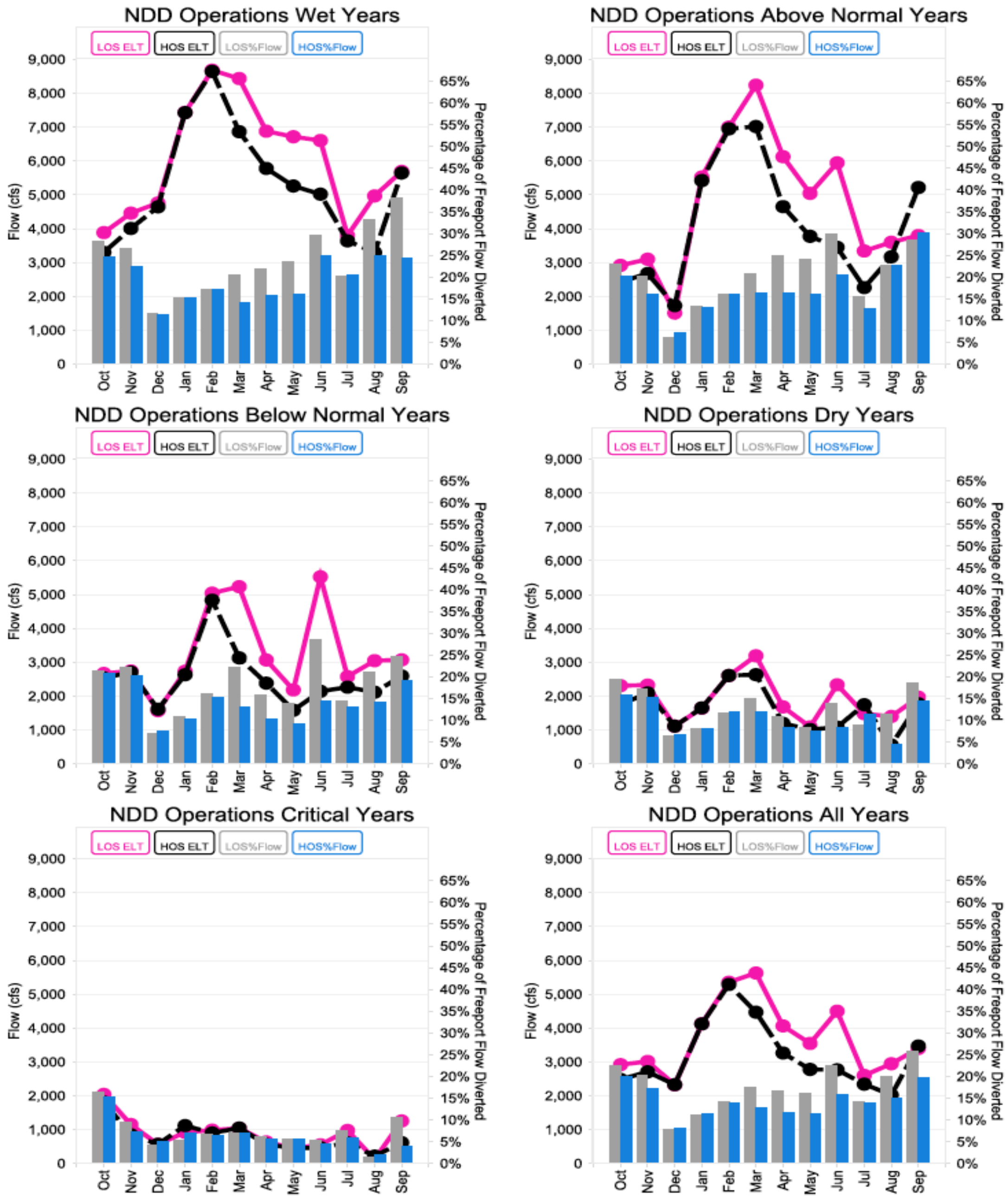

Figure 4.4. Average monthly export flows of North Delta diversion facility under HOS and LOS ELT for different year types, and percentage of total bypass channel flow exported.

BDCP proposes to mitigate the increase in losses of smolts associated with far-field effects through six strategies:

- Tiered pumping regimes to reduce withdrawals during the initial winter flood pulse (described in Chapter 3)

- Real-time operational changes that reduce export pumping when monitoring indicates that large numbers of migrants have entered the reach upstream of the facility
- Flow management that reduces tidal reversals at Georgiana Slough, decreasing the likelihood of smolts diverting into the interior of the Delta
- Non-physical barriers at Georgiana Slough
- Reductions in entrainment at the South Delta facility due to reduced export pumping
- Increased diversion of foragers and migrants onto the Yolo Bypass
- Improved channel margin, floodplain and tidal marsh habitat to support foraging juveniles

The benefits of the last of these strategies—habitat restoration—are not captured in the survivorship modeling that was completed by BDCP consultants (see chapter 7 for a discussion). In addition, the models do not incorporate real-time operations adjustments since the scope and terms of these operations have yet to be determined. The remaining strategies are incorporated into models used to assess smolt survivorship. Closely examined, BDCP model results indicate that these measures, in combination, roughly offset the losses created by reductions in flows and increases in predation in the bypass reach, meeting the standard of mitigation. There is no indication that these actions would result in substantial improvement in conditions for listed salmon. This includes the Yolo Bypass, which provides significant benefits for other covered species.

North Delta Facility Summary

We have not had sufficient time or resources to conduct a detailed review of the models used to assess survivorship in the bypass reach and the effectiveness of mitigation efforts. Overall, most of the models used for near and far field impacts are standard Delta models. Model results seem reasonable and fall within the boundaries of current understanding. This suggests that they provide an acceptable first-order approximation useful enough as a basis for further analysis and adaptive management experiments.

We view the efforts to model the effectiveness of predator management and non-physical barriers as having high uncertainty. In addition, as noted, there is insufficient detail on real-time management to assess its likelihood for success. The flow modeling that was done on the bypass reach makes assumptions about tidal marsh restoration in the Cache Slough area. This restoration plays an important role in tidal energy and efforts to manage flow reversals at Georgiana Slough. We are uncertain about both the impact of this tidal marsh restoration and, if modeled correctly, whether the assumed restoration would be completed in the ELT. This same issue applies to the Yolo Bypass. Scheduling contained in BDCP suggests that the Yolo Bypass project would not be complete until after the North Delta facility. This lag in completion hampers efforts to mitigate for the project. At minimum, given the large uncertainties, it seems prudent to have all mitigation efforts in place and tested prior to initiating operation of the diversion facilities.

Conclusion

To meet its biological goals and objectives, BDCP has developed 22 conservation measures. Two of these measures—CM#1, Water Operations, and CM#2, Yolo Bypass—are intended to create significant improvement in conditions for covered fishes by creating more natural flow conditions, improving fish passage and, in the case of the Yolo Bypass, improving floodplain spawning and rearing habitat. We focused our assessment on how CM#1 and CM#2 performed for winter and spring-run Chinook in this regard.

In general, we found that CM#1 does not significantly change the highly impaired flow regime upstream of the Yolo Bypass and Freeport, with the exception of an increase in spring flows on the Feather River under the HOS flow scenario (nor does it change outflows much as shown in Appendix B). BDCP proponents have made the strategic decision to focus principally on the Delta, rather than including CVP and SWP reservoirs that regulate flow into the Delta. This limits BDCP's effectiveness in its conservation measures since it does not address the major risk factors for listed salmon.

We found the increased frequency of flows into the Yolo Bypass to be an important step in restoring floodplain habitat. However, timing of outmigration and current design of CM#2 modifications limit the impact of this effort for listed salmon. The current adaptive management program underway for the Yolo Bypass needs to address this issue, including considering changing reservoir operations and alternative ways to divert fish into the Bypass.

Near field and far field effects of the North Delta facility have the potential to significantly reduce survivorship if not fully mitigated. Uncertainties over mitigation are high and will require a robust adaptive management plan. In our view, the Yolo Bypass program should be viewed as mitigation for the impacts of the North Delta facility on listed salmon. CM#2, along with all other mitigation efforts, need to be in place prior to operation of the facility.

Chapter 5: In-Delta Flow Performance

Introduction

BDCP Conservation Measure #1 (CM#1) aims to restore more natural net flows (i.e. net seaward) within the Delta by adding a point of diversion upstream of the Delta:

> Conservation Measure #1: "Construction and operation of the new north Delta intakes are designed to substantially reduce the incidence of reverse flow (Section 3.4.1.4.3, *Flow Criteria*) and restore a predominantly east-west flow pattern in the San Joaquin River. (Page 3.4-7, emphasis added).

This statement implies two classes of presumed effects that south Delta diversions induce through altered flows: direct effects whereby reversed flows in the south Delta contribute to entrainment of fish at the Delta export facilities, and indirect effects whereby changes in flow in the lower San Joaquin River are believed to alter the survival or migratory success of fish in the affected channels. Both of these presumed effects refer to net flows, which are determined by averaging out the substantial tidal flows that reverse direction twice daily. Although these net flows are small compared to tidal flows in much of the Delta, there is evidence that they can have substantial effects on some fish species.

In this chapter we evaluate changes in net flows in the Delta associated with changes in operations and the construction of the new facility. As in Chapters 3 and 4, we evaluate the differences between HOS and LOS scenarios and compare then to NAA, the no-action alternative. All of these analyses are in the Early Long-Term (ELT) shortly after the beginning of operations of the North Delta facility.

Concerns over modeling

As noted in Chapter 1 of this review, we have concerns over the use and over-interpretation of the modeling data provided to us. In conducting our analysis for this chapter and the following chapter on impacts of outflows on smelt, we have relied on output from CALSIM under various scenarios. Our analysis revealed several apparent anomalies in model output. Although we received clear explanations of the origin of these anomalies from the BDCP consultants, we remain concerned that the model output is unrealistic for projecting actual project operations and the resultant flows. In particular, certain modeled conditions arise through artifact that provide substantial improvements in conditions for delta smelt. Thus, conclusions drawn on the basis of these models rest on an unreliable foundation. These concerns are focused on Delta outflow during fall and southward flow in the southern Delta during winter. These flows have been linked to habitat and survival of delta smelt.

October

The USFWS Biological Opinion for delta smelt includes a fall X2 standard that applies following wet springs. Flows are usually low during this season so small variations in flow can have substantial effects on the location and area of the low salinity zone, and hence potentially on habitat conditions for smelt.

For various reasons X2 calculated by CALSIM differs substantially from that determined from outflow as in Jassby et al. (1995). We therefore focused on outflow as determined by CALSIM, rather than X2 as provided by BDCP modelers.

For this analysis we sorted flow data into a ranked series from lowest to highest values of Delta inflow under NAA. In Octobers of most years in the drier half of the series, outflow under HOS and LOS is up to twice that under NAA (Figure 5.1; median 77% higher for these 41 years). By contrast, during years of high inflow (right-hand half of Figure 5.1), HOS and NAA outflows roughly track each other, while LOS is much lower because the fall X2 requirement does not apply to that scenario. The anomaly occurring under dry conditions is not balanced by flows in other fall months. A few anomalies like those found in October crop up in November, but otherwise in those months either all three outflows track each other or LOS is lower.

To our knowledge there is no regulatory or operational requirement for reduced outflow under NAA or increased outflow under HOS or LOS in dry Octobers. Furthermore, there would be no reason to focus such a requirement in only one month if it were meant to benefit delta smelt, since they are present in the low-salinity zone from summer through fall. Outflow in fall can affect delta smelt recruitment so the modeled outflows can result in considerable differences in predicted recruitment under the three modeled scenarios (Chapter 6). We do not find these differences compelling because of a lack of a regulatory or other basis for the high outflows under HOS and LOS in dry Octobers.

January

January has been the month of greatest adult delta smelt entrainment historically, so the modeled conditions in January can have large impacts on forecasts of adult survival. The CALSIM modeling included a requirement that OMR flows during January be zero in wet years, no more negative than -3500 in above-normal and below-normal years, and no more negative than -5000 in dry and critical years. However, no estimates of current year type are possible in January, and rather than presume perfect foresight or use information available up to that point the modelers chose to operate the simulated system for January using the requirements that applied to the previous year type. Because dry Januaries can follow wet years, this resulted in an anomalous condition in which requirements for wet years applied during dry Januaries.

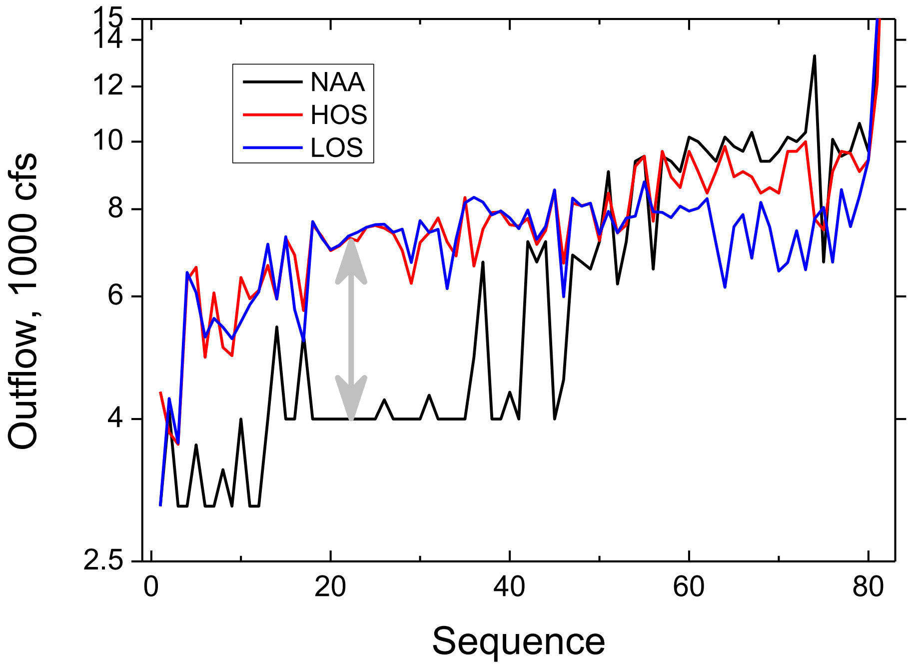

Figure 5.1. Net Delta outflow in October under the three scenarios sorted by inflow as determined by CALSIM under NAA; i.e., sequence 1 is the lowest inflow and 82 the highest. The gray arrow points out the region of interest where outflow under HOS and LOS is as much as double that under NAA. Outflow is plotted on a log scale to show proportional differences among scenarios especially at low flows, and because X2 can be modeled as a function of the log of outflow. The highest two outflows have been cut off to focus the figure on the lower values.

As a result of this anomaly, the modeled scenarios (LOS and HOS) called for reductions in export flows in Januaries following wet years, which substantially increased OMR during many Januaries at the dry end of the historical range for that month (Figure 5.2). This is unrealistic for several reasons. First, the actual values don't conform to the model requirements of 0, -3500 or -5000 cfs, depending on previous year type; instead they are quite variable and achieve zero rarely. Thus, there is no clear regulatory basis for these flows.

Second, the reduction in export flows was sometimes accomplished through increased outflow rather than reduced reservoir releases or increased exports from the North Delta (Figure 5.2). Thus, many January outflows during dry periods were much greater than the corresponding flows of the NAA alternative.

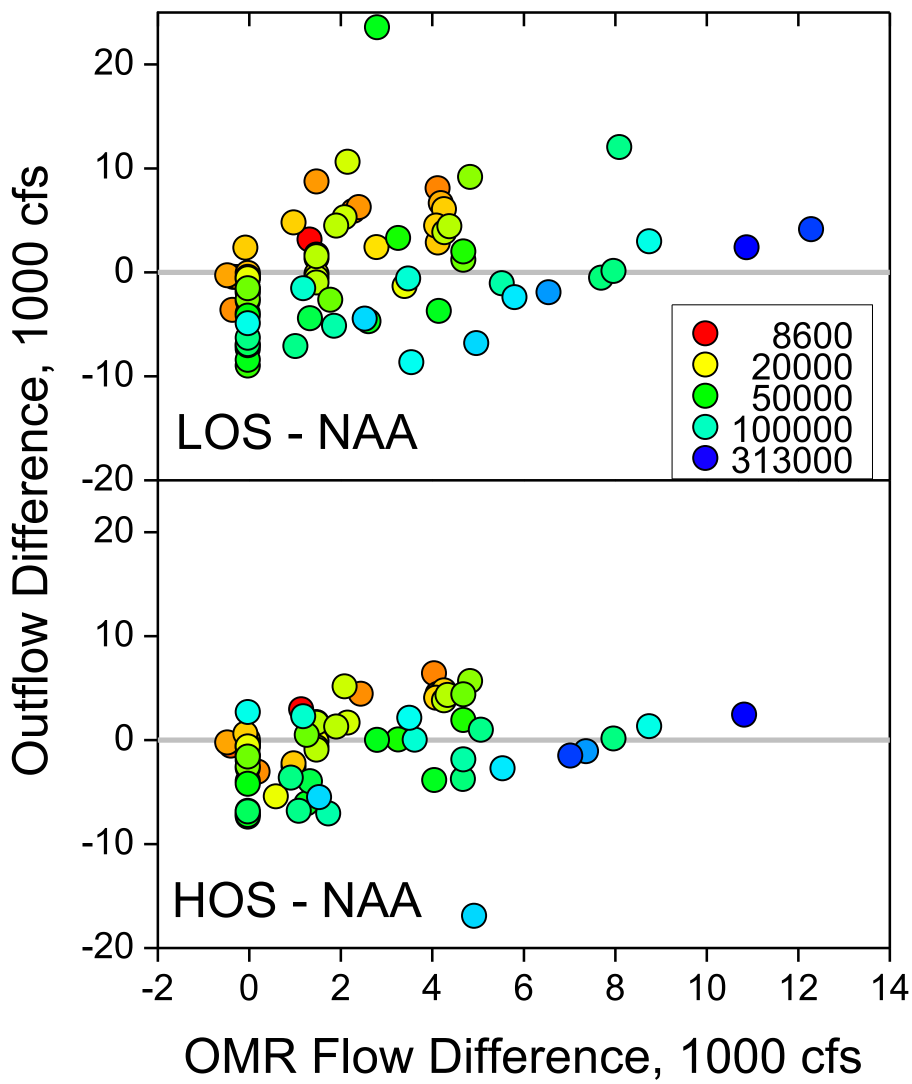

Figure 5.2. January flow conditions compared between the two modeled scenarios (LOS, top; HOS, bottom) as the differences from the flows under NAA. The colors show the range of NAA inflow. Under the LOS there were many Januaries when inflow was low but the outflow and OMR flow were increased by about the same amount over NAA.

Consequences

The anomalies discussed above seem to arise through the application of rules and constraints designed in some cases for real-time operations, using a model with a monthly time step. We understand and appreciate the difficulty in modeling such a complex system and the problems that would arise in attempting to mimic variation on a daily time scale. Furthermore, we trust that the modeling team has made every effort to produce output that conforms to the constraints and the modeled hydrology. Nevertheless, the specific model outputs we focus on above seem unrealistic, particularly since these anomalies are largely confined to October and January. We do not think the system is likely to be operated in real time to achieve the flows shown in model output.

Thus, discussions in this and the next chapter should be accompanied with this caveat: *these apply only if the system were actually to be operated to achieve the flows indicated by the models*. If rules are not in place to ensure these flows are achieved, the benefits to delta smelt (and presumably other species) will not be realized.

Analysis of flows

Construction of a new export facility will not by itself achieve the goals of restoring more natural flow patterns in the Delta; the effects of such a facility are entirely dependent upon its operational rules. We assessed how much the modeled operational scenarios (HOS and LOS) achieve the goals of restoring net natural flow directions within the Delta. In recent years, the Biological Opinions for delta smelt and salmonids have directed attention to net flows in OMR, which are the main channels carrying Sacramento water to the export facilities in the south Delta. OMR flows show relationships with salvage of some fish species at the fish facilities and are presumed to reflect entrainment risk to fish in the Delta, i.e. the direct effects of the projects. In earlier years, focus was on net flows in the lower San Joaquin River (QWEST) as a more general measure of the impacts of water management on net flows in the Delta, which were believed to cause indirect effects on fish populations.

OMR and QWEST flows are two measures for the effectiveness of CM#1 in restoring more seaward flows in the Delta (see Chapter 6 for an estimate of effects of the modeled flows on delta smelt entrainment). Here we examine both the changes in seaward flows and the degree of negative flows as predicted from CALSIM models.

A north Delta diversion will increase the frequency of positive net OMR and QWEST flows and reduce negative values to the extent that exports from the north Delta reduce exports from the south Delta. However, BDCP calls for continued use of south Delta diversion facilities and greatly restricts the operation of the north Delta diversion, particularly in dry periods and early winter. Thus, restoration of seaward flows in the Delta must be viewed in the context of the timing and conditions when the north Delta diversion can be used.

We describe how LOS and HOS alter the incidence and degree of reverse flows during the seasons of sensitivity for the covered fish. For each season of sensitivity, we group results by quartiles of outflow to assess how changes in flows occur under drier vs. wetter conditions. Low flows in the winter and spring are when concern over reverse flows is greatest for most species.

Direct effects

Direct effects are entrainment, or the number of fish diverted into the facilities. This number is not known for any species because substantial numbers of fish are lost in the waterways leading to the fish facilities and through the louvers at the fish facilities. Salvage is therefore a poor measure of entrainment effects, but there are no other direct measures. Estimates of entrainment as a proportion of total population of delta smelt are presented in Chapter 6. Such an analysis has not been developed for any other species of concern. Therefore, to broaden the analysis to all species we examined changes in modeled flow in OMR. This measure has been used in both Biological Opinions. OMR flow is both calculated by models and measured in the field; it is roughly equal to San Joaquin River inflow minus total exports. Because San Joaquin inflows are less than total exports under all but flood conditions, OMR flows are usually negative. We assume OMR is the primary focus of CM #1's goal to "reduce the incidence of reverse flow". To broaden the question we also assess the degree to which flows are made less negative by the alternatives.

Incidence of reverse flow

Because 'incidence' is a measure of frequency, the "Incidence of reverse flows" is the frequency with which OMR is changed from negative under NAA to zero or positive (northward) under the proposed alternatives; because model output is available by month, we examined frequency on a monthly basis (Table 1). The distribution across months of the change in net OMR direction implies that effects on each species will depend on its season of sensitivity.

The results below are consistent with the goal of CM#1 of achieving a greater frequency of positive net flows in Delta channels by shifting exports to the north Delta diversion site. This is true more for HOS than LOS operations.

LOS effects. The LOS reduced the incidence of negative flows by 5% overall (50 months out of the 984 months modeled; Table 1). Under NAA 110 months had positive (northward) OMR flows while 160 months had positive flows under LOS. Positive or zero OMR flows under LOS coincided with negative flows under NAA in all months save August, but most frequently in January – March. There were 21 months when OMR flows were positive under NAA but negative under LOS in April and May (Table 1).

The shift to positive OMR flows under LOS was sometimes quite large (about 6000 cfs) and occurred almost solely under higher river inflows during December through June. The occasions when NAA alone produced positive OMR flow occurred only in April and May and the change in OMR flows between NAA and LOS were small (<1000 cfs).

HOS effects. The HOS had a more substantial effect on the incidence of negative flows than LOS (Table 1). There were only 13 instances when positive OMR flows under NAA were negative under the HOS, and the differences were very small in those cases. As with LOS, the changed OMR status happened in all months save August. The most noticeable difference between HOS and the other two alternatives was in September and November when HOS was northward about a third of the time while NAA was always southward and LOS northward only a few times. The low frequency of northward flows under HOS in October may be related to the anomalies in outflow identified above, but the reasons for the otherwise high frequency of positive OMR flows in fall under HOS are obscure, as they are not called for by regulations and no fishes of concern are vulnerable to export entrainment at that time.

Table 1. Frequency by month of northward (including a few zero flows) or southward flows under NAA vs. LOS, and NAA vs. HOS. Columns in italics indicate those years and months when the direction of flow differed between NAA and the selected scenario. For example, in April there were 47 years when NAA flow was northward, in 5 of which LOS was southward, and 35 years when both flows were southward, out of a total of 82 years.

Month	NAA North		NAA South		All LOS North	NAA North		NAA South		All HOS North
	LOS North	*LOS South*	*LOS North*	LOS South		HOS North	*HOS South*	*HOS North*	HOS South	
Oct	0	*0*	*1*	81	**1**	0	*0*	*8*	74	**8**
Nov	0	*0*	*2*	80	**2**	0	*0*	*25*	57	**25**
Dec	3	*0*	*1*	78	**4**	3	*0*	*0*	79	**3**
Jan	4	*0*	*11*	67	**15**	4	*0*	*12*	66	**16**
Feb	8	*0*	*18*	56	**26**	8	*0*	*19*	55	**27**
Mar	6	*0*	*25*	51	**31**	6	*0*	*36*	40	**42**
Apr	42	*5*	*0*	35	**42**	44	*3*	*5*	30	**49**
May	25	*16*	*0*	41	**25**	31	*10*	*6*	35	**37**
Jun	1	*0*	*9*	72	**10**	1	*0*	*9*	72	**10**
Jul	0	*0*	*1*	81	**1**	0	*0*	*1*	81	**1**
Aug	0	*0*	*0*	82	**0**	0	*0*	*0*	82	**0**
Sep	0	*0*	*3*	79	**3**	0	*0*	*38*	44	**38**
All months	89	*21*	*71*	803	**160**	97	*13*	*159*	715	**256**

Magnitude of negative OMR flows

Entrainment rates are a function of population distribution and abundance, season of occurrence in the Delta, and flow conditions including export rates (or OMR conditions). The months of vulnerability for each species of concern were taken from the BDCP documents. For adult longfin and delta smelt the season of vulnerability is from December through March. For juvenile delta smelt the season is from March through June.

The effects of overall flow conditions, i.e. how relatively wet or dry it is, were assessed by grouping the months of vulnerability for all 82 modeled years into quartiles of outflow in the NAA; e.g., for adult delta smelt which are considered vulnerable during December-March, there were 82 months in each quartile of outflow. We examined conditions of OMR, river inflow and outflow under several operational scenarios. We examined differences under four levels of wetness for each month using outflow in the month as a measure of wetness. Historically fish are more often salvaged under drier conditions than under.

In Figure 5.3 we present comparisons of the HOS and LOS scenarios for each quartile of outflow (under the NAA scenario to ensure comparison of the same years in each graph).

Under the HOS and LOS alternatives, OMR differs from NAA during the seasons of sensitivity for adult delta smelt (Dec-Mar) and juvenile delta smelt (April-June).

Three patterns can be seen:

1. In the season of vulnerability for adult smelt (December – March), HOS and LOS both show about a 1000-5000 cfs increase toward positive in OMR under all quartiles of outflow, but all OMR values are strongly negative except in the wettest quartile of the data. Exports in December and January can be high and the use of a north Delta diversion can improve OMR (but see "Concerns over modeling" above). For juvenile smelt, the increase in OMR flow under LOS and HOS is smaller and less consistent. In all cases the level of OMR flow is much less negative than in December – March.
2. The HOS and LOS alternatives differ only slightly except during the drier periods when OMR flow is slightly less negative under HOS than under LOS.
3. Under wetter conditions all alternatives produce median OMR flows in the range targeted as protective in the Biological Opinions (more positive than -5000, but see Modeled Impacts on Delta Smelt in Chapter 6). The use of NDD under high-flow conditions allows the HOS and LOS to avoid the extreme negative OMR values that occur under NAA because of the high south Delta export rates that are possible then.

Thus, in summary, model results suggest that reverse flows in the south Delta become more positive under both LOS and HOS for all quartiles of outflow. These changes can be seen both in the frequency and in the distribution of flows in the two seasons of vulnerability and the four quartiles of NAA outflow. In wetter months the north Delta diversion does not fully replace south Delta exports until river inflows are relatively high, so that OMR remains negative in most months of smelt vulnerability. Changes in OMR during the period of vulnerability of young delta smelt are smaller than those during December – March because all alternatives are constrained by the Biological Opinions to a much higher baseline OMR flow.

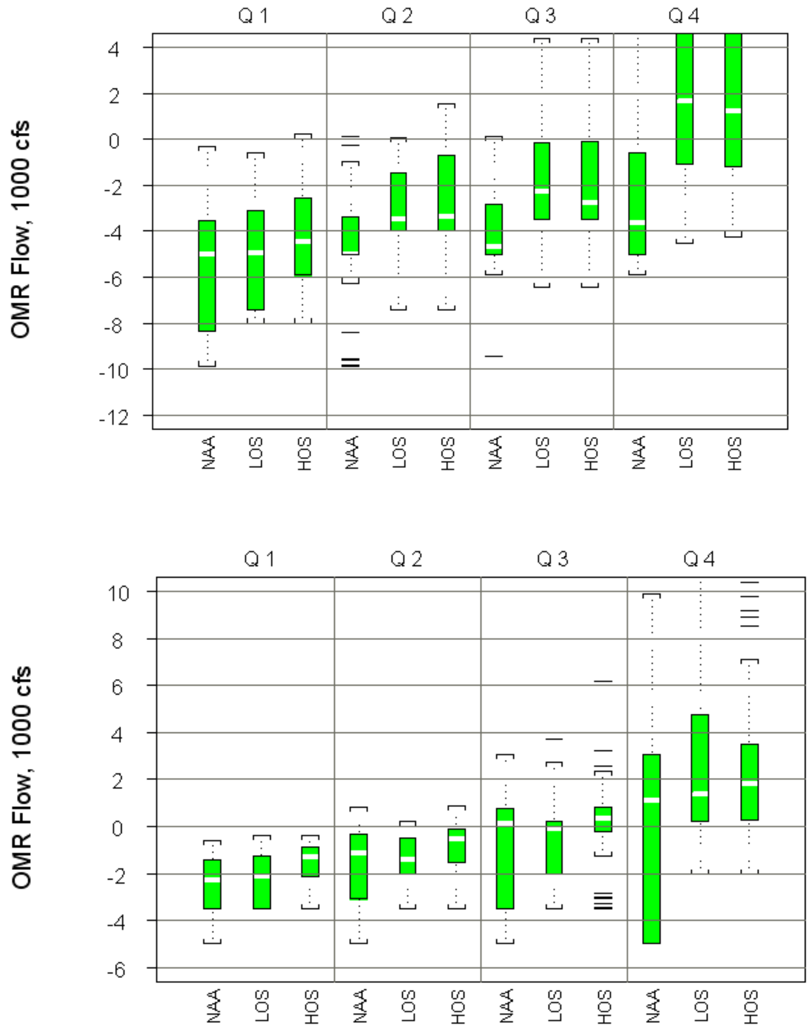

Figure 5.3. Values of OMR under the three alternatives for BDCP shown for quartiles of outflow under the No-Action Alternative. Boxes show first and third quartiles with the median as a white bar. The whiskers encompass points within 1.5 times the interquartile range, and the short lines are outliers. Top, period when adult longfin and delta smelt are vulnerable (Dec-March). Bottom, period when juvenile delta smelt are vulnerable (March-June).

Indirect effects

Net or tidally-averaged flow on the lower San Joaquin River at Jersey Point is parameterized as QWEST. This flow can be negative (i.e., eastward), which is considered an indicator of flow conditions unfavorable to fish. Negative QWEST could alter the speed or path of fish migrating through the Delta, thereby prolonging their migrations or making them susceptible to adverse conditions in the Delta. No field estimates of indirect effects have been made and they are conceptually difficult because the biological effects are difficult to define and because the net flows in the lower San Joaquin River are small compared to tidal flows. Nevertheless, regulatory agencies, particularly the CDFW and the

NMFS, have long expressed concern that negative values of QWEST due to project operations present fish with impediments to their effective migration.

The "east-west flow pattern in the San Joaquin River" referred to in the justification for CM#1 is apparently QWEST. QWEST is calculated in the Dayflow water balance program (http://www.water.ca.gov/dayflow/) as:

QSJR + QCSMR + QMOKE + QMISC + QXGEO - QEXPORTS - QMISDV - 0.65 (QGCD – QPREC),

i.e., the sum of inflows from San Joaquin River, eastside streams, and the Sacramento River via the Cross-Delta Channel and Georgiana Slough, minus south Delta exports, miscellaneous diversions in the Delta, and a fraction of the difference between precipitation and consumptive use within the Delta. However, for CALSIM modeling Delta consumptive use (QGCD), Delta precipitation (QPREC), and Delta miscellaneous diversions (QMISDV) are unavailable so the above equation simplifies to:

QWEST = QSJR + QMOKE + QCSMR + QXGEO – QEXPORTS.

QXGEO increases with Sacramento River flow and also depends on DCC gate operations. Specifically, QXGEO changes as 13.3% of Sacramento River flow with both DCC gates closed and 29.3% with both gates open (Dayflow documentation cited above). Sacramento River flow into the Delta will decrease by the amount diverted in the north Delta. Thus, among the flows controlled under BDCP, QWEST decreases by 100% of south Delta export flows and 13.3% or 29.3% of north Delta diversion flows depending on DCC gate positions.

There are many covered species of fish that migrate through or reside in the central Delta (Table 5.2). At least one of these species is present in the Delta during every month but August. Conditions in the central Delta are important for migratory species that spawn in the San Joaquin or Mokelumne Rivers because the entire population must pass through the central Delta. By contrast, only a fraction (unknown) of Sacramento fish enter the central Delta during migration. To cover the species that would be most affected by changes in flows in the San Joaquin River, we limit discussion to outmigrating salmonid juveniles (February – April) and upmigrating San Joaquin salmon (September – November).

Juvenile salmon

The occasional high springtime flow requirements of HOS (to benefit longfin smelt) coincide with the smolt emigration season (February – April). In drier conditions (the drier two quartiles) there is very little difference between NAA and LOS (Figure 5.4). The occasional occurrence of high flow requirements in HOS produce some differences between LOS and HOS scenarios, but mostly in the second quartile when the high flows are more likely to be triggered than in the driest quartile. All project scenarios diverge from the NAA under the wetter scenarios as more water is diverted from the north Delta and substitutes for high south Delta exports (Figure 5.4). The several thousand cfs differences in wetter months are occurring against baseline flows in the realm of 20000 cfs and greater, whereas the changes in flows in drier conditions are very small because limited North Delta diversion operations at low flows do not affect broad indices of Delta flow such as QWEST.

Table 5.2. Species of fish covered by BDCP that occur within the Central Delta for specific life history stages and the season of sensitivity to changes in flow conditions due to project operations (from various sources).

Species and Life History Stage within the Delta	Timing
Sacramento and San Joaquin steelhead juveniles	February - April
Winter-run Chinook salmon juveniles	November - April
Spring-run Chinook salmon juveniles	March-May
Green sturgeon	November-December
Delta smelt adults	December-March
Delta smelt juveniles	April-June
Longfin smelt adults	December-February
Longfin juveniles	February-March
Upmigrating San Joaquin steelhead	September-April
Upmigrating spring-run Chinook salmon	March-August
Upmigrating winter-run Chinook salmon	January-May
Upmigrating fall-run salmon Chinook salmon	September-November

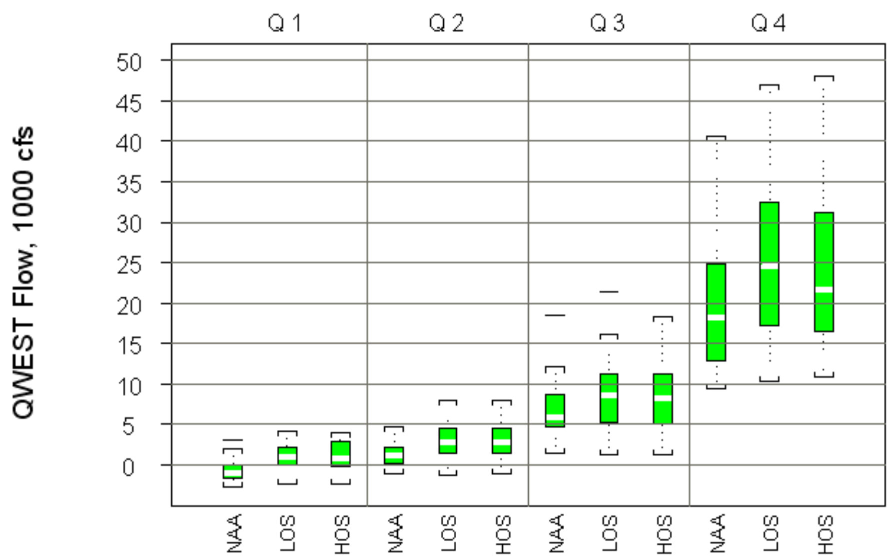

Figure 5.4. Feb-April QWEST flow for NAA and 3 alternative operational scenarios, grouped by quartiles of outflow. Two outliers for each scenario in Quartile 4, with values of 52,000 – 98,000 cfs, were cut off to allow better resolution of the lower values.

Adult San Joaquin fall-run salmon

Upmigrating salmon adults to the San Joaquin River pass through the south Delta and the lower San Joaquin River during September – November. In the fall there is very little difference among the alternatives that is not dwarfed by occasional high inflows due to flood releases or early winter storms (Figure 5.5). However, all alternatives show a general increase in QWEST compared to values for NAA because the use of the North Delta

Diversion is much less restricted and can more often substitute for south Delta diversions that are often operating at maximum flow under NAA.

In summary, project scenarios have small effects on QWEST in any season; changes in QWEST are smaller than those in OMR because use of the North Delta diversion does not translate into direct increases in flow, as it can for OMR. This is true for both the spring and fall. The high flows in HOS produce increases in QWEST in months around median wetness.

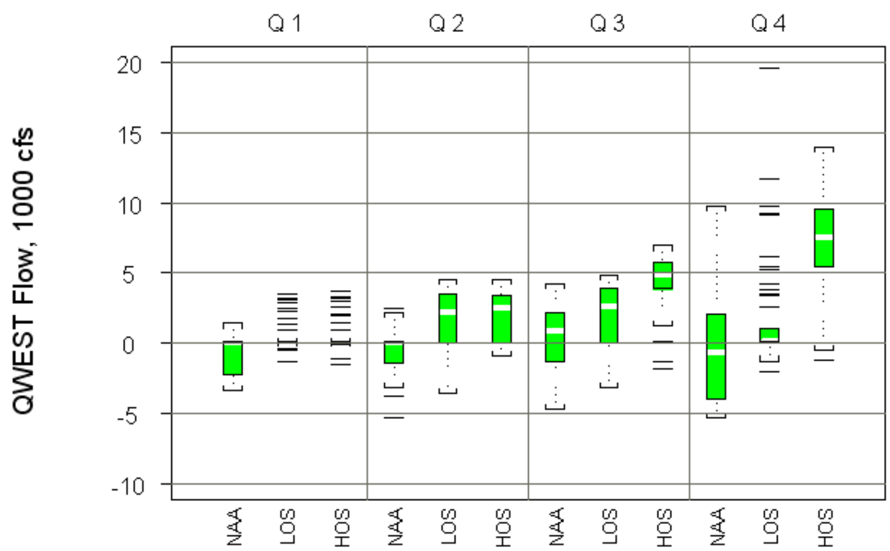

Figure 5.5. QWEST flows for the September-November season grouped by quartile of outflow. One outlier for each scenario in Quartile 4, with values of 22,000 – 30,000 cfs, was cut off to allow better resolution of the lower values.

Conclusion

The analysis presented here demonstrates broad improvement in in-Delta conditions under BDCP, as measured by changes in OMR and QWEST. However, we reiterate our concerns over the likelihood that Delta flows would actually be managed in the manner prescribed by the modeling. Changes in the frequency of reverse flows and their magnitude were somewhat obscured by the high variability among years, even those with similar hydrology. Some of this variability is a consequence of carry-over storage and the specifics of operational rules that may be triggered by conditions in one year but not another even if hydrology is similar. In the context of this variability, the improvements in flow conditions during periods of vulnerability of the smelt and salmon species were modest.

In analyzing model results of the operational scenarios we were surprised to see benefits occurring under dry conditions. The restrictions on North Delta diversions limit its operations to times of substantial river flows, so its ability to substitute for south Delta diversions should be limited to times of high flow. In fact, over a broad range of intermediate flows, the north Delta diversion augmented south Delta exports, rather than substituting for them. Thus, improvements to in-Delta flow conditions happened mostly in the highest quartile of Delta outflow under NAA. The differences between flows under the LOS and HOS were generally rather small.

Chapter 6: Estimated Effects of BDCP Flows on Smelt

Introduction

This chapter takes the model projections for three scenarios discussed in Chapter 5 (NAA, HOS, and LOS) and uses various simple statistical models to estimate the potential effects of these flows on delta and longfin smelt. The principal flows of interest are:

- Winter and spring flows in Old and Middle Rivers, which affect adult and larval to juvenile delta smelt, respectively
- Fall outflow, which may influence extent of habitat and therefore subsequent recruitment of delta smelt
- Spring outflow, which has a statistical relationship with subsequent abundance of young-of-the-year longfin smelt

We did not consider export effects on longfin smelt, for which there is no available statistical model and therefore no method to estimate losses without additional analysis beyond the scope of this review.

In making the calculations presented here we were constrained to use the CALSIM model output for the various flows by month and year. The concerns expressed in Chapter 5 apply here*: we do not believe that the system will actually be operated to obtain monthly patterns of flow like those in the CALSIM output*. This is particularly true in January and October, when wild swings in flows from one year to the next indicate a situation that would be very unlikely in the real system.

Direct Losses of Delta Smelt

Flows in Old and Middle River are related to salvage of delta smelt and other fish at the south Delta fish facilities. Annual salvage in turn is generally assumed to be a small fraction of entrainment losses, particularly for young (small) fish, because of various other losses attributed to export pumping, including predation in the waterways leading to the facilities and inefficient capture of delta smelt by the facilities.

Here we present estimates of export entrainment losses as a fraction of the population of delta smelt during the adult stage and the larval to early juvenile stage, only a small fraction of which is salvaged (Kimmerer 2008). The calculations were based on results of Kimmerer (2008) as amended for adult delta smelt by Kimmerer (2011). The general procedure was to determine a relationship for each of these two life stages between survival and flow variables that were available from CALSIM. Flows used were Old and Middle River flow (OMR) for adults, and net inflow (i.e., inflow less north Delta diversion flow, NDD) and export flow in the south Delta for larvae and juveniles combined.

We modeled the entire period of CALSIM analysis (WY 1922-2003) for the BDCP scenarios, and the historical period (1955-2003) for comparison. We calculated losses as described in

Appendix C for the BDCP scenarios for both time periods, and for the historical period using Dayflow variables and OMR flows from USGS monitoring.

The principal assumptions were:

- The relationships used to calculate survival or recruitment accurately reflected the corresponding population parameters; that is, the confidence intervals of the predictions were assumed to include the true values of the population parameters with 95% probability. Note that these analyses (Kimmerer 2008, 2011) have not been repeated by any analysts, although Miller (2011) provided a detailed critique. This is rather worrisome, because both the BiOP and several published modeling studies rely on the accuracy of those analyses (Maunder and Deriso 2011, Rose et al. 2013a, b).
- Changes due to BDCP actions were cumulative such that each factor could be examined in isolation from the others, and its effect considered separately from the others.
- The only changes considered were those due to the entrainment effects of flow. Long-term changes in sea level, tidal prism, temperature, salinity, and physical configuration of the Delta were neglected, despite their likely influence on the exposure of the smelt population to export entrainment. Exceptions to this were the influences of these factors on flows modeled by CALSIM.
- The flow time-series produced by CALSIM accurately reflected the influence of the various changes (but note concerns expressed above and in previous chapters).
- The broad spatial distributions of delta smelt will not differ substantially from those existing when the above analyses were made. This may not be true if the fraction of the population in the north Delta is higher now and in the future than when the analyses were made (Miller 2011, Kimmerer 2011).

Losses of adult delta smelt were calculated as a linear function of OMR flows. Annual percent loss under each of the three scenarios was similar for the historical and modeled time periods (Figure 6.1). The estimated proportion of adults lost to entrainment was slightly lower for the NAA than for the historical period, reflecting overall lower export flows presumably because some operating rules were not in force during the historical period. The High- and Low-Outflow scenarios (HOS and LOS) both had proportional losses that were ~ half of those under the NAA, or a net change in loss of about 3%/year.

Losses of larval + juvenile smelt were modeled as a function of exports from the south Delta and inflow to the Delta less diversions from the North Delta facility. The patterns for young smelt were somewhat similar to those for adults but with larger differences among scenarios. The NAA had substantially lower losses than the historical condition over the historical period (Figure 6.2). Flows projected for both the HOS and LOS resulted in much lower losses than for the NAA, with losses under the HOS reduced to ~2%/year on average.

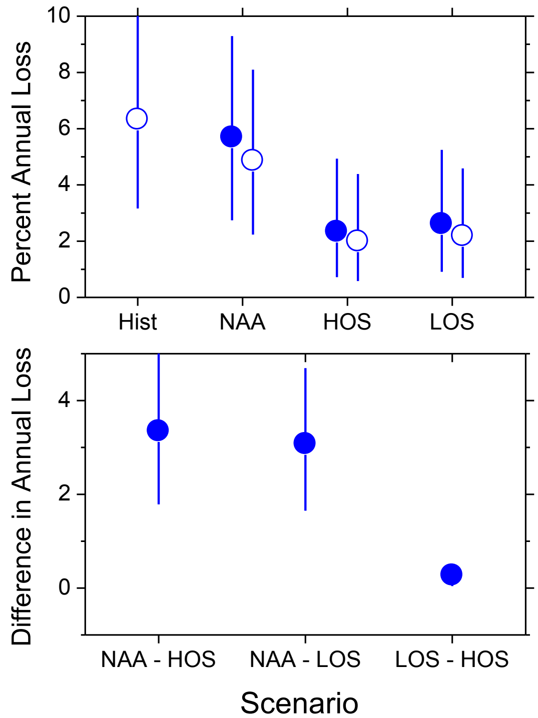

Figure 6.1. Annual percentage of adult delta smelt lost to export pumping for three scenarios and the historical time series. Symbols give means (see text) and error bars give the 95% confidence limit calculated as quantiles of the 1000 simulated samples of the respective distributions. Top panel, percent annual loss for 1922-2003 (filled symbols) and for 1980-2003 (open symbols) including the historical data. Bottom panel, differences between pairs of model scenarios.

We combined results for adults and larvae + juveniles within each calendar year by first calculating the proportion of the population that would remain after 20 years at the mean values in Figures 6.1 and 6.2, then multiplying the proportions remaining to get the influence of these scenarios over both life stages. This is effectively a long-term survival percentage. These are not predictions, and are useful only for examining differences among scenarios. The resulting percentages were 38% for the HOS, 23% for the LOS, and 2% for the NAA (Table 6.1). In other words, the two scenarios with a north Delta diversion resulted in 19- and 11-fold increases in survival over a 20-year period.

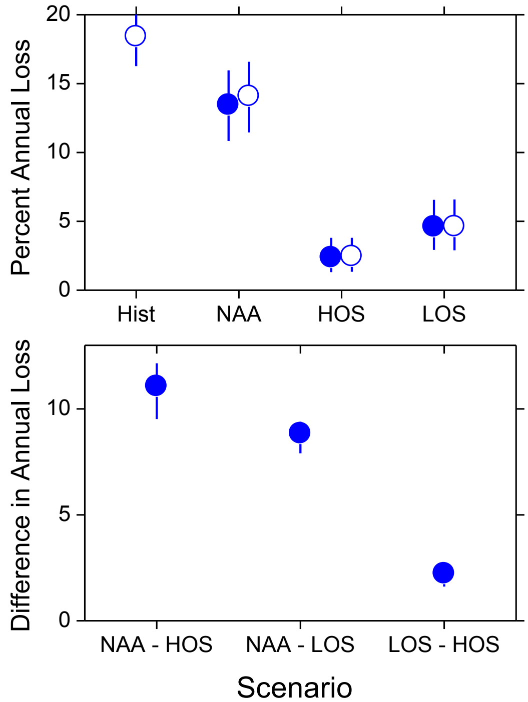

Figure 6.2. As in Figure 6.1 for losses of juvenile delta smelt.

These numbers are highly uncertain, since the value for NAA is so small and variable (Table 6.1). There are indications that losses have been overestimated, especially given the potentially large subpopulation of young delta smelt that may be resident in the Cache Slough complex, where they are immune from effects of export pumping in the south Delta (Miller 2011). Using the upper confidence limits of the projected population size at the end of 20 years (i.e., the lower 95% confidence limits of the loss estimates) the ratios of population remaining after 20 years would have been 14 for HOS and 9 for LOS. These confidence limits do not account for any upward bias in loss estimates, and the loss estimates can and should be refined to reflect current understanding.

Nevertheless, the results of this analysis show a substantial improvement in long-term survival of delta smelt under HOS and to a lesser extent LOS, *provided the water projects are operated in ways that result in flows similar to those in the simulation.* Taken at face value the mean difference in losses between NAA and either of the other scenarios would have roughly sufficed to reverse the decline in delta smelt during the early 2000s.

Table 6.1. Percent of delta smelt population remaining for each of three BDCP scenarios after 20 years of losses at the rates estimated and shown in Figures 1 and 2. Values given with 95% confidence intervals.

	Adults	Juveniles	Combined
NAA	31 ± 22	6 ± 4	2 ± 2
HOS	62 ± 25	62 ± 15	38 ± 19
LOS	59 ± 25	39 ± 15	23 ± 13

Outflow Effects

Two time periods are considered for effects of changed outflow: fall for delta smelt and spring for longfin smelt. These effects are typically cast in terms of X2. For this analysis we calculated X2 from outflow as determined by CALSIM, using the monthly relationship in Jassby et al. (1995), as has been done for all previous analyses of relationships of X2 to abundance indices or habitat of fish (e.g., Feyrer et al. 2007, Kimmerer et al. 2009). CALSIM also produces X2 but it is for the previous month and is somewhat different from that used previously, particularly since it is said to account for sea-level rise and the effects of additional tidal prism due to marsh restoration. Since we were focused on the early long-term (ELT), we elected for now to neglect these considerations and use an X2 value that reflected the anticipated outflows in the same way as in the analyses of X2 effects on fish.

Fall X2 Effects on Delta Smelt

The USFWS Biological Opinion (BiOP) for delta smelt proposes to use X2 in the September-December period as a management tool. The principal basis for this action is the analyses of fall habitat indices (Feyrer et al. 2007, 2011) and an unpublished analysis relating the Summer Townet index to the previous fall Midwater Trawl index and X2:

$$TNS_{y+1} \sim a + bMWT_y + cX2_y + \varepsilon_y \qquad (6.1)$$

where TNS is the summer townet index, MWT the fall midwater trawl index, y is year, ε is error, a, b, and c are fitted parameters, and the time frame was restricted to after 1987 to account for the changes in the foodweb resulting from the introduction of the clam *Potamocorbula amurensis* (See Chapter 7 regarding food limitation of delta smelt).

This model assumes that the main effect of fall X2 on delta smelt is through a combination of survival and growth and therefore population reproduction in the following spring, resulting in effects on abundance in the following summer. Equation 6.1 is somewhat illogical in modeling TNS as an additive function of MWT and X2, and it is also strongly influenced by the data point from 1998, the wettest fall among those included in the analysis. Removing that point weakens that relationship somewhat, although it remains strong. Nevertheless, we fitted an alternative model:

$$\log(TNS_{y+1}) \sim a + b\log(MWT_y) + cX2_y + \varepsilon_y \qquad (6.2)$$

which is more in keeping with the form of the other X2 models (Jassby et al. 1995). This model was fitted to all the data since 1987 using a robust regression method to allow for some over-dispersion in the residuals (function *rlm*, Venables and Ripley 2003). The regression coefficients were a=2.7, b= 0.62 ± 0.22, and c= 0.061 ± 0.55, R^2=0.68, and diagnostic plots revealed that this model was appropriate for the data (Figure 6.3). In particular 1998, and unusually wet year, did not have a strong influence on this relationship.

We extrapolated from this model to the BDCP scenarios using the CALSIM-modeled outflows. The target was the summer townet index, which we examined as a ratio to that predicted under NAA. In contrast to earlier analyses, we did not attempt to relate this to long-term population growth.

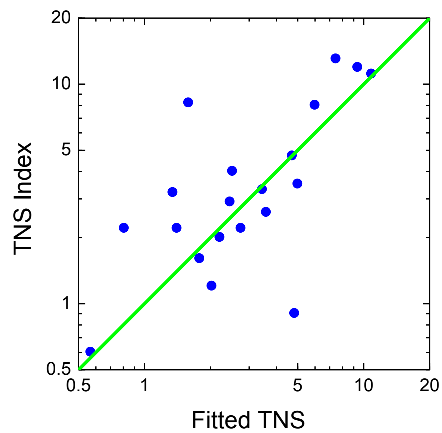

Figure 6.3. Fitted and measured summer townet index (TNS) with a 1:1 line. Values were fitted using Equation 6.2.

The modeled monthly outflow values were converted to X2 according to the monthly equation in Jassby et al. (1995), with the initial value (October 1921) set to the equilibrium X2 for the modeled flow. This was combined with historical monthly mean X2 values and all were averaged over September-December. Equation 6.2 was then used to predict the summer townet index from the mean fall midwater trawl index from 1988 to 2011 and X2 for the three scenarios.

Results showed HOS to have, on average, a slightly higher summer townet index than under NAA (Figure 6.4). The ratio of townet indices determined under HOS to that under NAA was 1.02, i.e., a 2% greater index under HOS, with 10^{th} and 90^{th} percentiles of 0.89 and 1.10 respectively. About a third of the values had lower confidence limits below zero, indicating low confidence that a real increase would be achieved under these conditions.

By contrast, the predicted ratio of townet index for LOS:NAA was about the same as that for HOS:NAA about half of the time, and the other half of the time it was much lower, with large confidence intervals related to the uncertainty in the prediction from the model. The calculated ratio had a median of 0.98 with 10^{th} and 90^{th} percentiles of 0.60 and 1.10. This peculiar pattern arose from the patterns of outflow in the CALSIM output (see Chapter 5). We have very low confidence that these patterns reflect how the system would really be operated, and therefore suggest these results be considered as conditional on proposed operational rules.

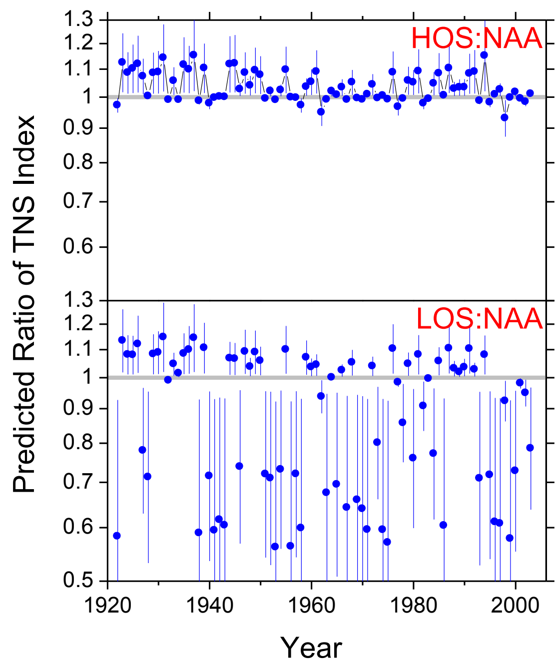

Figure 6.4. Ratios of predicted TNS index by year from HOS (top) and LOS (bottom) to those from NAA.

Spring Outflow/X2 Effects on Longfin Smelt

Longfin smelt has the strongest relationship of abundance index to X2 of any fish (Jassby et al. 1995). The index for a given level of X2 has declined, but the response to flow has not changed. We updated the latest published version of this relationship (Kimmerer et al. 2009) by adding two step changes in time: one in 1987-1988 corresponding to the spread of the clam *Potamocorbula amurensis*, and the other in 2003-2004, the POD decline (Thomson et al. 2010). The statistical model used was

$$\log_{10}(LFS_y) = a_y + bX2_y + \varepsilon_y \qquad 6.3$$

Where LFS is the annual index of longfin smelt abundance from the fall midwater trawl survey, y is year, X2 is monthly values averaged over either January-June (as in Jassby et al. 1995) or March-May, and ε is error. Fitting parameters are *a*, which takes one of three values by year group, and *b*, the slope of the X2 relationship.

The resulting relationship (Figure 6.5) shows both the effect of X2 and the two step-changes in abundance index. Diagnostic statistics showed that the model was appropriate. Since we were interested in the difference between the two alternative flow scenarios and NAA, the only parameter that concerned us here was *b*, which had a value of -0.054 ± 0.005 km^{-1}, essentially identical to previously published values. Averaging X2 over March-May gave a slope of -0.049 ± 0.005 km^{-1}, and the fit was slightly inferior to that of the January-June model.

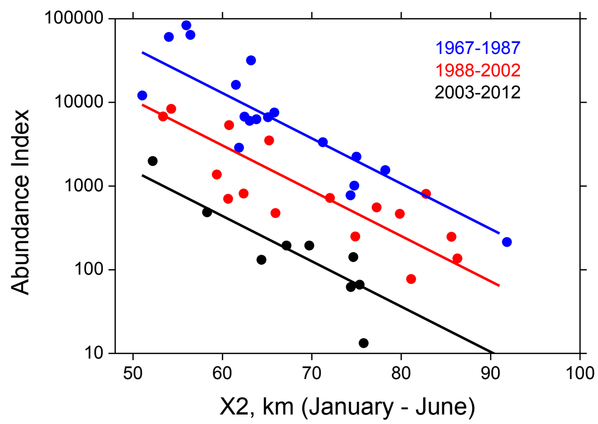

Figure 6.5. Abundance index of longfin smelt vs. X2 averaged over January-June, with step changes between 1987 and 1988 and between 2002 and 2003. Colors of points and lines indicate the time period.

The months selected in the original analysis were based on the assumption that the (unknown) X2 mechanism operated during early life history of longfin smelt, which smelt experts linked to this period. Autocorrelation in the X2 values through months means that statistical analysis provides little guidance for improving the selection of months. A better understanding of the mechanism(s) underlying the relationship would probably allow this period to be narrowed and focused, but for now there is little basis for selecting a narrower period for averaging X2.

The predictions from the above model were then applied to the X2 values calculated from the CALSIM projections of outflow for the 82-year period. We did not attempt to propagate prediction error because it is small compared to variability in outflow. Applying the January-June value for the three selected scenarios resulted in scant differences in predicted abundance indices (Figure 6.6). The median $\log_{10}$ ratio of indices for HOS:NAA was 1.00 (mean 1.05) with 10^{th} and 90^{th} percentiles of 0.91 and 1.27. Corresponding values for LOS:NAA were median 0.92 (mean 0.92) and percentiles of 0.83 and 1.00.

Thus, changes in outflow resulting from the CALSIM projections of spring outflow were small, particularly on the scale of the high variability with X2. HOS provided a minuscule increase in the mean but the median did not change from NAA, indicating that half of the years had higher, and half lower, values under HOS than under NAA. LOS gave values that were ~8% lower than those under NAA.

Although it would be desirable to link such calculations to a population-dynamics model, no such model is available; furthermore, previous analyses have shown that abundance of longfin smelt is highly predictable from X2 and, more recently, groups of years as done above. This does not mean that stock-recruit relationships are unimportant; an alternative analysis models a recruitment index, the log of the ratio of MWT to the MWT value 2 years earlier, as a function of X2 (Nobriga and Rosenfield, in prep.). However, it is unlikely this analysis would indicate a stronger effect of X2 on longfin smelt under BDCP.

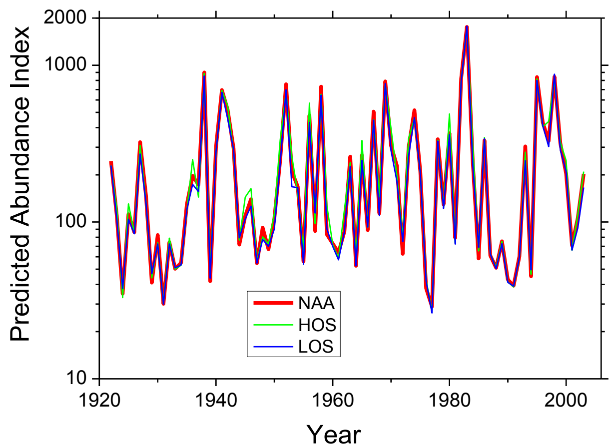

Figure 6.6. Predicted abundance from the model in Figure 6.3 for the three BDCP scenarios. The intercept for the third time period (2003-2012) was used to calculate these indices.

Conclusions

The modeled flow changes under BDCP have mixed effects on the two smelt species. For delta smelt, changes in flow in the south Delta had a marked effect on survival of both adult and young smelt, such that gains of several percent a year would be forecasted for the difference between the NAA and the two with-project alternatives. Effects of outflow on delta smelt were small for HOS compared with NAA, while projections under LOS showed about half the time a marked reduction in predicted summer abundance index compared to NAA. Effects of spring outflow on longfin smelt were not very large.

The results for delta smelt were somewhat surprising, since food supply is clearly an important limitation (Chapter 7) and more likely implicated in the decline than export losses. We nevertheless stand by these results subject to the following contingencies:

- The water projects will be operated to achieve similar flow patterns as in the CALSIM output we used in our analysis.
- Future re-analyses of the influence of export pumping on delta smelt are used to refine these estimates.
- Effects of increasing temperature, introductions of quagga or zebra mussels or other high-impact species, changing flow-X2 relationship, rising sea level, and catastrophic inundation of Delta islands do not materially alter the trajectory of delta smelt.

The last point is presented almost facetiously – things will change, in some ways we can predict and other ways we cannot. The BDCP takes account of some of these changes but others are just as likely over the time frame of the project and should be accounted for

(Chapter 8). Nevertheless, at present we lack the capability to include these factors in a more thorough analysis, but believe it should be done.

Longfin smelt, by contrast, are unlikely to be much affected by BDCP. The anticipated changes in outflow are rather minor, and the flows needed for substantial changes in longfin smelt abundance are likely too great to be practically achieved.

Chapter 7: Likely Response of Listed Fishes to Physical Habitat Restoration

Introduction

This Chapter focuses on the proposed restoration of physical habitat in the Delta and Suisun Marsh. Because of time constraints we have focused on the potential benefits of floodplain and marsh restoration to delta and longfin smelt. These benefits are postulated to occur through expanded physical habitat for the fish, or through export of food from the restored areas to smelt habitat.

Summary of Assessment

The BDCP proposes to restore 55,000 acres of subtidal to intertidal habitat[1] of which 20,600 acres is to be allocated among various Restoration Opportunity Areas (ROAs) in the Delta and Suisun Marsh and the remainder to be allocated later. If completed this restoration will substantially increase the inundated portion of the Plan Area; for example if all 7000 acres assigned to Suisun Marsh were restored it would roughly triple the area exposed to tidal action.

The ROA's include Suisun Marsh, Cache Slough, and the eastern, southern, and western Delta . The documentation is unclear on the depth profiles of these areas and for calculations below we have assumed that about half of each will be intertidal and the remainder subtidal with a mean depth of 2 meters. The document lists the aquatic and terrestrial species expected to benefit from these actions, but here we focus only on their likely effects on the two smelt species.

Our results to date lead to the following preliminary conclusions:

- Delta and longfin smelt are usually food-limited, meaning that population levels would rise if there were more zooplankton in their rearing areas. This limitation is probably stronger in spring-fall than in winter.
- The BDCP is overly optimistic about the likely benefits of tidal marsh restoration to the smelt species, particularly the extent of food production.
- A review of the literature suggests that tidal marshes may either import or export phytoplankton and zooplankton.
- Under highly favorable assumptions about production and export of plankton, restored tidal marshes could make at most a modest contribution to extant plankton production.

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[1] "Habitat" means the location and conditions in which a population of a species lives; here we follow the BDCP document in using the term to mean a physical space. We likewise use "restore" to mean to prepare that space for the potential occupation of one or more species, irrespective of the previous condition of the space.

- The subpopulation of delta smelt that inhabit the Cache Slough complex through summer may benefit from additional physical space in that area. The same could be true in Suisun Marsh although current use by smelts is low.
- The high level of uncertainty about outcomes points to the use of moderate- to large-scale experimental restoration projects to determine whether the proposed restoration will achieve the food-production goals and, if so, how to design them optimally.

Marsh Restoration

Review of conceptual basis

The BDCP anticipates many benefits to delta and longfin smelt. Although the documentation is unclear on the expected magnitudes of these benefits, it is uniformly optimistic that they will contribute substantially to recovery of the species. Here we focus on two potential benefits to the smelts from the restoration of tidal habitats. First, the restored habitats are expected to provide a food supply that will enhance the food supply available to the smelts. Second, the restored habitats are expected to provide additional physical space, resulting in an increase in smelt abundance. Neither of these proposed benefits is well developed in the documentation, and the literature cited seems to have been selected to support the claims made. The BDCP documentation furthermore contains factual errors and misinterpretations that cast doubt upon the projections that are made, however qualitative. We therefore conducted a reasonably thorough analysis of these specific claims, within the constraints of time available.

The first outcome requires two conditions: 1) that the smelt populations are currently food-limited, meaning that an increase in concentration of food organisms would result in a higher abundance of smelt; and 2) that the restored marshes will produce and export enough food organisms to make a difference to the population status of the smelts.

BDCP Appendix 5E uses “prod-acres” to index the expected productivity of phytoplankton in the restored areas. However, this index is conceptually flawed in two ways. First, it uses an estimate of growth rate rather than production of phytoplankton, which is the product of growth rate and biomass. Second, it assumes implicitly that all phytoplankton growth is available as food for the zooplankton consumed by the smelt species, but analyses published on the San Francisco Estuary and elsewhere show that most of the production is consumed by benthos and by microzooplankton such as ciliates (e.g., Lopez et al. 2006, Lucas and Thompson 2012, Kimmerer and Thompson submitted).

The smelt species are expected to occupy some of the restored habitats. This may provide benefits in the form of increased opportunities for individual fish to find suitable conditions such as spawning substrate, food patches, or shelter from predators. A potential benefit is to diversify the locations in which the smelt species occur, in an attempt to increase resilience of the populations to local perturbations such as high-temperature periods or toxic spills.

Analysis of components

For effects of food production and export we assessed the evidence for food limitation of the smelt populations, and for the amount of food (zooplankton) that restored marshes would export to waters where the smelt species occur. For physical habitat we examined current patterns of occurrence to determine the likely effect of additional physical habitat on the smelt species.

We do not address other potential indirect impacts of marsh restoration, or interactions with other proposed projects. Restoration of extensive areas of marsh will increase the tidal prism in the restored area. This will affect tidal currents and elevations both locally and all the way to Carquinez Strait, and therefore affect salinity penetration and the movement of sediments. The effects on salinity have been included in the modeling presented in BDCP documents, but we did not review this. The U.S. Army Corps of Engineers has proposed a project, now on hold, to deepen the Sacramento Deep-Water Ship Channel, which is currently an important part of the habitat of delta smelt. This and other non-BDCP projects should be taken into account when considering impacts of BDCP.

Are smelt species food-limited?

What is the evidence for and against food limitation in delta and longfin smelt? By food limitation we mean a situation in which an increase in concentration of food organisms would result in a higher abundance of smelt. This does not require that all or even most fish have depressed growth or reproductive rates, only that at least some of them do. Substantial food limitation would require the following to be true:

1. The density of food organisms is too low to support the maximum growth rate of the fish.
2. Therefore some fish are in poorer condition or grow more slowly than under food satiation.
3. Either or both of the following:
    a. Survival over a life stage depends on condition and therefore food supply
    b. Reproductive rate of an adult varies with growth rate during development through its effect on maturity or total eggs per female.
4. Higher reproduction leads to a larger population, all else being equal. We assume this condition must be true as a straightforward consequence of population dynamics.

Food limitation could occur at one or more life stages, which may occupy different parts of the estuary. During spawning and early life delta smelt are mostly in freshwater. During the late larval stage (~July) until the pre-spawning migration in December, part of the population is in the low-salinity zone (LSZ, salinity ~0.5-5), and part is in the Cache Slough-Liberty Island complex in the North Delta (Sommer et al. 2011). Longfin smelt also spawn in freshwater but move earlier and further seaward (Rosenfield and Baxter 2007, Kimmerer et al. 2009). We refer to fish between metamorphosis from the larval stage to their spawning migration as juveniles (i.e., including all fish caught in the fall midwater trawl survey). Both smelt species consume available plankton in their habitat, with the size of prey related to that of the fish.

Food limitation is surprisingly difficult to demonstrate in a fish population. Nearly all populations must be food limited to some degree. However, food limitation of individual fish can be difficult to detect. The prey and the fish are spatially patchy and temporally variable, so the degree of food limitation is sporadic and patchy. Great differences among individuals in feeding success result in differences in growth and survival, such that the survivors are those that have been well fed. Feeding success also interacts with other influences such as predation risk and physiological stress.

The analysis of food limitation relies on a variety of direct and indirect evidence (Details in Appendix D). Some studies suggest food limitation inferred from correlations of abundance or length with measures of food availability, indices of gut fullness and physiological condition of field-caught smelt, and laboratory-derived estimates of feeding rate in relation to food concentration. A few other studies do not support food limitation in these species. However, the weight of evidence suggests that food is limiting the populations of both smelt species.

Export of food from shallow restored areas

One purported benefit to smelts of restored shallow areas is that elevated food production in these areas will be exported as a subsidy to open waters where the smelts are abundant. The implicit conceptual model is that these shallow areas will produce an excess of phytoplankton and zooplankton that will then be exported by stream flow or tidal currents. A subsidy of phytoplankton could stimulate zooplankton production in the open waters, since the zooplankton in this estuary are chronically food-limited in their growth or reproduction (Müller-Solger et al. 2002, Kimmerer et al. 2005). However, grazing by clams is likely to prevent such a subsidy from having much effect on zooplankton production. The alternative subsidy is that of zooplankton grown within the restored areas, including larger forms such as mysids that are consumed by juvenile longfin smelt and adult delta smelt.

The magnitude of any subsidy depends also on the transport process. Where the transport is mediated by tidally-driven currents, the subsidy will be related to the tidal exchange and the difference in biomass between the restored area and the open water. Where it is mediated by river flow, the subsidy will depend on the net flow and the biomass in the restored area.

Here we examine the literature on subsidies from marshes, use a simple model to estimate the magnitude of such a subsidy of either phytoplankton or zooplankton, and estimate the proportional flux from the Suisun Marsh to Suisun Bay using output from a particle-tracking model as a measure of the extant subsidy. Our conclusions are:

- The literature does not support a confident assertion that marshes will subsidize zooplankton of the open waters.
- Calculated subsidies of phytoplankton and zooplankton are modest under optimistic assumptions about in-marsh production and design of restoration sites.

- A subsidy of zooplankton from Suisun Marsh to Grizzly Bay cannot be very large under current conditions, and is unlikely to be much larger with the proposed extent of restoration.

Do shallow areas export phytoplankton or zooplankton?

Marshes can be major producers of organic matter because of their extensive vegetated surface exposed to sunlight, shallow waters leading to light penetration through all or most of the water column, and the continual supply of nutrients from the open waters and from land (Figure 7.1). This appears to be true even for recently restored marshes (Howe and Simenstad 2011). Over the long term, mass must balance, so production in excess of respiration by organisms within the marsh must be either buried or exported as organic matter or organisms to adjacent estuarine waters.

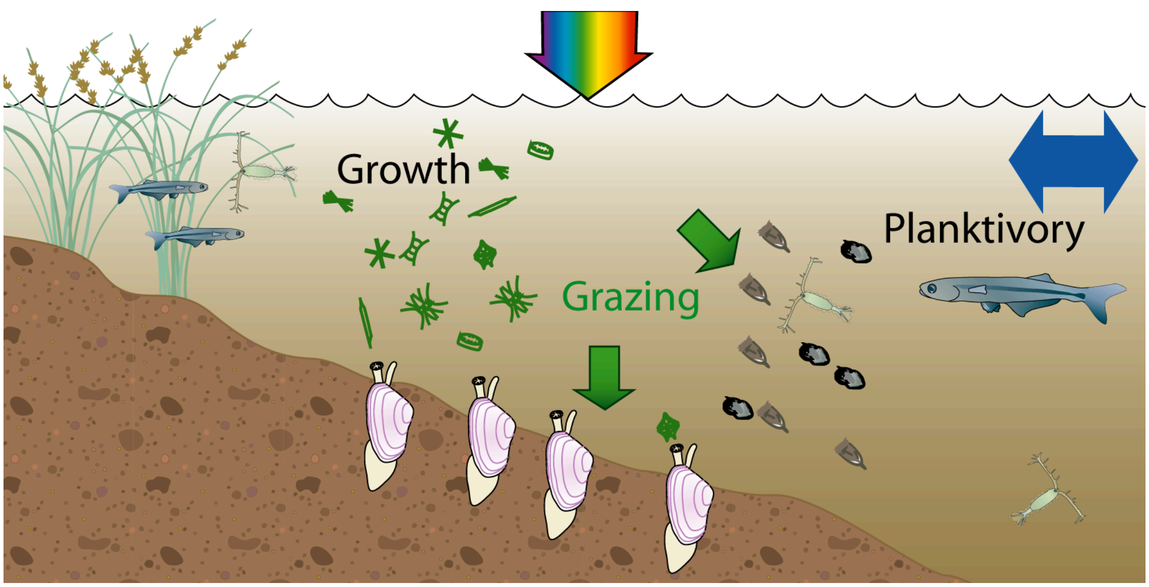

Figure 7.1. Conceptual model of the production of food for pelagic fish in a low-order tidal marsh channel. Because the water is shallow (and may be clearer than in adjacent channels) light penetration is good and growth of phytoplankton and benthic microalgae is high. Losses of phytoplankton occur through benthic grazing and by pelagic grazing, chiefly by microzooplankton but also by larger zooplankton such as copepods that can be consumed by fish. Benthic grazers filter a certain volume of water every day, so the shallower the water the more intensive the grazing on the plankton of the marsh. Small planktivorous fish such as Mississippi silversides seek shelter in the shallowest and vegetated areas; thus consumption of zooplankton is also more focused and more selective for larger organisms in shallow water. Tidal exchange of water with the adjacent higher-order (larger) channel transports nutrients, organic matter, and plankton between marsh and channel, but the direction of transport for zooplankton may be in or out of the marsh depending on the outcomes of the various production and consumption processes.

Export of organic matter from marshes to adjacent estuarine waters was first considered as the "outwelling hypothesis" (Odum 1980, Nixon 1980). This hypothesis holds that the export of labile organic matter provides an important subsidy to nourish adjacent waters of the estuary or continental shelf.

The outwelling hypothesis originated in studies of extensive, rich marshes on the east and Gulf coasts, but even there, quantitative demonstrations of its importance to estuarine or coastal foodwebs were few (Dame et al. 1986). Much of the difficulty arises from the technical challenge of measuring a small net flux in a large tidal signal with high variability (Dame et al. 1986). In addition, dissolved and particulate organic matter produced by rooted vegetation can be highly refractory and therefore largely unavailable to estuarine pelagic foodwebs, which are usually fueled mainly by phytoplankton (Sobczak et al. 2002, 2005).

Marshes can be sites of high productivity by benthic or planktonic microalgae because they are shallow, so waters are well-lit. Therefore a marsh could export organic matter as living phytoplankton. However, the extent of this export depends on consumption within the marsh, including consumption of phytoplankton by benthic grazers in shallow waters, as illustrated for flooded islands in the Delta by Lopez et al. (2006). Often overlooked in attempts at a mass-balance of phytoplankton is the high rate of consumption by microzooplankton, which typically consume about 60% of the production by phytoplankton in estuaries (Calbet and Landry 2004, York et al. 2011). Thus, the production actually available for consumption by mesozooplankton, and for export, is considerably lower than would be expected from estimates of primary production.

For zooplankton the magnitude and direction of the flux depends on behavior and on size- and taxon-specific patterns of mortality. In particular, visual predation by fish can exert strong control on the size distributions, and therefore species distributions, of zooplankton (Brooks and Dodson 1965). Vertical movements of zooplankton and hatching or settlement of larvae can lead to spatial patterns of abundance that do not reflect tidal transport (Houser and Allen 1996). Consumption of zooplankton by small fish that seek food and shelter in shallow areas can reduce zooplankton abundance near shore, and shift the size distribution toward smaller forms, in lakes (Brucet et al. 2005, 2010), lagoons (Badosa et al. 2007), and marshes (Cooper et al. 2012). The outcome can be net fluxes into shallow areas (Carlson 1978, Kimmerer and McKinnon 1989), and marshes can be simultaneously sinks for copepods and areas of aggregation for bottom-oriented larvae (Mazumder et al. 2009).

Thus, marshes may act either as net sources or sinks for plankton in the adjacent waters, depending on the availability of habitat for small fish and the degree of colonization by benthic grazers such as clams. The exact details of the exchange processes depend on the physical configuration of the marsh including permanence of inundation (Brucet et al. 2005), residence time of the water (Lucas and Thompson 2012), and the biological composition, i.e., the kinds and abundance of producers and consumers within the marsh including transient organisms (Kneib 1997). If the excess organic matter is being transported by fish as in some east coast marshes (Kneib 1997), little benefit would accrue to planktivorous fish in the open waters such as the smelts.

Few of these aspects have been examined in marshes of the San Francisco Estuary. Long-term studies of Suisun Marsh have revealed a lot about fish assemblages (e.g., Matern et al. 2002, Feyrer et al. 2003) and medusae and some zooplankton (Wintzer et al. 2011, Meek et al. 2013), and some detailed studies of exchange processes have been undertaken (Culberson et al.2004). Zooplankton abundance is highest in small sloughs of long residence time (P. Moyle, UC Davis, personal communication).

Foodwebs in diverse marshes of the San Francisco Estuary are supported more by local plant production than by estuarine phytoplankton (Howe and Simenstad 2007, 2011). This implies a division of organic-matter sources between those supporting littoral and marsh foodwebs and those supporting pelagic foodwebs (Grimaldo et al. 2009).

Lehman et al. (2010) estimated the fluxes of various substances in and out of Liberty Island, a flooded island in the Cache Slough complex in the northern Delta. They found large seasonal shifts in the magnitude and direction of fluxes. In particular, seasonal chlorophyll flux was into Liberty Island in spring and out in fall, based on point measurements, and into the island in all seasons but more so in spring and summer, based on the continuous measurements. Fluxes of copepods were out during spring and fall, and in during summer, based on a total of six sampling days. Although Lehman et al. (2010) linked fluxes into Liberty Island with storage within the island, it was equally likely to have been a function of consumption, particularly since high inward fluxes of chlorophyll and zooplankton occurred in summer when biological activity would have been high.

A few other marshes and restoration sites in the estuary have been investigated for their potential links to open waters. The South Bay Salt Ponds, which began to be reconnected to the tidal action of the Bay in 2006, are highly productive and may export organic matter to nearby estuarine waters (Thebault et al. 2008). A marsh at China Camp in San Pablo Bay was a net sink for mysids, probably through predation within the marsh (Dean et al. 2005).

Calculated subsidies

Here we assume that the restored areas will actually produce an excess of phytoplankton or zooplankton over adjacent waters, and ask what additional level of food availability to the smelt would result. This is based on a very simple model using data from IEP monitoring, described in detail in Appendix E (See Figure 7.2). The basis of this model is to calculate the subsidy based on high levels of biomass and growth rate in a 2500-acre marsh that is closely connected to smelt habitat and has an optimum rate of exchange with the open water. We assume smelt habitat is represented by the Low-Salinity Zone (LSZ), which has a volume of about 0.5 km^3.

A subsidy is maximized by a large marsh close to the smelt habitat, with tidal exchange close to but not above the net population growth rate of the plankton (Figure 7.3). The subsidy is degraded or even reversed by consumption (clams, planktivorous fish) within the marsh. Water depth may have a positive or negative effect on the subsidy.

The simple model in Appendix E shows that under an extremely favorable set of conditions both within and outside of the marsh, a modest subsidy of phytoplankton is possible.

Phytoplankton input to the LSZ could amount to 16%/day, or about half of the daily net production in the LSZ. However, smelt species do not eat phytoplankton, and the conversion of phytoplankton to zooplankton depends on factors in the open water such as grazing. The direct subsidy of zooplankton would be about 3%/day, also under unrealistically ideal conditions. Although this is not negligible, any reduction in this value would effectively eliminate the subsidy to open water.

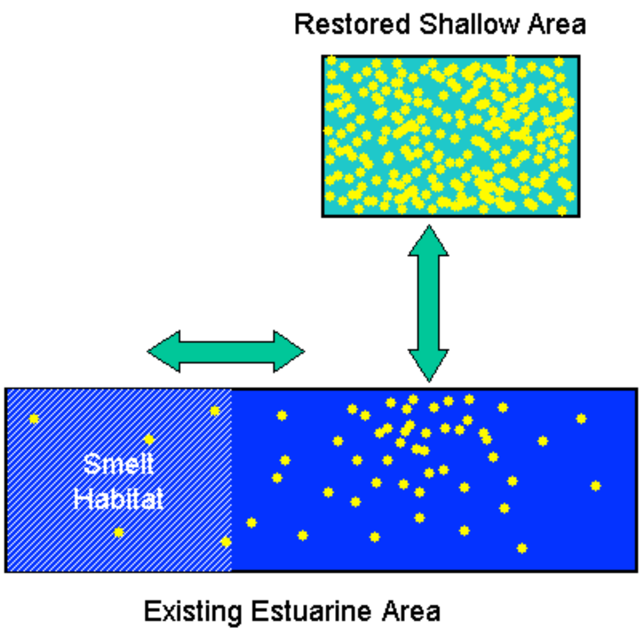

Figure 7.2. Schematic diagram of a subsidy of zooplankton (yellow circles) from a restored tidal marsh or other shallow area to an existing estuarine area. Zooplankton move by dispersion (double-sided arrows) between the restored and existing areas, and within the existing area from the outlet of the restored area to other regions of the estuary including smelt habitat. Advection may alter the flow of zooplankton, for example, if the restored area is on a creek that produces a net flow into the existing area.

Zooplankton export from Suisun Marsh

One of the proposed restoration areas is in the northern end of Suisun Marsh. We estimated the subsidy of copepods to the LSZ from this region using IEP monitoring data and using a particle-tracking model to estimate exchange rate (Appendix E). If the copepods behaved as passive particles, this subsidy would amount to about 2%/d of the population in the LSZ. This is unlikely to produce a noticeable increase in copepod biomass, as their potential population growth rates are on the order of 10%/d. However, particles that migrate to the bottom tidally or remain near the bottom, as most zooplankton do in the estuary (Kimmerer et al. 2002), were essentially trapped within the northern marsh. Behavioral responses to tidal currents, consumption within the marsh, the distance from the mouth of the marsh to the habitat of the smelts, and the operations of the salinity control gate on Montezuma Slough would all reduce or even eliminate this subsidy.

The real world

Several features of the actual restoration site would alter the subsidy to open waters from the analyses above. First, the enlarged restoration area will alter the tidal prism and therefore the exchange rate. The proposed restoration for Suisun Marsh would increase the inundated area 2-3-fold, with a corresponding increase in tidal currents. Since most of the exchange will be mediated by tides, this could substantially increase the exchange rate. Whether this would increase or decrease the subsidy would depend on the net population growth rate achieved in the marsh in relation to the exchange rate. Resolving the change in residence time would require a 3D model with very accurate bathymetry throughout the region. It is impossible to tell with available information whether the stronger tidal connections would result in a greater subsidy from Suisun Marsh, or whether this would be offset by zooplankton behavior or by consumption within the marsh. Such calculations could be done using a hydrodynamic and particle tracking model and some reasonable assumptions about zooplankton behavior.

The BDCP documents acknowledge (but then mostly ignore) that grazing by clams that settle in or near restored subtidal areas may remove all or most of the phytoplankton production and some of the zooplankton. Grazing by clams and zooplankton (including microzooplankton) removed all of the phytoplankton production in the LSZ nearly all the time from late spring through fall during 1988 – 2008 (Kimmerer and Thompson submitted.). Whether clams settle in the newly restored areas is critical in determining whether the area can export any phytoplankton (Lucas and Thompson 2012). At present clams are not abundant in Suisun Marsh except for the larger Suisun and Montezuma Sloughs, where they probably remove a substantial fraction of the phytoplankton and small zooplankton that would otherwise enter Grizzly Bay.

Zooplankton organisms are not passive, and undergo tidal migrations in Suisun Bay (Kimmerer et al. 1998, 2002). It is very likely that they will do so also in marsh channels, which would greatly lengthen the residence time for copepods produced in the marsh, particularly in the far northern area of Suisun Marsh. In addition, several studies have shown that zooplankton organisms may also be consumed by various planktivorous fish within a marsh, resulting in a net flux of zooplankton into the marsh (see literature review above).

Finally, some of the proposed restoration sites are far from the centers of distribution of delta and longfin smelt. Travel times from these sites to where the fish are may be on the order of weeks to months in the dry season or when the North Delta diversions are operating (Kimmerer and Nobriga 2008). A plankton population can double or halve its biomass in a few days depending on local food supply and predation. Thus, any export of zooplankton from a restored area should be assumed to subsidize only the local area.

All of these considerations are based on rather crude models of exchange and population processes. That is appropriate given the level of specificity of the BDCP design.

Nevertheless, this analysis raises significant questions about the putative subsidy from restored areas to estuarine foodwebs. To address this uncertainty, long before any actual restoration takes place a program of analysis, modeling, and experimental restoration should be undertaken.

Likely use of restored areas

Like other fish, smelt use a variety of habitats and appear to explore their environment to find suitable places for spawning, growth, and development. As pelagic fish, their principal habitat is open waters of the estuary, either in freshwater during the larval to early juvenile stages in spring to early summer, or in the low-salinity zone until winter. The low-salinity zone during summer-fall is generally in the western Delta and Suisun Bay, including the channels of Suisun Marsh. Delta smelt appear to be surface-oriented, which would allow them access to shallow areas (Aasen 1999).

The fundamental problem for both smelt species in the open-water, brackish regions of the estuary is the low food supply (discussed above) and possibly also the decreasing turbidity (Kimmerer 2004). Those trends may be difficult to reverse, spelling trouble ahead for the smelts. However, in recent years some proportion of the delta smelt population has remained in freshwater in the Cache Slough complex, despite high temperature there (Sommer and Mejia 2013). This may provide an alternative habitat in which the smelt population can either avoid poor conditions in the LSZ, or hedge its bets on future conditions. Longfin smelt are apparently not very abundant in Cache Slough.

Delta and longfin smelt have been collected in the Suisun Marsh fish survey (Matern et al. 2002). Delta smelt are not common in Suisun Marsh during summer-fall but were formerly common in winter to early spring (Matern et al. 2002) when the fish are migrating and spawning. About 0.7% of 3291 otter trawl samples from the Suisun Marsh survey during May-October of 1982 – 2009 and about 3% of 3320 samples during November – April contained delta smelt, mostly maturing juveniles and adults. The low catches in summer were not due to small size of the fish, since young-of-the-year longfin smelt of the same size range were captured frequently in that program. Temperature in the larger sloughs is ~1°C higher than in Grizzly Bay in July and August, based on IEP and UC Davis monitoring data, but if smelt avoid the warmer water in summer it does not explain the low catches for all of May-October. Longfin smelt are much more abundant in the Suisun Marsh channels than delta smelt, occurring in 8% of samples in May-October and 12% of samples in November-April with no obvious differences among the various sloughs.

The 20mm survey catches smelts during spring-summer in Montezuma Slough in Suisun Marsh and in central Suisun Bay including one station in Grizzly Bay near the major western entrance to the marsh. A graphical comparison of catch per trawl in these locations did not reveal a consistent difference for either species. A similar comparison of catch per trawl between Montezuma Slough and Grizzly Bay in the Fall Midwater Trawl survey also did not reveal a consistent difference, except that delta smelt were somewhat less abundant in the slough than in Grizzly Bay during September. Thus, it appears delta and longfin smelt are roughly as abundant in the larger sloughs of Suisun Marsh as in the open water of the estuary.

The key question for this aspect of restoration is whether additional physical habitat would result in larger populations of smelt. Abundance of delta smelt is related to an index of habitat availability based on salinity and turbidity (Feyrer et al. 2007, 2011, Nobriga et al. 2008). However, the size of the LSZ (volume or area) does not seem to be strongly related to the abundance of either smelt species (Kimmerer et al. 2009, in press). This may be because the LSZ is a contiguous stretch of water whose physical features are ephemeral, and the fish can move around readily within that region. In contrast, shallow tidal areas may offer enough physical structure to provide a wealth of sub-habitats with variable conditions. In that case, having more habitat area could lead to a greater abundance of fish. Note that a relationship between the quantity of habitat and the size of a fish population need not rely on a density-dependent relationship between habitat and the survival or reproduction of individual fish, which seems unlikely for delta smelt at current population levels.

Thus, we are cautiously optimistic that restoration of habitat may result in colonization and subsequent population expansion of delta smelt in the Cache Slough area including the Sacramento Ship Channel (Moyle 2008, Sommer and Mejia 2013). Longfin smelt seem unlikely to benefit from this. We cannot determine whether either species would benefit from similar restoration in the Suisun Marsh or the western Delta. The other restoration sites are too remote from the current population centers to offer much reason for optimism about their colonization by either smelt species.

Floodplain

The BDCP proposes to alter the Fremont Weir at the upstream end of the Yolo Bypass so that the Bypass would flood at lower stages of the Sacramento River. We consider here only the likely effects on the smelt species.

Review of conceptual basis

Although the smelt species do not use floodplain as habitat, elevated production of plankton on the floodplain may provide a subsidy to smelt habitat. This situation differs slightly from that of the potential subsidy from marshes discussed above. First, the floodplain is a flow-through system so that increased biomass of plankton will be transported by the mean, river-derived flow rather than by tidal flow. Second, residence time on a floodplain varies with flow conditions, from hours to a few days under high-flow conditions to effectively infinite in ponds remaining after the floodplain stops draining.

Analysis of components

Apart from its suitability as habitat for fish and other species, the Yolo Bypass may also support foodwebs within the estuary. The mechanism for this would be higher phytoplankton and zooplankton production because of shallow depth and better light penetration than in river channels, as well as higher temperature (Lehman et al. 2007). Whether this translates to zooplankton is uncertain; zooplankton abundance on the Bypass was similar to that in the Sacramento River during 1998-2001 (Sommer et al. 2004). Plankton biomass on a floodplain may increase late in the season as residence time increases and fish switch to larger prey (Grozholz and Gallo 2006), but that was not observed on the Yolo Bypass in most years (Sommer et al. 2004).

At very high flows residence time on the Bypass is probably too short to allow for a buildup of biomass, while at lower flows such a buildup may occur but the rate of export may be low (Schemel et al. 2004). This implies that, as with tidal exchange in marshes (Figure 7.3), there is an intermediate range of flow that maximizes export of plankton.

A subsidy from the Yolo Bypass may be more or less direct to delta smelt habitat, notably in the Cache Slough complex at the southern end of the Bypass. In addition, it may subsidize the low-salinity habitat used by both smelt species in late spring through fall.

In Appendix F we examine the evidence for a subsidy of zooplankton to the open water of the estuary under the current configuration using existing zooplankton data. We do not actually calculate the magnitude of the subsidy, since several factors would intervene to alter conditions. In particular, the Bypass could be flooded later in the year than is now the case, and the greater light penetration and higher temperature would provide for greater plankton production than now occurs. Furthermore, Bypass flow would represent a greater proportion of total inflow to the Delta later in the year, resulting in less dilution of the plankton coming off the Bypass.

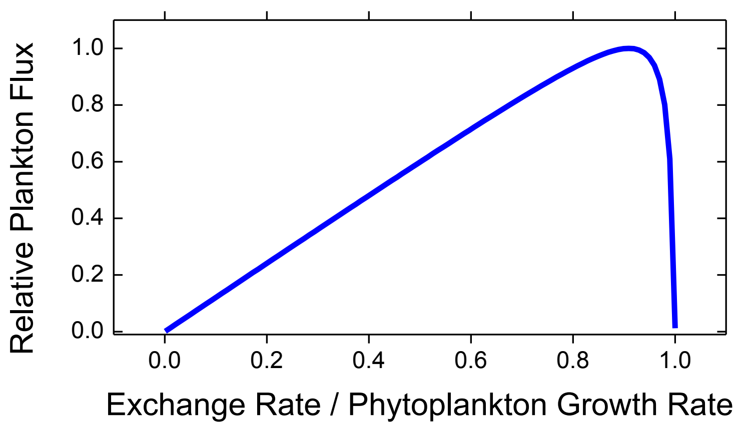

Figure 7.3. Relative magnitude of phytoplankton flux from a tidal marsh as a function of exchange rate, scaled to the growth rate of the phytoplankton. The model is based on a balance among import of nutrients to the marsh, uptake of nutrients to support growth of phytoplankton, and export of phytoplankton. All nutrient uptake is by phytoplankton, there is no consumption, and the phytoplankton concentration in the receiving water is zero.

Our analysis shows no evidence that the open waters of the estuary receive a detectable subsidy of phytoplankton or zooplankton. If anything, plankton abundance is inversely related to Yolo Bypass flow, either during the month of sampling between flow during the winter and zooplankton abundance in the following summer.

Conclusions

There are many reasons for restoring physical habitat in the Delta and Suisun Marsh, and a host of species that are likely to benefit. Among the listed fish species, young salmon use marsh and floodplain during residence, salutatory downstream movement, and active migration. However, it is unclear whether conditions in the Delta have a substantial role in the population dynamics of salmon, and therefore we have elected to focus on the smelt species, for which the Delta is a key part of home (Sommer and Mejia 2013).

The BDCP is overly optimistic about the potential benefits to delta and longfin smelt of physical habitat restoration. Longfin smelt do not appear to use marshes as habitat to any great extent. Delta smelt are also considered pelagic but their persistent abundance in the Cache Slough complex, and greater abundance in shallow rather than deep water, suggests some potential benefit to their population of expanded marsh in that area. The magnitude of this benefit is impossible to predict, as is the degree to which marsh and floodplain restoration might cause an increase, or reverse the decline, in the delta smelt population. Under these conditions it is premature to assert that the restoration activity will have such an effect, until studies including pilot projects and even some smaller full-scale restoration projects can show whether an effect is to be expected.

The idea that restored marsh and floodplain will export substantial amounts of zooplankton to the open waters of the estuary is not tenable. The ecology of shallow waters suggests that shallow areas are more likely to be sinks for zooplankton. Even if they were sources, simple mass-balance considerations indicate that the resulting export would produce at most a small enhancement of extant zooplankton of the open waters. This idea should be dropped from discussions of BDCP, although experimental work should press ahead to determine under what conditions marsh habitats could be sources of significant food for delta and longfin smelt in the open waters.

Chapter 8: Regulatory Oversight and Assurances

Introduction

The previous chapters have demonstrated the relatively high uncertainties associated with proposed conservation actions in BDCP. These uncertainties will likely result in the need to change Plan goals and objectives in the future, along with the prescribed conservation measures to address them.

This chapter addresses the question whether the draft Bay Delta Conservation Plan includes governance policies that are "transparent and resilient to political and special interest influence." We divide our analysis into two parts: (1) analysis of the regulatory oversight of plan implementation and adaptive management; and (2) evaluation of the regulatory assurances and proposed 50-year "no surprises" guarantee.

Regulatory Oversight

Introduction

The draft BDCP vests primary responsibility for implementing the Plan in a Program Manager, who shall "ensure that the BDCP is properly implemented throughout the duration of the Plan" (BDCP 7-2). The Program Manager's authority is broad and includes protection and restoration of habitat, reduction of ecological stressors, management of conserved habitat, coordinated operation of the CVP and SWP, and development of the new facilities authorized by the Plan (BDCP 7-3).[1]

The Program Manager's implementation of the BDCP is subject to oversight by the Authorized Entity Group, which will be comprised of the Director of the California Department of Water Resources as operator of the SWP, the Regional Director of the U.S. Bureau of Reclamation as operator of the CVP, and one representative each of the CVP and SWP contractors if the contractors are issued permits under the Plan (BDCP 7-8).[2] The BDCP also covers certain diversions of water that are not part of CVP or SWP operations and recognizes that these water supply operators may seek incidental take permits under the terms and conditions of the BDCP. If this occurs, these water projects would become Authorized Entities, but would not be members of the Authorized Entity Group (BDCP 7-8).

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[1] The Program Manager also will have responsibility over the Implementation Office, which will assist the Program Manager in all aspects of implementation of the Plan, BDCP 7-4 to 7-5, and the Science Manager and Adaptive Management Team as described in Chapter 9 of this report.

[2] A question has arisen whether the fish and wildlife agencies legally may grant incidental take permits to the CVP and SWP contractors under the federal Endangered Species Act and the California Natural Community Conservation Planning Act. We address this question in the Appendix G.

The Authorized Entity Group's authority over the BDCP also is broad and multifaceted. The draft BDCP states:

> The Authorized Entity Group will provide oversight and direction to the Program Manager on matters concerning the implementation of the BDCP, provide input and guidance on general policy and program-related matters, monitor and assess the effectiveness of the Implementation Office in implementing the Plan, and foster and maintain collaborative and constructive relationships with the State and federal fish and wildlife agencies, other public agencies, stakeholders and other interested parties, and local government throughout the implementation of the BDCP (BDCP 7-8 to 7-9).

This oversight structure means that the Authorized Entity Group will exercise significant authority over both the coordinated operation of the CVP and SWP and implementation of the BDCP itself. Indeed, the draft Plan declares that the Program Manager "will report to the Authorized Entity Group, and act in accordance with the group's direction" (BDCP 7-2).

The draft Plan vests regulatory responsibility within the BDCP in a "Permit Oversight Group," which is composed of the Regional Director of the U.S. Fish and Wildlife Service, the Regional Administrator of the National Marine Fisheries Service, and the Director of the California Department of Fish and Wildlife (BDCP 7-11). It then states that the three agencies "are expected to issue regulatory authorizations to the Authorized Entities" pursuant to the federal Endangered Species Act and the California Natural Community Conservation Act (BDCP 7-11).

The draft Plan also provides that, "[c]onsistent with their authorities under these laws, the fish and wildlife agencies will retain responsibility for monitoring compliance with the BDCP, approving certain implementation actions, and enforcing the provisions of their respective regulatory authorizations" (BDCP 7-11). This means that, although the USFWS, NMFS, and CDFW will work together as members of the Permit Oversight Group for the purpose of supervising implementation of the BDCP, each agency will retain its independent regulatory powers over the CVP, SWP, and other water users under the federal and state Endangered Species Acts.[3]

This structure is consonant with both the Endangered Species Acts and the California Natural Community Conservation Planning Act, because it separates the regulatory oversight responsibilities of the federal and state fish and wildlife agencies from the operational responsibilities of the Program Manager and the Authorized Entity Group. This structural delineation is undermined, however, by the draft Plan's more detailed definition of the "function" of the Permit Oversight Group, which blurs the distinction between implementation and regulation. It also is undermined by provisions in the draft Plan that grant the Authorized Entity

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3 This independent regulatory authority is subject, however, to an important caveat—the draft Plan's requirement of consistency between future section 7 consultations and the BDCP—as described below. *See* pp. 7-8 to 7-9.

Group—rather than the regulatory agencies—veto authority over changes to the conservation measures, biological objectives, and adaptive management strategies, as well as over amendments to the BDCP itself.

Regulatory vs. Programmatic Responsibilities: Implementation

The draft Plan grants the Permit Oversight Group a significant role in implementing the conservation goals and adaptive management strategies of the BDCP:

> The Permit Oversight Group will be involved in certain decisions relating to the implementation of water operations and other conservation measures, actions proposed through the adaptive management program or in response to changed circumstances, approaches to monitoring and scientific research (BDCP 7-11).

It then provides that the Permit Oversight Group "will have the following roles, among others, in implementation matters":

- *Approve, jointly with the Authorized Entity Group,* changes to conservation measures or biological objectives proposed by the Adaptive Management Team.
- *Decide, jointly with the Authorized Entity Group,* all other adaptive management matters for which concurrence has not been reached by the Adaptive Management Team.
- Provide input into the selection of the Program Manager and the Science Manager.
- *Provide input and concur* with the consistency of specified sections of the Annual Work Plan and Budget with the BDCP and with certain agency decisions.
- *Provide input and concur* with the consistency of the Annual Delta Water Operations Plan with the BDCP.
- Provide input and accept Annual Reports.
- *Provide input and approve* plan amendments[4] (BDCP 7-11 to 7-12: emphasis added).

These definitions are poorly drafted, and they assign programmatic authority to the fish and wildlife agencies that may undermine their regulatory responsibilities. We therefore recommend that the draft BDCP be revised in two ways:

First, where the parties to the negotiations want to grant the Permit Oversight Group authority to determine whether certain actions or documents are consistent with the BDCP, the Plan should define its responsibilities more clearly and precisely than does the current language—*e.g.,* "provide input and concur"; "provide input

[4] The draft Plan also contains a placeholder "function," which states that the Permit Oversight Group also may play a role in "decision-making regarding real-time operations, consistent with the criteria of *CM1 Water Facilities and Operation* and other limitations set out in the BDCP and annual Delta water operations plans." As the details of this role as still under negotiation, we do not address it here except to note that the role of the Permit Oversight Group should be clearly defined and limited to regulatory oversight as explained in the text.

and accept"; and "provide input and approve." Thus, the draft Plan should be revised to state:

> The Permit Oversight Group shall have exclusive authority to determine whether the Annual Work Plan Budget and Annual Delta Operations Plan are consistent with the BDCP. If the Permit Oversight Group does not issue a determination of consistency, the document in question shall be revised and resubmitted to the Permit Oversight Group for approval or further remission and revision.

Second, the Permit Oversight Group's role should be limited to regulatory oversight. The "functions" listed in the draft Plan conflate the Permit Oversight Group's regulatory responsibilities with the programmatic implementation duties that are best left with the Program Manager and the Authorized Entities Group. Although there is some practical value in collaboration among the regulators and the regulated—*e.g.,* having the fish and wildlife agencies give their "input" during the drafting of annual operations plans—it is better policy to maintain the exclusive regulatory role of the Permit Oversight Group. A regulatory agency that has a stake in the creation of the program and policy decisions that it must ultimately review will not be able to bring its independent judgment to bear in evaluating those same decisions for consistency with the Plan and other applicable laws.

The conflation of regulatory and programmatic responsibilities is especially dangerous in the case of revisions to the biological objectives, conservation measures, and other adaptive management strategies. As currently written, the draft Plan grants the Authorized Entity Group an effective veto over proposed changes to the these programs, even if the Adaptive Management Team, the Science Manager, the Program Manager, and the Permit Oversight Group have concluded that changes are needed to ensure programmatic compliance with the BDCP or to fulfill the requirements of the federal and state Endangered Species Acts (BDCP 7-11).

A better course would be to revise the draft Plan to allow the Science Manager and Adaptive Management Team—subject to oversight and approval from the Program Manager and Authorized Entity Group—to make revisions to the biological objectives, conservation measures, and other adaptive management strategies. These changes then would be submitted to the Permit Oversight Group for review and approval or remission. The Permit Oversight Group also should have independent authority to revise the biological objectives, conservation measures, and other adaptive management strategies if it concludes that the existing programs are inadequate to comply with the BDCP or other governing law.

Regulatory vs. Programmatic Responsibilities: Policy Modifications and Amendments to the BDCP

A similar problem exists for modifications to the BDCP itself. The draft Plan recognizes that "Plan modifications may be needed periodically to clarify provisions or correct unanticipated inconsistencies in the documents" (BDCP 6-45). It then identifies three types of plan modifications: administrative changes, minor modifications, and formal amendments. Only the latter two concern us here.

The draft Plan defines "minor modifications" as including transfers of acreage between Restoration Opportunity Areas or conservation zones and "[a]djustments of conservation measures or biological objectives . . . consistent with the monitoring and adaptive management program and intended to enhance benefits to covered species" (BDCP 6-46). It then describes "formal amendments" as including, but not limited to:

- Changes to the geographic boundary of the BDCP.
- Additions of species to the covered species list.
- Increases in the allowable take limits of covered activities or the addition of new covered activities to the Plan.
- Substantial changes in implementation schedules that will have significant adverse effects on the covered species.
- Changes in water operations beyond those described under *CM1 Water Facilities and Operations*. (BDCP 6-47).

The "minor modifications" and "formal amendments" thus include all aspects of BDCP implementation that will be vital to the success or failure of the BDCP. Yet, the draft Plan expressly provides that the Authorized Entities may veto any such changes.[5] For minor modifications, the draft BDCP states: "If any Authorized Entity disagrees with the proposed minor modification or revision for any reason, the minor modification or revision will not be incorporated into the BDCP" (BDCP 6-46).[6] The draft Plan similarly declares that formal amendments "will be subject to review and approval by the Implementation Office and the Authorized Entities."[7]

The BDCP is fundamentally a set of terms and conditions that allow the principal regulatory agencies—the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Wildlife—to authorize the construction and operation of physical improvements to the Delta that will facilitate more reliable (and, one may hope, more environmentally sustainable)

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[5] Please note that the draft BDCP states that the Authorized Entities—not the Authorized Entity Group—hold this veto power. This may be a typographical error, as the Authorized Entities are not granted implementation decisionmaking authority (except through the Authorized Entity Group) any other place in the document. If it the BDCP negotiators in fact intend to vest veto authority in the Authorized Entities, however, this is especially problematic as the Authorized Entities potentially include water users other than those that comprise the Authorized Entity Group. BDCP 7-8.

[6] By contrast, if any of the fish and wildlife regulatory agencies disagrees with a proposed minor modification, its rights are limited to insisting that the proposal be treated as a formal amendment to the Plan. BDCP 6-46.

[7] At least in the case of formal amendments the draft Plan recognizes a relative parity in the rights of the regulators and the regulated, acknowledging that such amendments "will require corresponding amendment to the authorizations/ permits, in accordance with applicable laws and regulations regarding permit amendments." BDCP 6-47. It also states, however, that the "fish and wildlife agencies will use reasonable efforts to process proposed amendments within 180 days." BDCP 6-46.

exports of water by the CVP and SWP. Although the motivating purpose of the BDCP is to facilitate this water development, the regulatory agencies' foundational responsibility is to ensure that the project does not jeopardize the continued existence of the species that are listed for protection under the federal and state Endangered Species Acts.

To accomplish this essential obligation, the fish and wildlife agencies must both insist on an initial set of biological objectives, conservation measures, and conditions on coordinated project operations that will fulfill this purpose; *and* they must have the means of ensuring that the implementation of the BDCP will continue to achieve that goal throughout its fifty year term.

We do not believe that the draft Plan satisfies this second requirement, as it vests veto authority over necessary changes in the biological objectives, conservation measures, adaptive management strategies, and the terms and conditions of the BDCP itself, not in the regulatory agencies, but in the regulated entities that comprise the Authorized Entity Group. We therefore recommend revision of the draft Plan to require that all "minor modifications" and "formal amendments" to the BDCP be subject to review and approval by the Permit Oversight Group.

As explained above, we also recommend that the draft Plan be revised to authorize the Permit Oversight Group itself to initiate and make changes to the biological objectives, conservation measures, and other adaptive management strategies that the fish and wildlife agencies conclude are needed to ensure the protection and recovery of the species listed under the federal and state Endangered Species Acts. This unilateral authority must extend to all of the identified "minor modifications" and to at least one of the defined "formal amendments"—*viz.* "substantial changes in implementation schedules that will have significant adverse effects on the covered species" (BDCP 6-47).[8]

The other listed "formal amendments"—which include alteration of the geographic boundaries of the Plan and the addition of new species and covered activities—are different, as they include possible changes to the scope and structure of the BDCP, rather than adaptive changes to the implementation and achievement of the goals of the existing BDCP. The draft Plan therefore properly states that formal amendments

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[8] The governance structure set forth in the current draft Plan also may jeopardize the likelihood that the BDCP will be incorporated into the Delta Plan. *See* California Water Code § 85320-85322. The Delta Reform Act provides:

> The BDCP shall include a transparent, real-time operational decisionmaking process in which *fishery agencies ensure that applicable biological performance measures are achieved in a timely manner with respect to water system operations.* [*Id.* § 85321 (emphasis added).]

The Authorized Entity Group's veto authority over changes to the biological objectives, conservation measures, and adaptive management strategies means that the fish and wildlife agencies would not have the power to ensure that the biological measures will be achieved. The draft Plan therefore violates this statutory mandate, and the CDFW and the Delta Stewardship Council consequently would likely be precluded from incorporating the BDCP into the Delta Plan.

"will involve the same process that was required for the original approval of the BDCP"--i.e., approval of both the Authorized Entities and the Permit Oversight Group (BDCP 6-47).[9]

Regulatory Assurances and the "No Surprises" Policy

Introduction

The draft Plan proposes to create two types of "regulatory assurances." First, it seeks to eliminate the uncertainties associated with consultation under section 7 of the federal Endangered Species Act for coordinated CVP and SWP operations by stipulating that future biological opinions shall be consistent with the terms and conditions of the BDCP. Second, it offers "no surprises" guarantees both for deviations between the biological opinions and the BDCP and for future changes to the BDCP itself. In addition, the draft Plan places difficult scientific, legal, and political burdens on the state and federal governments' power to terminate the incidental take permits and to rescind the BDCP.

In our judgment, these regulatory assurances compound the risks described in the preceding section because they severely constrain the fish and wildlife agencies' ability to respond to inadequacies in the biological objectives, conservation measures, and other adaptive management strategies—even apart from the veto authority that the draft Plan vests in the Authorized Entity Group.

Section 7 Consultation and the BDCP

According to the draft Plan, once the facilities authorized by the BDCP are constructed, the Plan will largely displace the existing section 7 consultation requirements applicable to coordinated CVP and SWP operations: "On the basis of the BDCP and the companion biological assessment, it is expected that USFWS and NMFS will issue a new joint biological opinion (BiOp) that would supersede BiOps existing at that time as they relate to SWP and CVP actions addressed by the BDCP" (BDCP 4-2). The draft Plan then requires that the new biological opinion (as well as any subsequent biological opinions issued during the 50-year term of the BDCP) be consistent with the terms and conditions of the BDCP itself:

> The BDCP is intended to meet the requirements of the ESA and provide the basis for regulatory coverage for a range of activities identified in the Plan. . . .

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[9] The draft Plan also provides that, "[i]n most cases, an amendment will require public review and comment, CEQA and NEPA compliance, and intra-Service Section 7 consultation," and it requires the fish and wildlife agencies to use "reasonable efforts to process proposed amendments within 180 days." BDCP 6-47. 180 days is probably insufficient time, however, to allow for section 7 consultation, internal agency analysis of the effects of proposed formal amendments on listed species and their habitat, and the drafting, public review, and completion of a new or supplemental EIS/EIR.

It is also worth noting that even this limited "bilateral" approval process for structural amendments to the BDCP may not be consistent with federal law. The ESA rules provide that all incidental take permits "are issued subject to the condition that the National Marine Fisheries Service reserves the right to amend the provisions of a permit for just cause at any time during its term." 50 C.F.R. § 222.306(c).

> Unless otherwise required by law or regulation, in any Section 7 consultation related to a covered activity or associated federal action and covered species, USFWS and NMFS will each ensure that the resulting BiOps are consistent with the integrated BiOp for the BDCP (BDCP 6-44).

We do not necessarily object to this consistency directive. An important goal of the BDCP is to provide all parties—especially the Authorized Entities—with a measure of regulatory and operational certainty that will enable them both to invest in the new facilities and to make water management decisions in their respective service areas in reliance on water deliveries from the CVP and SWP. To the extent that future section 7 consultations conform to the terms of the BDCP, that certainty is enhanced. We also note the first clause of the second sentence quoted above, which expressly reserves the authority of USFWS and NMFS to issue biological opinions that depart from the terms of the BDCP if necessary to comply with the governing law. This law, of course, includes section 7(a)(2) of the federal ESA, which requires all consulting agencies to ensure that their actions are "not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of [critical] habitat." 16 U.S.C. § 1536(a)(2).

We do believe, however, that the proposal to substitute the BDCP for section 7 consultation as the principal means of applying the federal Endangered Species Act to the CVP, SWP, and other Authorized Entities reinforces our recommendations from the preceding section—*viz.* that the Permit Oversight Group must maintain the independent regulatory prerogatives that the fish and wildlife agencies currently possess and must have authority to approve or to deny proposed changes in the biological objectives, conservation measures, and other terms and conditions of the BDCP as required to protect and recover the species covered by the Plan. Our support for the biological opinion/BDCP consistency directive should be read with this caveat.

"No Surprises"

The draft Plan contains two "no surprises" guarantees. The first applies to changes in coordinated CVP and SWP operations or water supply capabilities that may be required by future biological opinions that do not conform to the BDCP. The second is a more general "no surprises" commitment that protects the Authorized Entities from certain changes to the BDCP itself[10].

According to the draft Plan, "Ecological conditions in the Delta are likely to change as a result of future events and circumstances that may occur during the course of the implementation of the BDCP" (BDCP 6-30). The draft then lists seven "Changed Circumstances Related to the BDCP"—levee failures, flooding, new species listings, wildfire, toxic or hazardous spills, nonnative invasive species, and climate change (BDCP 6-31). For each of these "reasonably foreseeable" changes, the draft Plan describes the "planned responses" that BDCP administrators will undertake (BDCP

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[10] As noted in chapter 2, USBR is not covered by the "no surprises" assurance. BDCP 6-29.

6-31 to 6-42).[11] The draft Plan states that the responses "have been designed to be practical and roughly proportional to the impacts of covered activities on covered species and natural communities, yet sufficient to effectively address such events" (BDCP 6-30). The BDCP budget will include funds to cover the costs of implementing some of the planned responses to "reasonably foreseeable" changed circumstances (BDCP 6-30).[12]

The draft Plan also recognizes that "unforeseen circumstances" may require changes to the biological objectives, conservation measures, adaptive management strategies, or the terms and conditions of the BDCP itself. It defines unforeseen circumstances as "changes in circumstances that affect a species or geographic area covered by an HCP that could not reasonably have been anticipated by the plan participants during the development of the conservation plan, and that result in a substantial and adverse change in the status of a covered species" (BDCP 6-42 citing 50 C.F.R. § 17.3 & 50 C.F.R. § 222.102). The draft Plan contains a similar definition of "unforeseen circumstances" under state law. These are "changes affecting one or more species, habitat, natural community, or the geographic area covered by a conservation plan that could not reasonably have been anticipated at the time of plan development, and that result in a substantial adverse change in the status of one or more covered species" (BDCP 6-43 citing California Fish & Game Code § 2805(k)).

The draft Plan then sets forth the following regulatory assurances under federal and state law:

> Under ESA regulations, if unforeseen circumstances arise during the life of the BDCP, USFWS and/or NMFS may not require the commitment of additional land or financial compensation, or additional restrictions on the use of land, water, or other natural resources other than those agreed to in the plan, unless the Authorized Entities consent (BDCP 6-42).

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[11] The Implementation Office is charged with identifying the onset of a changed circumstance, working with the Permit Oversight Group to fashion a response, and for implementing and monitoring the responsive actions (BDCP 6-31).

[12] This funding process is described in Chapter 8 of the draft BDCP. *See* BDCP 8-60 to 8-64. The draft states generally that, to "allow for the ability to respond to changed circumstances should they occur, the Implementation Office should maintain a reserve fund for covering costs of changed circumstances" (BDCP 8-61). The draft Plan explains that this is because "the risk of some changed circumstances—*e.g.,* failure of levees attached to tidal marsh and floodplain restoration—and cost of remedial measures increases as greater portions of the conservation strategy are implemented." *Id*.

The draft BDCP only includes levee failure and wildfire damage to preserved lands as possible "changed circumstances for which responses are expected to result in additional implementation costs." *Id.* It omits "changed circumstances related to climate change, flooding, failure of water operations infrastructure, nonnative invasive species, new species listings, and toxic or hazardous spills," explaining that the response costs for these are accounted for in the initial BDCP funding, will be paid by the state and federal governments under the "no surprises" guarantees, or would be the responsibility of a third party. BDCP 8-61 to 8-62.

> In the event of unforeseen circumstances, CDFW will not require additional land, water, or financial compensation or additional restrictions on the use of land, water, or other natural resources without the consent of the plan participants for a period of time specified in the Implementation Agreement (BDCP 6-43).[13]

As noted above, for federal agencies that are subject to section 7 consultation (including consultation for coordinated CVP/SWP operations), the draft Plan contains an additional "no surprises" pledge if new biological opinions contain operational or water supply restrictions that differ from those set forth in the BDCP:

> Furthermore, USFWS and NMFS will not require additional land, water, or other natural resources, or financial compensation or additional restrictions on the use of land, water, or other natural resources regarding the implementation of covered activities beyond the measures provided for under the BDCP, the Implementing Agreement, the incidental take permits, and the integrated BiOp (BDCP 6-44).

The purpose of these regulatory assurances is to exempt the Authorized Entities from any of the costs of complying with the federal and state Endangered Species Acts except as defined in (and funded pursuant to) the terms of the BDCP. These "no surprises" guarantees therefore may place the financial burden of some future changes to the BDCP and project operations exclusively on state and federal taxpayers.

Although both federal Endangered Species Act regulations and the California Natural Community Conservation Planning Act authorize "no surprises" guarantees, we believe, given the uncertainties outlined in the previous chapters, that there is a significant risk that the costs of compensating the projects and their contractors for future "unforeseen" hydrologic, engineering, and operational changes will be excessive. More importantly, we are concerned that the state and federal governments' assumption of liability may deter the fish and wildlife agencies from making changes to future biological opinions or to the BDCP itself that the agencies believe are necessary to protect and recover listed species. The following example focusing on the "reasonably foreseeable" changed circumstance of climate change illustrates our concerns.

The draft Plan defines climate change as "[l]ong-term changes in sea level, watershed hydrology, precipitation, temperature (air or water), or ocean conditions that are of the magnitude or effect assumed for the effects analysis and that adversely affect conservation strategy implementation or covered species are considered a changed circumstance" (BDCP 6-41). It then provides that the

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[13] The draft Plan notes that, under California law, "such assurances are not applicable in those circumstances in which CDFW determines that the plan is not being implemented in a manner consistent with the substantive terms of the Implementation Agreement." BDCP 6-43 (citing California Fish & Game Code § 2820(f)(2)).

"occurrence of this changed circumstance will be determined jointly by the Implementation Office and fish and wildlife agencies" (BDCP 6-41).[14]

According to the draft Plan, however, alterations in the ecosystem and threats to listed species caused by climate change will not trigger any management or regulatory responses beyond those set forth in the BDCP. "Because the BDCP already anticipates the effects of climate change, no additional actions will be required to remediate climate change effects on covered species and natural communities in the reserve system" (BDCP 6-41). Rather, the Adaptive Management Team will monitor these changes and the Implementation Office will "continually adjust conservation measures to the changing conditions in the Plan Area as part of the adaptive management program" (BDCP 6-42).

The draft Plan also states that all responses to climate change "will be made as part of the adaptive management and monitoring program. Measures beyond those contemplated by the adaptive management and monitoring program are not likely to be necessary because the conservation strategy was designed to anticipate a reasonable worst-case scenario of climate change. *A change in conservation measures in response to climate change beyond that considered in Chapter 3,* Conservation Strategy, *and through the adaptive management and monitoring program is considered an unforeseen circumstance.*" (BDCP 6-42: emphasis added).

There are two serious problems with this changed circumstances strategy:

First, although the "biological goals and objectives [of the BDCP] have been established at the landscape level to take climate change into account during conservation strategy implementation," and the "conservation strategy, monitoring and research program, and adaptive management and monitoring program already include responses to anticipate climate change effects at the landscape, natural community, and species scales" (BDCP 6-42), the draft Plan correctly anticipates that the biological objectives, conservation measures, and other adaptive management strategies are likely to be modified over time as required to respond to the changed conditions brought about by climate change. Yet, as described previously, all such modifications are subject to approval by the Authorized Entities (BDCP 6-46). The fish and wildlife agencies consequently lack independent authority to determine the appropriate policy and management responses to climate change, even within the confines of the defined responses set forth in Chapter 3 of the BDCP.

Second, changes in conservation measures that differ from the defined responses are "unforeseen circumstances," which trigger the "no surprises" guarantee. Again, while the draft Plan anticipates a broad array of ecological changes likely to be caused by climate change, and lays out a detailed set of programmatic responses, it is folly to believe that the BDCP scientists and negotiators have correctly identified

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[14] We reiterate here the problems that we identified in the preceding section: conflation of the fish and wildlife agencies' regulatory and programmatic roles and the granting of an effective veto to the regulated entities through the Implementation Office.

all of the hydrologic changes, biotic responses, and risks to the ecosystem that will in fact occur over time. As one recent interdisciplinary study of California water policy emphasized:

> New approaches to ecosystem management under changing conditions will require continued, large-scale experimentation aided by computer modeling. This task is complex, because experiments, especially on a large scale, often yield ambiguous results. Also, as with hydrology, the past is not always a good predictor of the future with many ecosystems. Linking human and natural systems, combined with changes in climate and influxes of alien species, creates novel, dynamic ecosystems with no historical analog. Thus, efforts to restore ecosystem functions and attributes involve hitting a moving, only partially visible target. Finally, ecosystem changes are often nonlinear and interrelated. Declines in habitat quality or abundance reduce ecosystem resiliency, with the result that even small changes in conditions can lead to abrupt system collapse and reorganization to a new state. Such thresholds or tipping points are difficult to predict. *Taken together, these factors suggest that efforts to improve conditions for California's native aquatic species will necessarily involve trial and error, and that success is far from guaranteed.*
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> * * *
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> The difficulty is compounded by the high uncertainty of success for specific actions, given ecosystem complexity, gaps in knowledge of how to manipulate many key processes, and, most important, continuing change in climate, invasive species, and other conditions in California. *As a result, a flow regime or water quality target that seems adequate today may not provide the same services in 20 to 30 years. Aiming at a moving target in semi-darkness means that there will be many misses.* (From: Hanak et al., 2011: emphasis added).

The potential consequences of the "no surprises" guarantee in this context are troubling. Fisheries biologists generally agree that diminished seasonal outflow and warming water temperatures place several listed species at risk of extinction (see Cloern et al., 2011; Moyle et al., 2013). The projects that would be authorized by the BDCP should reduce some of the sources of stress on these species by reducing entrainment and predation and by creating substitute habitat, but they will not address several other important stressors such as diminished summer and fall outflow and rising water temperatures. Therefore, sometime during the 50-year term of the BDCP, it may be necessary to construct additional upriver storage (*e.g.,* by increasing the capacity of Shasta Reservoir) to enable more sustained cold-water releases to protect salmon spawning and out-migration.

Yet, under the draft Plan, this action would constitute an "unforeseen circumstance," because it falls outside the defined responses to climate change set forth in the BDCP. The consequence would be that the state and federal taxpayers would have to bear all of the costs of constructing and operating the new or expanded storage, even though the fish and wildlife agencies determined that this action is needed to protect one or more listed species from extinction (while maintaining reservoir releases and exports at the levels and timing authorized by the BDCP).

Alternatively, if funding were not available to construct the new storage capacity, and the fish and wildlife agencies made jeopardy findings and issued new biological opinions that altered reservoir release requirements in a manner that reduced water supply or export capacity, the state and federal governments would have to compensate the Authorized Entities for the value of the lost water or the cost of replacement supplies.[15]

For these reasons, we do not believe that the 50-year "no surprises" guarantees are wise or prudent policy. We understand that the Authorized Entities seek to protect their capital investment and obtain maximum security of their water service capabilities, and that a relatively fixed set of biological objectives, conservation measures, and operational constraints help to achieve these goals (BDCP 1-26). But a 50-year commitment is ill-advised in an ecosystem as complex, variable, and scientifically inscrutable as the Delta. As our colleague Peter Moyle has observed, in the Delta Ecosystem, "[o]ver-negotiation of details in advance is unlikely to enable adequate responsiveness and flexibility" and "even the most well-informed, scientifically based management will encounter surprises and make mistakes" (From Moyle et al., 2012).

The parties to the BDCP negotiations therefore should consider separate "no surprises" guarantees—one governing construction of the BDCP projects, and a series of operational "no surprises" commitments that would be reevaluated every

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[15] During the July 23, 2013, meeting with DWR Director Mark Cowin and CDFW Director Chuck Bonham, Director Cowin stated that it was not the parties' intent to apply the "no surprises" policy to actions taken outside the plan area that may be required to address the effects of climate warming or other changed conditions on listed species. Although we were pleased to learn this, we retain the concerns described in the text for two reasons: First, the draft Plan does not state that new infrastructure or operational changes needed to ensure the survival of species covered by the BDCP are exempt from the "no surprises" guarantee if they are located outside the plan area. Rather, the draft links CVP and SWP facilities and water supply operations upstream of the plan area to the conservation measures that may be required to protect covered species and their downstream habitat (BDCP 1-20). Without an explicit limitation on the "no surprises" guarantee to new, "unforeseen" conservation measures undertaken within the plan area, we believe that there is an unacceptable risk that the Authorized Entities could raise a plausible claim that the "no surprises" policy exempts them from liability for new facilities and operational changes upstream of the plan area that are needed to protect covered species within the plan area.

Second, the draft Plan expressly extends the "no surprises" assurance for future section 7 consultations over new facilities and other changes in CVP operations that are outside the plan area and not part of the BDCP covered activities. The draft Plan stipulates that "USFWS and NMFS will further ensure that the terms of any BiOp issued in connection with projects that are independent of the covered activities and associated federal actions do not create or result in any additional obligation, cost, or expense to the Authorized Entities" (BDCP 6-44).

If the parties to the BDCP negotiations do not intend for the "no surprises" guarantee to cover new construction and project operational changes outside the plan area, then they should revise the draft Plan to say so explicitly and clearly. We also recommend that the sentence quoted above, which exempts the Authorized Entities from all costs associated with section 7 consultations to project facilities and operations other than BDCP covered activities be deleted.

ten years based on *current* information on the appropriateness of the biological objectives, the success or failure of the conservation measures, species survival and recovery, overall ecosystem health, climate change, invasive species, discharges, the effects of authorized project operations, other stressors, and regulatory compliance.

We have chosen ten years for the recommended length of renewable "no surprises" assurances because a ten-year period is likely to include a variety of different types of water years and thus will be sufficiently lengthy to enable BDCP managers and regulators to evaluate how well the biological objectives and conservation measures perform across a spectrum of hydrologic conditions. At the same time, ten years is short enough to minimize the risk that the terms and conditions of the BDCP become antiquated and ineffective in light of the inevitable and unpredictable changes to the ecosystem. Indeed, a series of renewable ten-year "no surprises" guarantees could create a constructive incentive for the parties to the BDCP to monitor progress and achievement of the biological objectives and conservation measures and to make adaptive management changes as required to sustain and recover the covered species and their habitat.[16]

Revocation of Incidental Take Permits and the BDCP

Many of our concerns about the rigidities of the draft Plan and the scope and length of the regulatory assurances would be lessened if there were an effective means of revoking the incidental take permits and thus rescinding the BDCP. But there is not.

As described in the draft Plan, the "Permit Revocation Rule," adopted in 2004, allows the federal fish and wildlife agencies "to nullify regulatory assurances granted under the No Surprises rule and revoke the Section 10 permit only in specified instances, including where continuation of a permitted activity would jeopardize the continued existence of a species covered by an HCP and the impact of the permitted activity on the species has not been remedied in a timely manner" (BDCP 6-48: quoting 69 Fed. Reg. 7172 (Dec. 10, 2004)). The draft Plan states,

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[16] There is nothing in federal or state law that requires that the term of a "no surprises" guarantee be coextensive with the term of the HCP/NCCP. Indeed, the California Natural Communities Conservation Planning Act requires that the duration of all regulatory assurances be based on a careful assessment of the limits of scientific understanding of the covered species and their habitat. California Fish & Game Code § 2820(f) states that the CDFW's "determination of the level of assurances and the time limits specified in the implementation agreement for assurances may be based on localized conditions and shall consider":

> (A) The level of knowledge of the status of the covered species and natural communities.
>
> (B) The adequacy of analysis of the impact of take on covered species.
>
> (C) The use of the best available science to make assessments about the impacts of take, the reliability of mitigation strategies, and the appropriateness of monitoring techniques.
>
> (D) The appropriateness of the size and duration of the plan with respect to quality and amount of data.
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> * * *
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> (H) The size and duration of the plan.

however, that the "USFWS or NMFS will begin the revocation process only if it is determined that the continuation of a covered activity will appreciably reduce the likelihood of survival and recovery of one or more covered species and that no remedy [other than revocation] can be found and implemented" (BDCP 6-49).

Similarly, under the California Natural Communities Conservation Planning Act, the Department of Fish and Wildlife may revoke the state incidental take permit "if necessary to avoid jeopardizing the continued existence of a listed species" (BDCP 6-49: citing California Fish & Game Code § 2820(c)).[17] The federal and state fish and wildlife agencies also may revoke the permits if the Authorized Entities fail to fulfill their obligations under the BDCP, but only following the dispute resolution process set forth in the Implementing Agreement and "providing the Implementation Office and Authorized Entities with a reasonable opportunity to take appropriate responsive action" (BDCP 6-49).

Before the fish and wildlife agencies may revoke the incidental permits, they must follow a variety of procedures and substantive standards. These include determining, in concert with the Implementation Office, "whether changes can be made to the conservation strategy to remedy the situation" and whether "there are additional voluntary implementation actions that the Authorized Entities could undertake to remedy the situation."

More importantly, the draft Plan also requires the federal fish and wildlife agencies to determine whether they or some other agencies can take actions to ensure the survival of the listed species, rather than imposing such burdens on the parties to the Authorized Entities:

> The USFWS or NMFS will determine whether the fish and wildlife agencies or other state and federal agencies can undertake actions that will remedy the situation. The determination must be based on a thorough review of best available practices considering species population status and the effects of multiple federal and nonfederal actions. *It is recognized that the fish and wildlife agencies have available a wide array of authorities and resources that can be used to provide additional protection for the species, as do other state and federal agencies* (BDCP 6-48 & 6-50: emphasis added).

The draft Plan thus makes it difficult for the fish and wildlife agencies to revoke the incidental take permits if the biological objectives, conservation measures, and adaptive management changes do not achieve their primary goal of protecting and recovering the listed species. Procedural and substantive rigor is not in and of itself

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[17] Section 2820(c) actually addresses a more limited violation of the terms of an NCCP, providing for suspension or revocation if a plan participant fails to "maintain the proportionality between take and conservation measures specified in the implementation agreement and does not either cure the default within 45 days or enter into an agreement with the department within 45 days to expeditiously cure the default." California Fish & Game Code § 2820(c). The more general revocation standard is set forth in section 2820(b)(3)(A)-(D) of the Act.

reason to doubt this last line of defense against extinction. But two additional facts lead us to the conclusion that permit revocation is not likely to be a credible means of ensuring the survival of the species if the BDCP fails its most essential task.

First, neither the federal fish and wildlife agencies nor the California Department of Fish and Wildlife have ever revoked an incidental take permit. Indeed, there is only one case in which a federal incidental take permit has been suspended, and that was for the permittee's violation of the terms and conditions of the habitat conservation plan, rather than because of changes in ecological conditions or the permittee's failure to agree to amendments to the biological objectives and conservation measures[18]. Revocation of the incidental take permits covered by the BCDP therefore would be an unprecedented event.

Second, a decision to revoke the incidental take permits would not be simply a scientific determination that the BDCP—as written today and implemented at some future date during its 50-year existence—is not adequate to ensure the conservation and recovery of the listed species. Although the BDCP assigns the authority to revoke the state incidental take permit to the Director of the California Department of Fish and Wildlife (BDCP 6-50), it stipulates that "[a]ny decision to revoke one or both federal permits must be in writing and must be signed by the Secretary of the Interior or the Secretary of Commerce, as the case may warrant" (BDCP 6-49).[19] In our judgment, this poses an undue risk that the revocation decision would be based on science *and* political considerations. Indeed, there would seem to be no other purpose for elevating the revocation authority from the fish and wildlife agencies to the two Cabinet-level Secretaries.

For these reasons, we do not believe that the state and federal authority to revoke the incidental take permits compensates for the deficiencies in the draft BDCP described above.

Conclusion

We conclude that governance structure set forth in the draft BDCP is neither "transparent [nor] resilient to political and special interest influence." The draft undermines the authority of the federal and state fish and wildlife agencies both by assigning them program responsibilities and by granting the Authorized Entities veto power over changes to the biological objectives, conservation measures, and adaptive management strategies that may be needed to ensure that the Plan achieves its stated goals. To address this deficiency, we recommend that the BDCP be revised to remove the Permit Oversight Group from program decisionmaking and to clarify the regulatory authority of the fish and wildlife agencies both within the BDCP and in their independent roles as principal regulators under the federal and

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18 *See* U.S. Fish and Wildlife Service Letter to Victor Gonzales, President of WindMar Renewable Energy, Feb. 2, 2012 (decision of partial suspension of incidental take permit).

19 This would change the process for permit revocation set forth in the federal ESA rules, which vest revocation authority in the Director of the U.S. Fish and Wildlife Service. 50 C.F.R. § 17.22(b)(7).

state Endangered Species Acts and the California Natural Community Conservation Planning Act.

We also believe that the regulatory assurances contained in the draft Plan jeopardize the ability of the fish and wildlife agencies to respond to changed conditions that may require future revisions to the biological objectives and conservation measures of the BDCP. The "no surprises" guarantees—by which the state and federal governments would assume the financial costs of new infrastructure and regulatory changes in CVP/SWP operations needed to address the effects changed circumstances not provided for in the BDCP—are especially troubling. To address this problem, we recommend that the proposed 50-year "no surprises" guarantees be converted into a series of renewable guarantees—the first to cover construction of the projects authorized by the BDCP and the successors to cover project operations for sequential ten-year periods.

Finally, although the fish and wildlife agencies retain the authority to revoke the incidental take permits—and thus to rescind the BDCP—if necessary to avoid jeopardizing any listed species, the draft Plan makes it difficult to do so by requiring the federal agencies to take action against other stressors on the species before determine that it is necessary to revoking the permits. The draft also removes the revocation decision from the federal agencies themselves and places it with the Cabinet-level Secretaries in whose Department the fish and wildlife agencies are located. We believe that these heightened substantive and procedural requirements reduce the likelihood that permit revocation would serve as an effective backstop in the event that the BDCP fails to achieve its overriding purposes of ensuring the survival and contributing to the recovery of the species. Indeed, these limitations on permit revocation strengthen our conclusions that the governance problems described throughout this chapter be repaired so that the fish and wildlife agencies retain the authority to insist on changes to the biological objectives and conservation measures of the BDCP as required to achieve species conservation and recovery.

CHAPTER 9: SCIENCE AND ADAPTIVE MANAGEMENT IN BDCP

Introduction

From the outset BDCP makes it clear that it will be science-based and adhere to the principles of adaptive management. The plan recognizes that all 22 conservation measures that are designed to meet the plan goals and objectives face high levels of uncertainty and that measures used to implement them will inevitably require adjustment and refinement. Indeed, given the unprecedented complexity of BDCP, it will most certainly fail without substantial investments in a program of science and monitoring linked to a robust adaptive management program that allows it to change course.

At the time of this review, the science and adaptive management component of BDCP was, by the project proponents' own admission, a work in progress with many of the key elements yet to be determined. We briefly review here the available information with the understanding that these elements are likely to change, possibly considerably, before the public draft is released.

Adaptive Management Program

The plan documents recognize that BDCP is compelled to adhere to an array of standards for adaptive management of the program (summarized in Chapter 3 of BDCP). This includes requirements of USFWS and NMFS five-point policy on adaptive management (65 Fed. Reg. 35241-35257), NCCPA requirements for monitoring and adaptive management programs (Fish & Game Code § 2820(a)(7) & (8), and the requirements of the Delta Reform Act for science-based adaptive management of all ecosystem and water management programs in the Delta (Water Code § 85308(f)).

The BDCP documents describe the well-known adaptive management cycle involving: *plan*, where management problems are recognized leading up to a plan of action to test management actions, *do*, where plans are implemented, accompanied by monitoring, and *evaluate*, where monitoring information is evaluated to measure effectiveness, and information learned initiates anew the planning portion of the cycle. As described in BDCP, the conceptual approach to adaptive management is closely aligned to the approach codified in the Delta Plan and the draft Delta Science Plan.

Governance and Implementation of Adaptive Management

BDCP envisions that its adaptive management program will be organized and run by its Implementation Office. The office will be run by a Program Manager who will be hired by the Authorized Entity Group (AEG). The AEG will be made up of DWR, Reclamation, and the state and federal water contractors. The Program Manager selects and supervises a Science Manager, who takes on the responsibilities of running the adaptive management programs and coordinating, in unspecified ways, all science and monitoring activities.

The Science Manager will chair and manage an Adaptive Management Team (AMT) made up of a broad array of regulators, regulated entities, and science programs. These include representatives appointed by members of the AEG, the Permit Oversight Group (POG: CDFW, USFWS, NMFS), the Interagency Ecological Program (IEP), Delta Science Program (DSP), and NOAA Southwest Fisheries Science Center. This group will receive input from a Technical Facilitation Subgroup, part of a Stakeholder Council made up of multiple of stakeholder groups, regulated entities, and regulating entities.

The AMT, led by the Science Manager, will have the responsibility for designing, administering and evaluating the BDCP adaptive management program, including the development of performance measures, monitoring and research plans, synthesis of data, solicitation of independent review, and developing proposals to modify biological goals and objectives as well as conservations measures.

The AMT is to operate by consensus only, meaning all members must agree to all actions. Where consensus cannot be reached the matter is elevated to the AEG and POG for resolution. As a matter of course, all changes in conservation measures and biological goals and objectives must be approved by the POG and AEG. The entity responsible for decisionmaking (for example, NMFS regarding changes in biological goals and objectives for salmon) will decide the issue. However, as discussed in Chapter 8, *any member of the AEG or POG may request review of the decision at the highest level of the relevant federal department or state, up to the appropriate department secretary or the Governor of California* (BDCP Chapter 7, Section 7.1.7).

An essential goal of the adaptive management program—seeking consensus for all decisions from all regulated and regulating entities as well as key providers of science—is understandable and, if it could be achieved, laudable. However, for several reasons this is unlikely to be successful.

First, as discussed in Chapter 8, this structure confuses the roles of regulators and regulated entities. It gives exceptional decision power to regulated entities, particularly those with a great financial stake in outcomes (state and federal water contractors). We are skeptical that difficult, perhaps costly decisions could be achieved in an efficient and effective manner since *any* member of the AEG or POG can, in effect, elevate any decision, no matter how trivial, to the highest levels of government. This is likely to have a chilling effect on decisionmaking, making all parties cautious and risk-averse. These traits—caution and fear of taking risks—are antithetical to the principles of adaptive management by which all management decisions are viewed as experimental and inherently risky. The most likely outcome from this approach to governance of adaptive management is that preliminary decisions made during the initial phases of the plan are, through sheer inertia, likely to remain permanent, rendering the concept of adaptive management moot.

Second, the AMT is made up of a mix of regulators, regulated entities, and scientific providers such as IEP and DSP. This places the science providers in the position of being decisionmakers, creating clear conflicts of interest. Most importantly, as discussed below, this eliminates one of the most important aspects of science in support of adaptive management: scientific independence.

Adaptive Capacity

The AMT, with approval from the POG, AEG or higher federal and state authorities, will oversee implementation of the adaptive management program, presumably through the Science Manager. A central issue likely to arise when finalizing BDCP is the adaptive flexibility available. All such programs have a natural tension between wanting to provide assurances—such as how much water will be exported from the Delta—and needing flexibility in amount and timing of exports to test and implement adaptive management programs. The current BDCP documents offer little to no guidance on adaptive capacity. This is likely to play a major role in how adjustments are made in conservation measures and, more importantly, how real-time operations (an element of adaptive management) are implemented. BDCP has sought to defer this decision, both within the document and to its Decision Tree process (discussed below).

Science Program

Science should underpin the discussions and information needed to make and implement adaptive management decisions. The extensive literature on adaptive management cites a strong, well-funded, and well-organized science and monitoring program as essential for adaptive management. The BDCP documents do not provide extensive information about science to support adaptive management, other than a solid commitment to build and support a strong science program and, in the EIR/EIS, a significant funding commitment. As currently described, the science program would be run by the Science Manager under the direction of the Program Manager and the AEG. The role of the science manager would be to fund an array of activities, guide synthesis and analysis, and coordinate with the numerous public and private institutions working on the Delta. Beyond this, there are few specifics.

BDCP's current efforts on science have come in for extensive criticism from several entities, including the National Research Council (2012), the Delta Independent Science Board (Memo to Delta Stewardship Council dated May 20, 2013) and the Public Policy Institute of California (Hanak et al., 2013, Gray et al., 2013). To be fair, the project proponents recognize that the BDCP science program is a work in progress and likely to change before the public draft of the plan is released. However, several significant issues will need to be resolved:

- *Integration*: the National Research Council in its review of Delta science was highly critical of the lack of integration of scientific efforts in the Delta. The NRC and others have pointed out that coordination is less effective than integration. BDCP is a once-in-a-generation opportunity to reorganize science in the Delta to make it more integrated and more effective for addressing the major issues of the day. As structured, BDCP builds a new stand-alone science program that seeks to coordinate with other programs, such as IEP and DSP, rather than to integrate them. This is unlikely to prove successful.

- *Independence*: as noted above, the AMT blurs the distinction among decision-makers, regulated entities, and the providers of science and technical advice. In addition, the BDCP science program is, in effect, run by the regulated entities and lacks independence. This creates the potential for bias in the selection of what science gets funded and what is ultimately made available to the public. Given that most major disputes in the Delta come down to differences of opinion in court about the best available science, demonstrating scientific integrity and transparency should be the highest priority.

- *Oversight*: as currently structured, there is no independent oversight of the BDCP science program. There is a commitment to promoting peer-review of scientific work products and plans. In addition, there is mention of coordinating with the existing DSP and the Delta Independent Science Board. But oversight, which is essential for creating public assurances that the best available science is being utilized in decision-making, is currently absent from the plan.

- *Funding*: science is expensive, and for a program this large and complex, it is likely to be *very* expensive. There are no discussions regarding budget in the BDCP plan documents. However, in the administrative draft EIR/EIS there are substantial commitments to funding a science program. There are categories of funding (monitoring, research, etc.), but little information as to how it would be distributed, organized and administered. Still, this level of commitment is significant and necessary.

To be effective, during revision of the plan documents, BDCP will have to address the considerable weaknesses in science governance, integration with other programs, independence and transparency, oversight and funding. Notably, there is a parallel process underway, led by the DSC, to develop a comprehensive plan for science in the Delta. This "One Delta, One Science" effort is essential for the success of BDCP. It seems to us that BDCP's science effort should be fully integrated with the Delta Science Plan, if not led by the DSP. However, to date, BDCP has had limited involvement with this planning process.

Decision Tree

Earlier chapters of this review note that most controversial decisions, or decisions with high scientific uncertainty, are proposed to be resolved through adaptive management (i.e., *deferred*). One of the most important decisions will involve initial operations of the dual export facilities approximately ten years after issuance of the HCP/NCCP permit. The operations are to be based on the best available science on how to meet the co-equal goals of ecosystem benefit and water supply, with the goal of meeting the HCP/NCCP conservation standards.

A fundamental tension exists between two competing hypotheses regarding BDCP. The first, controlling hypothesis is that better management of existing export volumes with the dual facility, coupled with significant investments in floodplain, channel margin, and tidal marsh habitat to improve food webs, will improve conditions for covered species sufficiently to meet the HCP/NCCP standards. The second, embedded within the agency red flag comments and "progress reports", is that these steps are insufficient and that lower exports (higher outflow) will be needed to meet these standards. This issue is a paramount concern since it directly affects the economic viability of water supplied from the project.

As part of CM#1, BDCP will use a decision tree to address initial starting operations. As a starting point, BDCP embodies the two competing hypotheses in the LOS and HOS operating criteria, viewing them as brackets on the potential range of operations. The goal of the decision tree is to conduct a series of detailed studies and experiments to develop specific flow criteria, particularly for spring outflow (longfin smelt) and Fall X2 (delta smelt), in the decade before operation of the export facility begins.

The decision tree is the first, and probably most important, element of the BDCP adaptive management program. Much of the success of the adaptive management program will be tied to this element, since the original adaptive management and science infrastructure will presumably be built around addressing the competing hypotheses.

The decision tree approach to addressing starting operations is, in our view, laudable and appropriate. It makes no sense to wait until all uncertainties over this issue are resolved (a course of action proposed by diverse stakeholder groups). Experience says this issue will never be resolved to everyone's satisfaction and will require constant (and contentious) adaptive management. This is a necessary and appropriate step. Regrettably, there is little information given in the BDCP documents about how the decision tree would be implemented, including who would fund it, how it would be structured, how decisions would be made, what science experiments would be conducted, etc. The lack of detail about the decision tree in the BDCP documents raises several key concerns:

- It takes time to develop and implement a large, complex scientific undertaking of the kind envisioned by the decision tree approach. The POD crisis in the mid-2000's and the mobilization of the scientific community to address it is an example of a successful approach. But that still took considerable time and many issues addressed by the POD effort remain unresolved.

- To inform the potential placement and design of habitat restoration efforts to support food webs, new approaches to numerical modeling will be needed that better represent how these habitats function. Finding and funding the technical teams for this kind of work will take time and resources. A particular concern is whether contracting will be run through existing state and federal agencies who are notoriously slow at developing contracts.

- In addition, field experiments will be needed to inform and calibrate these models. This involves identifying locations to conduct experiments, modeling and designing actions, acquiring land or easements, implementing pre-project monitoring programs, implementing actions, monitoring responses, and incorporating results into system models. All of these actions take time and resources, but as is well-known by anyone working on ecosystem restoration in the Delta, the rate-limiting step is inevitably the length of time it takes to secure permits (see recent review in Hanak et al., 2013).

- Because any decision made regarding flow and habitat will have multiple, competing constituencies and regulatory interests, an extensive and often contentious public engagement effort will be needed. The history of the Delta suggests that all such significant decisions are litigated, further slowing this process.

These four concerns, as well as others, make us skeptical that the decision tree is likely to achieve the goal of resolving operations issues within a 10 to 15 year time period. We cannot say with certainty that it will not be successful. A committed, well-funded, well-managed effort on the part of all parties may yield useful conclusions. However, given that this is the less likely outcome, it seems imperative that BDCP negotiate export operations criteria that, in the absence of a successful decision tree process, will be implemented at the start of the project.

Our work in previous chapters has cast doubt on the viability of the controlling hypothesis that underpins BDCP. To this end, we think it prudent to, at minimum, adopt the HOS operating criteria as the starting condition if the decision try fails to identify operating procedures. In addition, if BDCP is truly committed to adaptive management and the use of best available science, it is not appropriate to set artificial boundaries—HOS and LOS—on the decision tree process. It is our view that the decision tree research effort should seek to define best operating procedures rather than being forced to operate within the HOS and LOS range. There is a reasonable chance that the decision tree process may ultimately determine that the HOS flow criteria are not protective enough.

Conclusion

The draft documentation provided by BDCP makes a strong commitment to the principles of adaptive management supported by a robust science program. Given the complexity of BDCP and the great scientific uncertainties underpinning many of the central elements of BDCP, this is absolutely necessary for success. As currently described, the BDCP adaptive management program either lacks sufficient information to be assessed or is unlikely to achieve its overall goals and objectives. This stems from two basic problems:

- The adaptive management program has a confused and conflicting governance structure that, in our view, is likely to inhibit adaptation rather than promote it.

- There is insufficient information, beyond funding levels, to judge how the science program might function and how the knowledge it generates would be converted to action. The current information in the documents indicates that the program lacks integration with existing programs, scientific independence and transparency, and sufficient independent oversight.

We recommend that BDCP seek substantive engagement (beyond "coordination") with the ongoing efforts by the DSC and the Delta Stewardship Council to develop a Delta Science Plan. The goal should be to integrate BDCP science and adaptive management into the broader science infrastructure of the Delta and not to construct a new, stand-alone science organization. Additionally, BDCP needs to revisit how adaptive management decisions are made, reallocating planning and decisionmaking authorities.

The decision tree process that seeks to resolve issues over initial operating criteria and habitat restoration investments is both appropriate and necessary. Unfortunately only limited information is available about this program so we cannot evaluate it. We are confident, however, that it is unlikely to resolve the major issues over the trade-offs between flow and ecosystem investments. For this reason, in the absence of resolution of decision tree process starting operations should be similar to HOS criteria.

Chapter 10: Summary and Recommendations

Introduction

We present a narrow review of aspects of BDCP that relate to conservation of federally listed fishes. We identify both strengths and weaknesses of BDCP's conservation measures in its effort to balance water supply reliability with ecosystem goals and objectives. Due to time and resource limits this review is incomplete. We did not examine all issues associated with aquatic ecosystems. For example, we did not evaluate habitat restoration on the San Joaquin River. Nor did we evaluate conservation issues for all covered fishes, giving limited attention to Sacramento splittail, San Joaquin steelhead, sturgeon and lamprey. Instead, we focused on the conservation measures that affect winter-run and spring-run Chinook salmon, delta smelt, and longfin smelt, because these measures are the most controversial and have greatest impacts on water supply operations. We also focused on a limited subset of the alternatives listed in BDCP documentation: the Early Long Term conditions under a No-Action Alternative (NAA), Low Outflow Scenario (LOS) and High Outlflow Scenario (HOS)[1].

We summarize our findings on the six guiding questions identified in Chapter 1, plus several recommendations sought by the NGOs after we began our work. These are intended to help inform The Nature Conservancy and American Rivers in their engagement efforts with BDCP. Where appropriate, we describe alternative approaches that might be taken for BDCP to more effectively meet its goals. On many issues we have no recommendations.

Question 1: Operations

Do operations of the dual facilities meet the broader goal of taking advantage of wet and above average years for exports while reducing pressure on below average, dry and critically dry years? What substantive changes in operations (and responses, see below) are there both seasonally and interannually?

We analyzed the CALSIM data on export operations under NAA , HOS and LOS for ELT conditions. We note that the modeling of flows under BDCP has three compounding uncertainties: uncertainty over system understanding and future conditions, model uncertainties associated with CALSIM, DSM2 and UnTrim, and behavioral/regulatory uncertainty, where the model cannot fully capture operational flexibility. For this reason, model outputs should be viewed as

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[1] NAA ELT is the no-project alternative using the 2008, 2009 BiOps with high spring outflow, 2025 climate and sea level conditions. LOS is with-project alternative with low fall and spring outflow, 2025 climate and sea level conditions. HOS is with-project alternative with high spring and fall outflow standards, 2025 climate and sea level conditions.

approximations useful for comparing different scenarios rather than as a predictor of future conditions. This issue influences all of our conclusions.

Based on our review we conclude:

- The array of existing and projected flow regulations significantly constrains operations in BDCP. The assumed operational flexibility associated with new North Delta facility is limited.
- HOS and LOS operations promote greater export during wet periods through increased use of North Delta diversions during the winter and spring. During dry and critical years, there is not much difference in *average* exports compared to NAA. For this reason, BDCP generally fails to meet the broader objective of reducing pressure on the Delta during dry periods.
- In some dry periods regulatory controls on OMR flows and North Delta diversions lead to significant increases in outflow and OMR flows over NAA. These unexpected results are the consequence of stricter flow requirements for HOS and LOS and operations being tied to previous water-year type in the fall and early winter. We are unsure if the project would actually be operated this way under these conditions.
- We evaluated how NAA, HOS and LOS performed during extended droughts. Of the three scenarios, HOS appears to be most protective of both supply and ecosystems by reducing the frequency and duration of dead pool conditions on Sacramento Valley reservoirs and assuring higher spring and fall outflows.

Recommendations: caution must be used in interpreting CALSIM model results for both export and environmental performance of BDCP due to compounding uncertainties. However, modeling results suggest that overall flow conditions are improved over NAA.

Question 2: Impacts of North Delta Facility

Based on operations criteria, does the Plan properly identify ecological impacts likely to occur adjacent to and in the bypass reach downstream of the new North Delta diversion facilities? If there will be direct and indirect harm to listed species by the facilities, does the Plan prescribe sufficient mitigation measures?

We reviewed the Conservation Measures and Effects Analysis of BDCP, including supporting appendices to evaluate conditions upstream of the North Delta facility, as well as near- and far-field effects of the facility itself. Our focus was on winter- and spring-run Chinook salmon, rather than all covered species. Based on this review we conclude:

- The BDCP consultants have appropriately identified the range of impacts on listed salmon likely to be associated with the operations of the North Delta facility. These include near-field effects such as impingement on intake screens and high predation losses at the facility, to far-field effects such as reduced survivorship of juvenile salmon due to higher transit times and redirection into the interior Delta. Using multiple modeling approaches, they have created reasonable estimates of losses due to operation of the facility.

- Mitigation for take associated with the new facility includes restricting diversion flows during initial pulse flows in the river, predator control, non-physical barriers, real-time operations to protect outmigrants, and modification of the Fremont Weir to divert fish onto the Yolo Bypass. With the possible exception of benefits from Fremont Weir modifications the uncertainties over mitigation actions are all high.

- We see high potential value in the Yolo Bypass for mitigating the effects of North Delta diversions on juvenile salmon, particularly in drier conditions. Therefore, existing adaptive management programs on the Bypass must be supported, with accelerated pilot studies, monitoring and ecological modeling, to ensure success of any modifications of the Bypass.

- Mitigation is hampered by the lack of a viable adaptive management plan or real-time management plan in the current BDCP for the North Delta facility. Still, even with these uncertainties, if managed well, fully implemented and functioning as described in the plan, the actions appear to mitigate for losses associated with the North Delta facilities.

- These mitigation efforts alone are unlikely to lead to significant increases in salmon populations, and extinction risk remains high for winter- and spring-run Chinook salmon, particularly during extended drought and warm periods when reservoirs are low. However, reservoir management is not within the scope of BDCP.

Recommendations: given the uncertainties over mitigation for the North Delta facility, we recommend that all mitigation actions be evaluated and completed prior to initiating operations the North Delta facility. Of highest priority is to bolster and complete adaptive management activities in progress on the Yolo Bypass. Additionally, we recommend establishing an adaptive management and real-time management program with the capacity to conduct significant experiments in flow management, predator control, and non-physical barrier implementation *prior* to initiating facility operation. These should be conditions of the HCP/NCCP take permit.

Question 3: In-Delta Conditions

Are changes in operations and points of diversion prescribed in the Plan sufficient to significantly improve in-Delta conditions for covered species? The focus is on listed species, including delta and longfin smelt, steelhead, winter and spring run Chinook, and green sturgeon.

We focused our analysis on in-Delta conditions that may affect delta smelt and longfin smelt. We reviewed the effects analysis and supporting documentation and conducted our own modeling based on CALSIM output. Based on this work we conclude:

- The CALSIM output we used showed conditions that appeared anomalous based on our understanding of how the system would actually be operated. Although we have been assured that these conditions were logical consequences of model design and operation to meet flow requirements, we remain unconvinced that they reflect actual future operations under the hydrologic conditions simulated. We therefore caution that **the conclusions below are contingent upon the actual operations of the system resembling those in the model output.** They are also contingent on the biological models accurately reflecting responses of the species to flow conditions.

- Roughly half of the export from the Delta will go through the North Delta facility. In addition, OMR flow regulations are more restrictive (protective) under HOS and LOS scenarios than NAA. Thus the incidence of positive OMR flows rose from 11% under NAA to 16% under HOS and LOS conditions. HOS and LOS are consistently more protective of smelt than NAA under these modeling assumptions.

- OMR flow regulation under HOS and LOS for October through January is governed by previous water year type. This leads to anomalously high (positive) OMR flows and corresponding outflow during some dry periods, creating apparent benefits for delta smelt. We are uncertain if this would manifest in real operations.

- Entrainment results in fractional population losses of delta smelt that can be calculated from modeled flow conditions. Based on these calculations, we estimate that HOS and LOS reduced fractional population losses by half compared to NAA. If actual operations were similar to the model results, they would lead to significant decreases in entrainment.

- Estimates of relative differences in long-term survival percentages (not predictions) showed a 19-fold increase for HOS and 11-fold increase for LOS over NAA, albeit with large uncertainty. A difference of this magnitude over the last 20 years would have reversed the decline of delta smelt in the 2000s.

- Increases in spring outflow are projected by the models to produce only a very small increase in longfin smelt abundance index under HOS compared to NAA, and a comparable decrease under LOS.

- Increases in fall outflow under HOS are projected to produce a small increase in recruitment by the following summer, and under LOS a modest decrease, but because of high variability in the data used to make these predictions, these values are very uncertain.

Recommendations: we remain uncertain about significant reduction in fractional population losses of delta smelt under the new HOS and LOS operating criteria. We recommend investment in resolving these uncertainties before operations are finalized. If these relationships are supported, then operational rules need to be refined to protect the benefits of these improvements over a broad range of conditions.

Question 4: Benefits of Habitat Restoration

Are covered pelagic fish like longfin smelt and delta smelt likely to benefit from restoration of floodplain and tidal marsh habitat at the scale proposed by the Plan? Given the current state of knowledge, and assuming that all Plan commitments are met, are these efforts likely to result in relaxed X2 and spring outflow standards?

A fundamental hypothesis embedded in the BDCP goals and objectives is that improvements in physical habitat, particularly floodplain and tidal marsh, will improve conditions for covered fishes. We focused our assessment on the relationship between habitat restoration and longfin and delta smelt. Based on this analysis we conclude:

- BDCP correctly identifies food limitation as a significant stressor on delta and longfin smelt, particularly in spring through fall. Increasing food availability in smelt rearing areas would likely lead to increases in population.
- Tidal marshes can be sources or sinks for phytoplankton and zooplankton. Most appear to be sinks, particularly for zooplankton. There is high on-site consumption of productivity within marshes.
- Even under the most highly favorable assumptions, restored marshes would have at best a minor contribution to plankton production in smelt rearing areas.
- Smelt can benefit by having direct access to enhanced productivity. This is likely the case for the subpopulation of smelt that reside in Cache Slough.
- BDCP is too optimistic about benefits of tidal marsh and floodplain restoration for smelt, particularly the extent of food production. These optimistic views are indirectly guiding the LOS outflow criteria. There is no clear connection, however, between the two and investments in marsh restoration are unlikely to lead to reduced demand for outflows.

Recommendations: it is possible but unlikely that marsh restoration will materially improve conditions for smelt, although other ecosystem and species benefits of marsh restoration are much more likely. Only moderate- to large-scale experimental restoration projects are likely to resolve this uncertainty and to help in designing future efforts. BDCP should design and describe a specific program to resolve this issue. Until this uncertainty is resolved flow management will remain the principal tool to mitigate project impacts.

Question 5: Governance

Does the Plan provide achievable, clear and measurable goals and objectives, as well as governance that is transparent and resilient to political and special interest influence?

We analyzed the proposed governance structure of BDCP, including the responsibilities and authorities of new entities such as the Authorized Entity Group (AEG), the Permit Oversight Group (POG), the Adaptive Management Team (AMT), Implementation Office, Program Manager and Program Scientist. Based on this review we conclude the following:

- The governance plan, as structured, blurs the responsibilities between implementation and regulation. It grants AEG final decisionmaking power over actions that should be solely within the authority of the permitting agencies. It also involves the permitting agencies too heavily in implementation of the project.

- As written, the plan grants the AEG veto authority over proposed changes in the program, including any changes in biological goals and objectives or conservation measures.

- The AEG has the power to veto any minor modification, revision or amendment to the Plan that may be necessary to manage listed species.

- The regulatory assurances set forth in the draft Plan severely constrain the fish agencies' ability to respond to inadequacies in biological objectives.

- Given the high uncertainties inherent in BDCP, it is very likely that unforeseen circumstances will require significant changes in biological goals and objectives and conservation actions. Under the 50-year "no surprises" guarantee, the fish agencies assume financial responsibility for many significant changes. This liability could deter needed regulatory changes to BDCP and CVP/SWP operations.

- The procedural hurdles necessary to revoke the incidental take permit of BDCP are so great that revocation is unlikely to occur over the 50-year life of the permit. Indeed, permit revocation and termination of the BDCP would be unprecedented under both state and federal law.

Recommendations: The POG should be granted exclusive regulatory authority to determine whether budgets and workplans are consistent with the permit and to approve revisions to the biological goals and objectives or amendments to the plan. It should have the authority to initiate changes needed to insure protection of the covered species. The POG's functions should be limited to regulatory oversight rather than direct involvement in implementation. There should be a "no surprises" guarantee for construction of the project. Upon completion of the project, there should be renewable "no surprises" guarantees every ten years. These renewals should be based on conditions at the time of renewal and appropriateness of biological goals and objectives. This approach creates an incentive for all parties to adapt to changes in conditions to sustain covered species, rather than simply fulfilling obligations on conservation measures.

Question 6: Science and Adaptive Management

Is there a robust science and adaptive management plan for BDCP? As described, is the proposed "decision tree" likely to resolve major issues regarding Fall X2 and Spring Outflow prior to initial operations?

We reviewed the science and adaptive management plans in both the plan and EIS/EIR documents. Most issues with high uncertainty or controversy in the Plan are relegated to resolution through an adaptive management process. Based on the documentation, we conclude:

- Given the major uncertainties facing BDCP a robust, well-organized and nimble adaptive management plan will be necessary. The current plan adheres to and strongly promotes the principles of adaptive management and science.

- The requirement of unanimous consent for all decisions by the AMT, and veto power of any member of the AEG and POG is a barrier to adaptive management.

- There is a blurring of the responsibilities between regulators and those responsible for implementation of adaptive management that has the potential to create conflicts. There is a conflicting relationship between AMT decisionmaking and the scientific organizations providing support for decisonmaking.

- The plan recognizes the importance of adaptive capacity, meaning flexibility in operations and actions that allow for learning. Yet it does not describe this capacity in a meaningful way.

- There is almost no description of a science program. What is provided lacks evidence for integration with existing programs, transparency, independence from bias and influence, and structured oversight. These are all necessary for success.

- The decision tree process to establish initial operating conditions is appropriate. Done well, it can resolve many issues. However, it is unlikely to resolve the central issue over starting conditions in time to implement them.

- Although difficult decisions are relegated to a future adaptive management program, actually implementing such a program on such a scale will be very difficult and will require careful design. BDCP does not provide information sufficient to determine whether it will be effective. We remain skeptical that it will.

Recommendations: many of the recommendations for changes in governance made previously will go a long way toward improving the adaptive management program, including the separation of regulators from implementation efforts. However, the plan still needs a complete description of how its adaptive management program would function. The AMT, in whatever form it takes, should be advised by a science program, without scientists responsible for decisionmaking. The science program should be integrated with existing Delta science programs, rather than inventing a new parallel program. The best opportunity for integration is the current efforts to establish a Delta Science Plan through the Delta Science Program and Delta Stewardship Council. Given that the decision tree is unlikely to fully reduce uncertainties in time, coupled with our concerns over how the project would be operated rather than modeled, we recommend that default starting operating conditions be negotiated that approximates the HOS scenario, with a goal of identifying and operationalizing attributes of this scenario that are most beneficial to listed fishes.

Appendices

Appendix A: Operational rules for the North Delta Facility

Appendix B: Impaired Flows into an Impaired Estuary

Appendix C: Effects of changes in flow conditions on entrainment losses of delta smelt

Appendix D: Evidence for food limitation of the smelt species

Appendix E: Model of plankton subsidy from marsh to estuary

Appendix F: Effects of Floodplain Inundation

Appendix G: Can incidental take permits be issued to water contractors?

Appendix A: Operational rules for the proposed North Delta Facility (from Draft Administrative Bay Delta Conservation Plan).

Table 3.4.1-1. Water Operations Flow Criteria

<table>
<tr><th>Parameter</th><th>Criteria</th></tr>
<tr><td>Old and Middle River/San Joaquin inflow-export ratio</td><td>

October, November: Flows will not be more negative than an average of −2000 cfs during D-1641 San Joaquin River pulse periods, or −5,000 cfs during nonpulse periods.
November, December: Flows will not be more negative than an average of −5,000 cfs and no more negative than an average of −2,000 cfs when the delta smelt action 1 triggers.
January, February: Flows will not be more negative than an average of 0 cfs during wet years, −3,500 cfs during above-normal years, or −4,000 cfs during below-normal to critical years, except −5,000 in January of critical years.
March: Flows will not be more negative than an average of 0 cfs during wet or above-normal years or −3,500 cfs during below-normal to critical years.
April, May: Allowable flows depend on gaged flow measured at Vernalis. If Vernalis flow is below 5,000 cfs, OMR flows will not be more negative than −2,000 cfs. If Vernalis is 5,000 to 6,000 cfs, OMR flows will not be more negative than −1,000 cfs. If Vernalis exceeds 6,000 cfs, OMR flows will be at least 1,000 cfs. If Vernalis exceeds 10,000 cfs, OMR flows will be at least 2,000 cfs. If Vernalis exceeds 15,000 cfs, OMR flows will be at least 3,000 cfs. If Vernalis exceeds 30,000 cfs, OMR flows will be at least 6,000 cfs.
June: Similar to April, but if Vernalis is less than 3,500 cfs, OMR flows will not be more negative than −3,500 cfs. If Vernalis exceeds 3,500 cfs, OMR flows will be at least 0 cfs. If Vernalis exceeds 10,000 cfs, OMR flows will be at least 1,000 cfs. If Vernalis exceeds 15,000 cfs, OMR flows will be at least 2,000 cfs.
July, August, September: No constraints.

</td></tr>
<tr><td>Head of Old River gate operations</td><td>

December, June 16 to September 30: Operable gate will be open.
All other months: Operable gate will be partially or completely closed as needed to support OMR flow criterion and, via real-time operations, to minimize entrainment risk for outmigrant juvenile salmonids and/or manage San Joaquin River water quality.

</td></tr>
<tr><td>Spring outflow</td><td>

March, April, May: As described in Section 3.4.1.4.4, Decision Trees, initial operations will be determined through the use of a decision tree. If at the initiation of dual conveyance, the best available science resulting from structured hypothesis testing developed through a collaborative science program indicates that spring outflow is needed to achieve the longfin smelt abundance objective the following water operations would be implemented within the decision tree. The evaluated starting operations would be to provide a March–May average outflow scaled to the 90% forecast for the water year, with scaling as summarized in the table below.

March–May Average Outflow Criteria for “High Outflow” Outcome of Spring Outflow Decision Tree
<table>
<tr><th>Exceedance</th><th>Outflow criterion (cfs)</th></tr>
<tr><td>10%</td><td>>44,500</td></tr>
<tr><td>20%</td><td>>44,500</td></tr>
<tr><td>30%</td><td>>35,000</td></tr>
<tr><td>40%</td><td>>32,000</td></tr>
<tr><td>50%</td><td>>23,000</td></tr>
<tr><td>60%</td><td>17,209</td></tr>
</table>
</td></tr>
</table>

Table 3.4.1-1. Continued

<table>
<tr><th>Parameter</th><th>Criteria</th></tr>
<tr><td></td><td><table><tr><td>70%</td><td>13,274</td></tr><tr><td>80%</td><td>11,382</td></tr><tr><td>90%</td><td>9,178</td></tr></table>
Alternatively, if best available science resulting from structured hypothesis testing developed through a collaborative science program shows that Delta foodweb has improved, and evidence from the collaborative science program shows that longfin smelt abundance is not strictly tied to spring outflow, the alternative operation under the decision tree for spring outflow would be to follow flow constraints established under the Bay-Delta Water Quality Control Plan.
February, June: Flow constraints established under the Bay-Delta Water Quality Control Plan will be followed.
All other months: No constraints.</td></tr>
<tr><td>Fall outflow</td><td>September, October, November: As described in Section 3.4.1.4.4, Decision Trees, initial operations will be determined through the use of a decision tree. Within that tree, the evaluated starting operations would be to implement the USFWS (2008) BiOp requirements, and the alternative operation would be to revert to the Bay-Delta Water Quality Control Plan requirements. The alternative operation would be allowed, if the research and monitoring conducted through the collaborative science program show that the position of the low-salinity zone does not need to be located in Suisun Bay and the lower Delta, as required in the BiOp, to achieve the BDCP objectives for Delta smelt habitat and abundance.
All other months: No constraints.</td></tr>
<tr><td>Winter and summer outflow</td><td>Flow constraints established under the Bay-Delta Water Quality Control Plan will be followed.</td></tr>
<tr><td>North Delta bypass flows</td><td>October, November: Flows will exceed 7,000 cfs.
July, August, September: Flows will exceed 5,000 cfs.
December through June: Variable, as shown in Error! Reference source not found..</td></tr>
<tr><td>Export to inflow ratio</td><td>The export to inflow (E:I) ratio for CM1 operations is under development. Two options are under consideration, with the primary difference being the location at which inflow from the Sacramento River is measured.
Option 1 (assumed in the low-outflow scenario [LOS] and the evaluated starting operations [ESO] scenario):
Combined export rate is defined as the diversion rate of the Banks Pumping Plant and Jones Pumping Plant from the south Delta channels.
Delta inflow is defined as the sum of the Sacramento River flow downstream of the proposed north Delta diversion intakes, Yolo Bypass flow, Mokelumne River flow, Cosumnes River flow, Calaveras River flow, San Joaquin River flow at Vernalis, and other miscellaneous in-Delta flows.
Option 2 (assumed in the high-outflow scenario [HOS]):
Combined export rate is defined as the sum of the diversion rate of the Banks Pumping Plant and Jones Pumping Plant from the south Delta channels and the diversion at the proposed north Delta intakes.
Delta inflow is defined as the sum of the Sacramento River flow at Freeport (upstream of the proposed north Delta diversion intakes), Yolo Bypass flow, Mokelumne River flow, Cosumnes River flow, Calaveras River flow, San Joaquin River flow at Vernalis, and other miscellaneous in-Delta flows.</td></tr>
<tr><td colspan="2">OMR = Old and Middle Rivers</td></tr>
</table>

Table 3.4.1-2. Flow Criteria for North Delta Diversion Bypass Flows from December through June

Constant Low-Level Pumping (December–June)

Diversions up to 6% of river flow for flows greater than 5,000 cfs. No more than 300 cfs at any one intake.

Initial Pulse Protection

Low-level pumping maintained through the initial pulse period. For the purpose of monitoring, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% over a 5-day period and (2) flow greater than 12,000 cfs. Low-level pumping continues until (1) Wilkins Slough returns to prepulse flows (flow on first day of 5-day increase), (2) flows decrease for 5 consecutive days, or (3) flows are greater than 20,000 cfs for 10 consecutive days. After pulse period has ended, operations will return to the bypass flows identified below under Post-Pulse Operations. These parameters are for modeling purposes. Actual operations will be based on real-time monitoring of fish movement.

If the first flush begins before December 1, May bypass criteria must be initiated following first flush and the second pulse period will have the same protective operation.

Post-Pulse Operations

After initial flush(es), Level I operations apply. After 15 total days of bypass flows above 20,000 cfs, Level II operations apply. After 30 total days of bypass flows above 20,000 cfs, Level III operations apply.

Based on the objectives stated above, it is recommended to implement the following operating criteria:

- Bypass flows sufficient to prevent upstream tidal transport at two points of control: Sacramento River upstream of Sutter Slough and Sacramento River downstream of Georgiana Slough. These points are used to prevent upstream transport toward the proposed intakes and to prevent upstream transport into Georgiana Slough.

Level I			Level II			Level III		
December–April			December–April			December–April		
Sacramento River Flow			Sacramento River Flow			Sacramento River Flow		
Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low-level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000 cfs	no limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,000 cfs plus 0% of the amount over 20,000 cfs

Table 3.4.1-2. Continued

May			May			May		
Sacramento River Flow			Sacramento River Flow			Sacramento River Flow		
Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low-level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	12,400 cfs plus 0% of the amount over 20,000 cfs
June			June			June		
Sacramento River Flow			Sacramento River Flow			Sacramento River Flow		
Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow	Is Over	Is Not Over	Bypass Flow
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low-level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,400 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,600 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	11,800 cfs plus 0% of the amount over 20,000 cfs

Appendix B: Impaired flows into an impaired estuary

The Sacramento River watershed is the main source of inflow to the Delta and is integral to current operations of the SWP and CVP. The construction of a new North Delta facility will not change the reliance on the Sacramento watershed very much. However, in conjunction with limited changes in reservoir operations and modifications to the Yolo Bypass, it will alter the timing of inflows to the Delta.

One of the goals of BDCP and the Delta Plan is to create a more natural flow regime. As noted in Chapter 4, there is little natural about the landscape, and humans are fully integrated into the ecosystem. Still, returning more natural seasonal flow changes will help in managing species whose life history traits are tied to flow cues.

The projected changes in outflow under BDCP are presented in Figure 3.1. These monthly averages are compared to current (not ELT) unimpaired outflow from the Delta, an imperfect measure of outflow under unregulated conditions that can be used for comparison of BDCP scenarios. All alternatives, including the no-project alternatives, do little to alter the significant changes in Delta outflow regime. The winter flood pulse associated with high runoff from mixed rain/snow storms has been greatly reduced in all but wet years. More significantly, the spring snowmelt pulse is attenuated, and largely missing in most of the drier years. Only late summer/early fall baseflow seasons have flows that are equal to or larger than unimpaired conditions.

Since the Sacramento outflow is a dominant signature for estuarine conditions (second to tides), we examined the magnitude of change in inflow from the Sacramento and compared it to unimpaired flow conditions. We used two simple methods to illustrate the magnitude of change overall and relative changes between ELT scenarios. The first involves calculating a monthly impairment index, *I,* where:

I = (scenario flow)-(unimpaired flow)/(unimpaired flow)

Where I approaches 0, the scenario flow is less impaired, where $I > 0$ scenario flows exceed unimpaired flows and where $I < 0$, scenario flows are less than unimpaired flows. The magnitude of I is a simple way of describing the magnitude of seasonal impairment. These results are summarized in Figure 3.2 for all water year types.

The impairment index is strikingly similar in pattern for all year types, with high negative impairments during the winter and spring and high positive impairments for the summer and early fall. This result is surprising because there are only subtle differences between year classes. The only significant variation between year classes occurs in the late summer/early fall when Fall X2 outflow rules predominate.

This broad similarity in impairment highlights how uniform the hydrology of the Delta has become: an issue raised in Lund et al., 2007 and Hanak et al, 2011 as contributing to the regime change in Delta ecosystems. It also shows how little effect the HOS and LOS scenarios are likely to have on Sacramento inflows to the Delta.

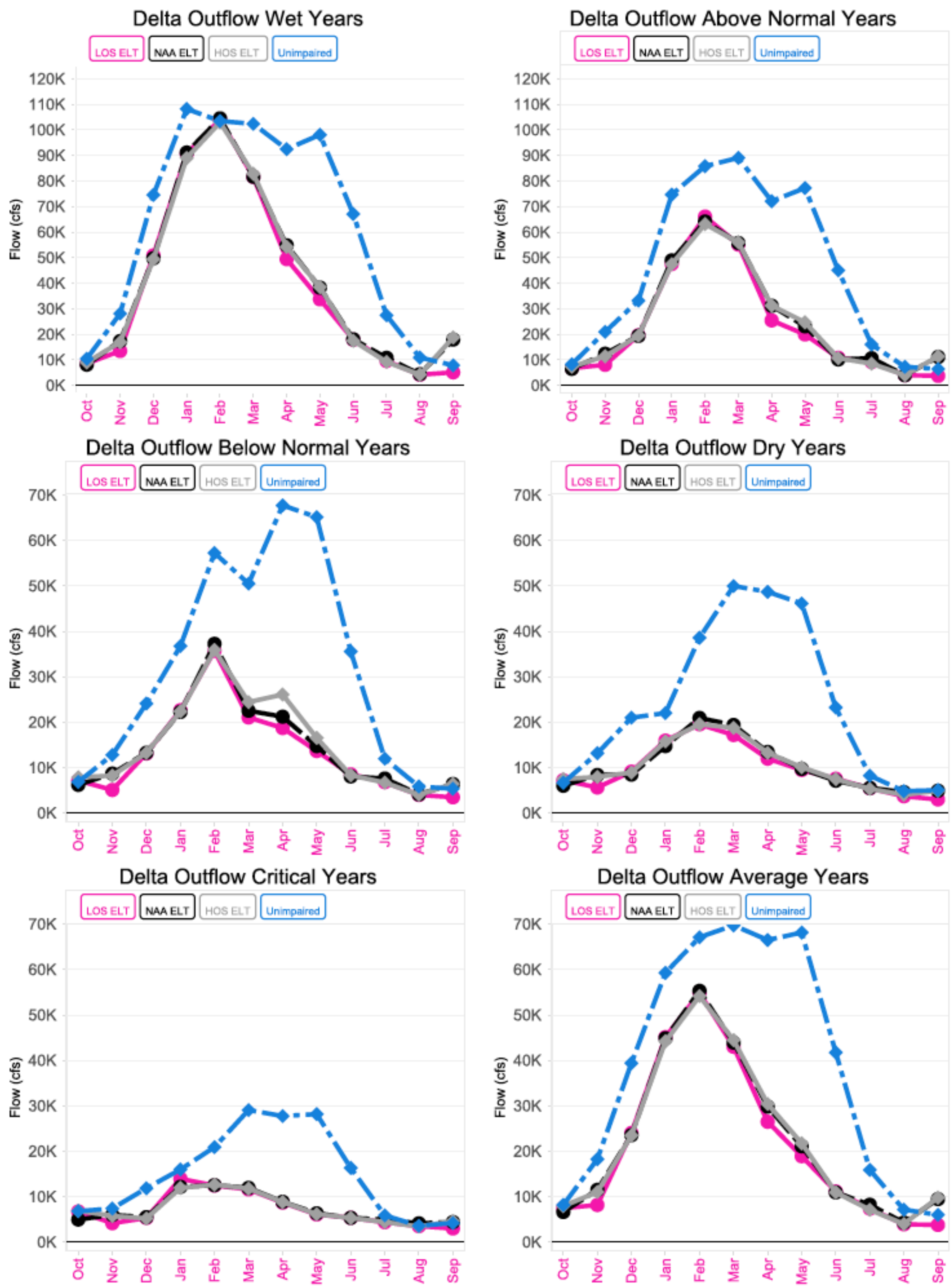

Figure 3.1: Delta outflow under HOS, LOS, and NAA ELT in comparison to unimpaired outflow

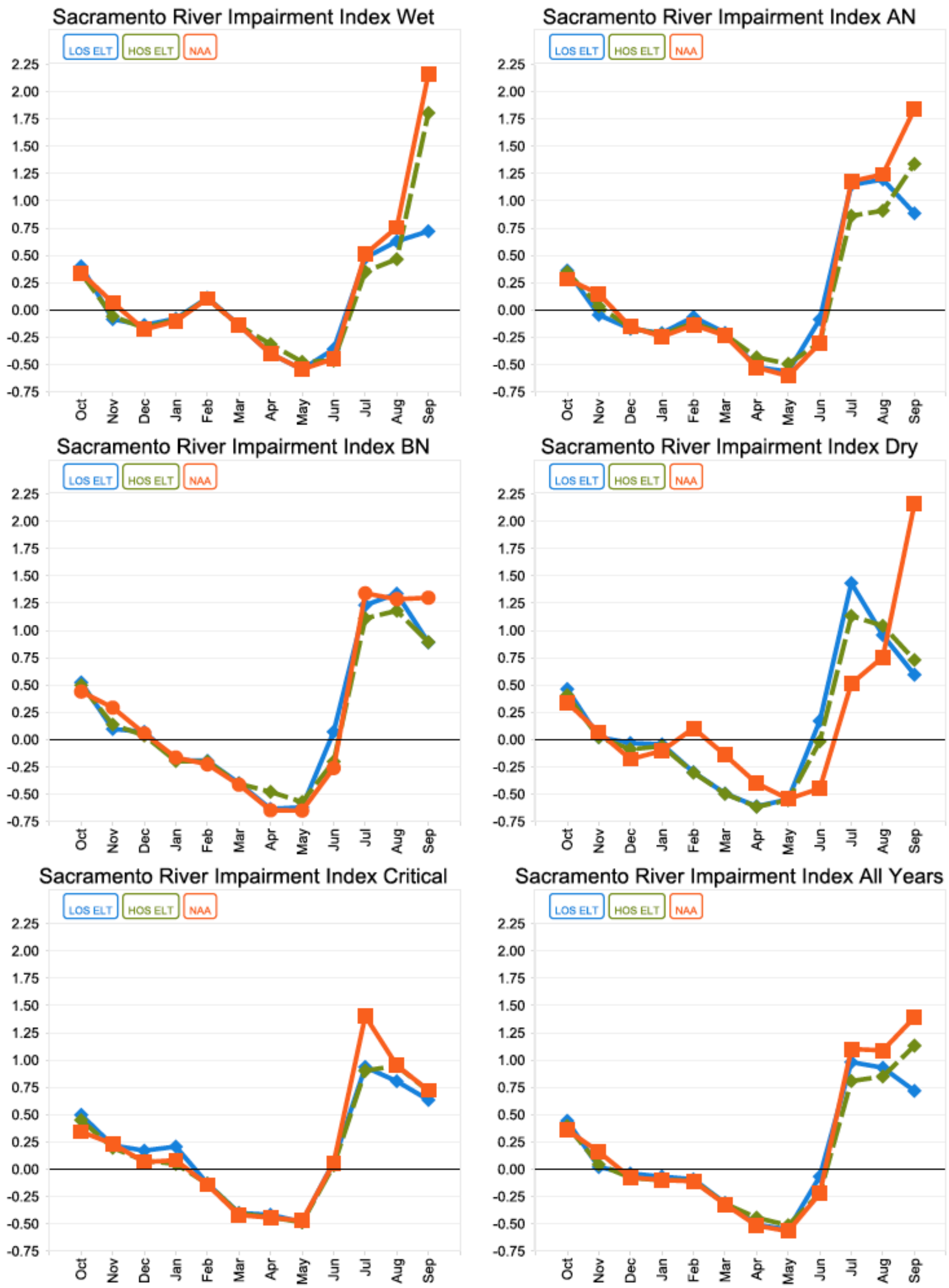

Figure 3.2: Sacramento River impairment index for HOS, LOS and NAA ELT.

A second approach can be used to characterize total impairment of individual year types. In this, we have plotted unimpaired vs. impaired flow for each scenario and each year type, and fitted a line and calculated r^2. The deviation of the slope of the line from 1 (impaired = unimpaired) illustrates the overall magnitude of impairment, while r^2 is a measure of variation in relative impairment. These results are shown in Figures 3.3-3.5.

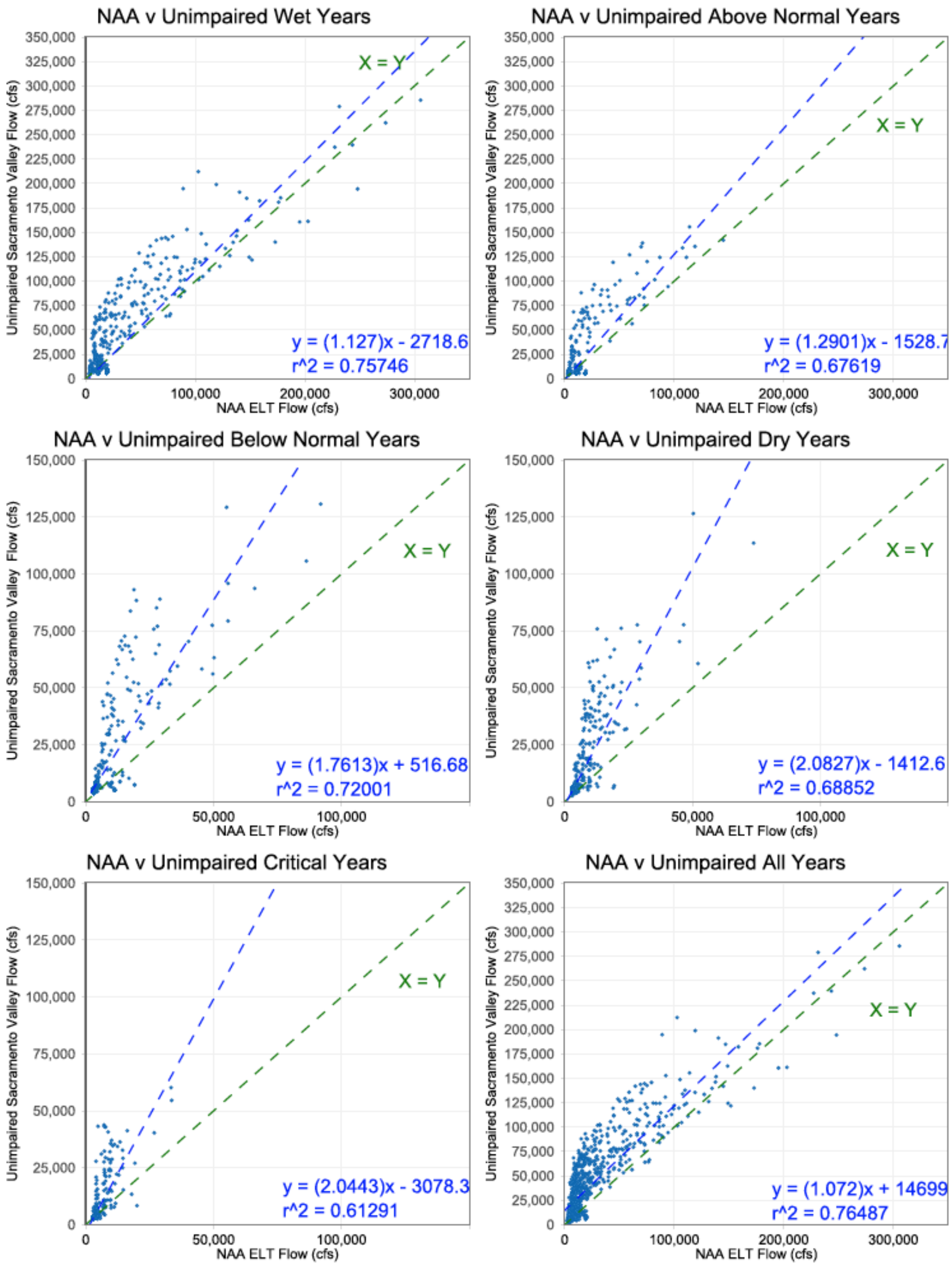

Figure 3.3. Scatterplot of NAA alternative Delta outflows vs. estimated unimpaired flows for ELT conditions. Higher slope and lower r^2 provide a relative measure of impairment.

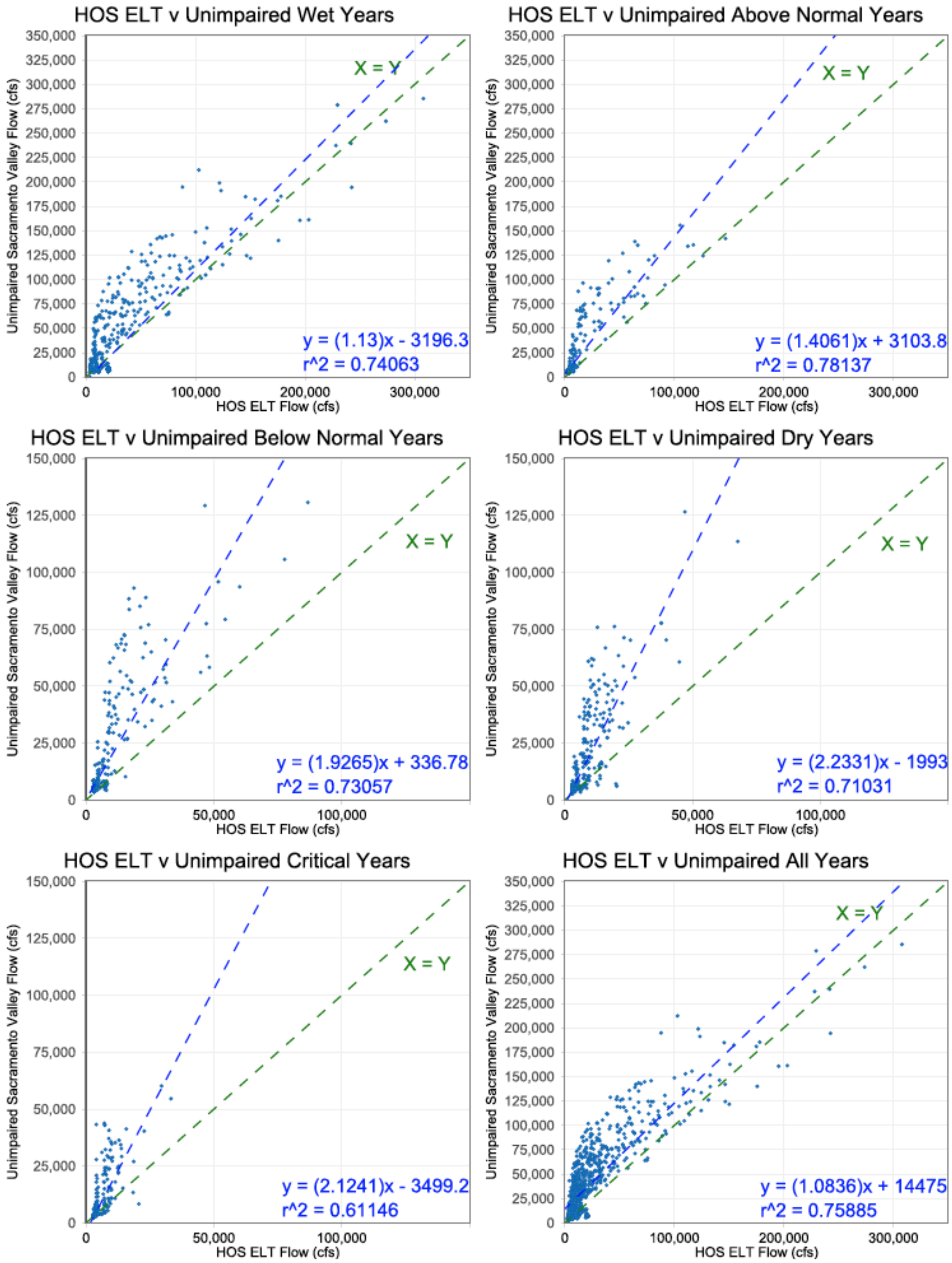

Figure 3.4: Scatterplot of HOS alternative Delta outflows vs. estimated unimpaired flows for ELT conditions. Higher slope and lower r^2 provide a relative measure of impairment.

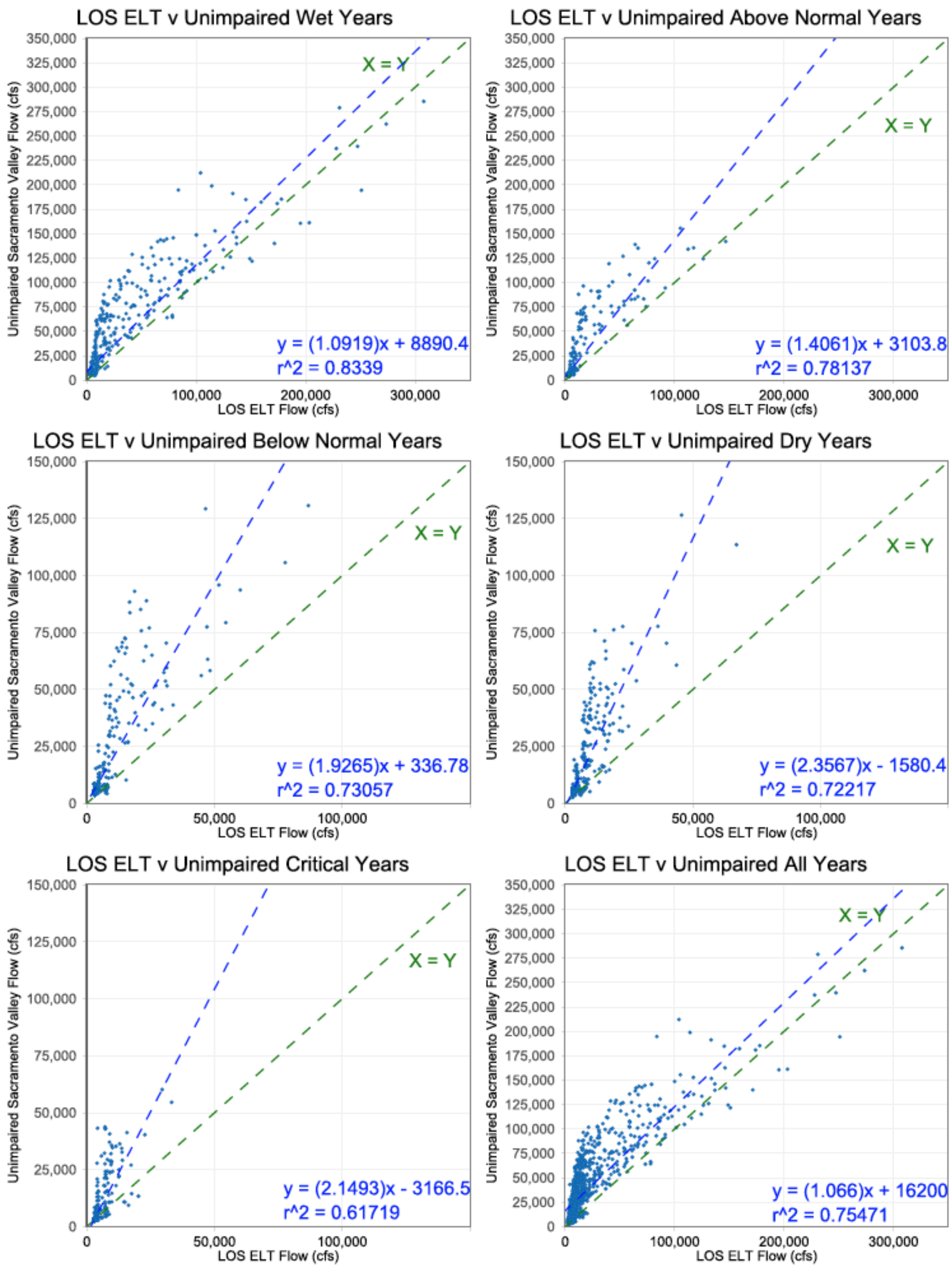

Figure 3.5. Scatterplot of HOS alternative Delta outflows vs. estimated unimpaired flows for ELT conditions. Higher slope and lower r^2 provide a relative measure of impairment.

The results of impairment scatterplots shows that in general, the magnitude of impairment, as measured by slope, and the magnitude of variation from unimpaired flow, as measured by r^2, are least in wet years and maximum in drier years. This reflects the dominance of water use and operations on Delta hydrology during dry years when the capacity for water alteration is greatest. In addition, there appears to be no substantive difference between the scatterplots of the different scenarios.

Conclusion

Examination of two closely related flow regimes, Delta outflow and Sacramento inflows, show that there is little difference in NAA, HOS, and LOS conditions. All represent high levels of impairment, in comparison to unimpaired flows, and the new North Delta facility and changes in export timing and magnitude have little impact on overall flow regime.

Appendix C: Effects of changes in flow conditions on entrainment losses of delta smelt

This Appendix describes the methods and results of analyses of flows in the South Delta and their potential effects on delta smelt. The general procedure was to determine a relationship between survival or recruitment during some life stages of delta smelt, and calculate the expected response based on conditions modeled using CALSIM and using historical data. CALSIM results were available for 1922-2003 for three BDCP scenarios: NAA, HOS and LOS. Historical data were used for inflow, export flow, and outflow during 1955-2003, and Old and Middle River flows from 1980 to 2003.

The calculations were based on results of Kimmerer (2008) as amended for adult delta smelt by Kimmerer (2011). Miller (2011) pointed out some potential biases in that analysis. Young delta smelt may be more abundant in the northern Delta than previously believed, which would mean that the proportional losses calculated by Kimmerer (2008) were too high (Miller 2011); however, this potential bias was not considered amenable to quantitative analysis with the available data (Kimmerer 2011). Nevertheless, the estimates of entrainment losses and reductions in losses herein may actually be somewhat overestimated.

The principal assumptions for this analysis are stated in Chapter 6. For the analyses of export losses we used a resampling method to account for uncertainty in the underlying statistical relationships between flow and entrainment. The error distributions from these models were sampled 1000 times to arrive at uncertainty estimates. The same 1000 samples were used for each year and scenario. This allowed us to include variability due to model uncertainty, and to allow direct comparisons among scenarios. The calculation was repeated for each year to provide the variability due to the hydrological conditions modeled under each scenario. Confidence limits were estimated as quantiles of the resulting set of simulated values for each parameter.

Losses of adult delta smelt

Losses as a proportion of the population of adult delta smelt had been estimated from salvage density, catches in the Spring Kodiak and Fall Midwater Trawl surveys, and flows in the south Delta (Kimmerer 2008, 2011). We related these estimates to total southward flow in Old and Middle Rivers:

$$Q_{sd} = mean_{Dec-Mar}\begin{pmatrix} 0, Q_{OM} \geq 0 \\ -Q_{OM}, Q_{OM} < 0 \end{pmatrix} \qquad (1)$$

where Q_{SD} is mean flow in the South Delta during December-March, and Q_{OM} is monthly mean or modeled flow in Old and Middle Rivers.

Estimated annual proportional losses P_L were related to Q_{SD} by linear regression for each year during which data were available (water years 1995-2006),

$$P_L \sim \max(0, a + bQ_{SD}) \quad (2)$$

where a=-0.03 and b= 0.0082 ± 0.0034 are regression coefficients. P_L was calculated using a revised estimate of the scaling factor Θ which accounts for uncertainty in the calculation of P_L; Θ has a mean of 22 and standard deviation of 5.2 (Kimmerer 2011).

Because P_L is a mortality we calculated means for a 20-year period by converting these values to survival, calculating geometric means, and converting back to proportions lost:

$$\overline{P_L} = 1 - \frac{1}{N}\prod_{N}(1 - P_{Li}) \quad (3)$$

where the overbar indicates a mean, N is the total number of years, and P_{Li} is the proportional loss for each year. The 20-year period was somewhat arbitrary but is roughly the timescale for the decline in abundance of delta smelt. To examine differences between pairs of the three scenarios we calculated the arithmetic means of differences for each pair.

There was little difference in mean P_L values between the full time series used in the analysis and the reduced time series that included the historical period (1980-2003). The No-Action Alternative (NAA) had a slightly lower percent annual loss than the historical period. The High and Low-Outflow scenarios (HOS and LOS) had similar values that were slightly below half of that of the NAA, or a net change in loss of about 3%/year.

Losses of juvenile delta smelt

Losses as a proportion of the population of juvenile delta smelt had been estimated from the spatial distribution of fish in the 20mm survey and flows in the south Delta supplemented by particle-tracking results (Kimmerer and Nobriga 2008, Kimmerer 2008). We related these estimates to total inflow to the Delta and export flow, noting that these results may vary depending on the proportion of inflow that is from the San Joaquin River. As with adults, CALSIM output was averaged over March – May for each year and scenario.

Annual proportional loss was calculated from a regression originally derived from particle-tracking data and applied to estimated losses of young smelt:

$$P_L \sim \max(0, a + bQ_{In} + cQ_{Ex} + dQ_{In}Q_{Ex}) \quad (4)$$

where a=-3, b= 0.36 ± 0.17, c= 0.90 ± 0.24, and d= -0.10 ± 0.03 are regression coefficients (Kimmerer 2008).

P_L values were accumulated and plotted as above (see Figures in Chapter 6). The annual means for the NAA were somewhat lower than the historical values, reflecting overall lower export flows than in the historical period. Both of the alternative scenarios resulted in substantial decreases in loss rates from about 14%/year to 3-5 %/year, and the LOS showed about a 2%/year higher loss rate than the HOS.

Appendix D: Evidence for food limitation of the smelt species

Delta smelt larvae consume mainly early life stages of copepods, switching to adult copepods as soon as they are able to catch and ingest them (Nobriga 2002, Hobbs et al. 2006, L. Sullivan, SFSU, pers. comm.). Juvenile delta smelt feed mainly on adult copepods (Moyle et al. 1992, Lott 1998, Nobriga 2002, Hobbs et al. 2006), although they consume other zooplankton such as cladocerans in freshwater. The diets of adults include larger organisms such as mysids and amphipods (Bippus et al. poster 2013; Johnson and Kimmerer 2013 talk).

Evidence in favor of food limitation (numbers in parentheses indicate the steps in the logic chain in Chapter 7)

Both smelt species

1. (1) Following the spread of the overbite clam *Potamocorbula* in 1987, sharp declines occurred in phytoplankton biomass and productivity, diatom production, and abundance of copepods and mysids, which are the principal prey of both species (Alpine and Cloern 1992, Kimmerer et al. 1994, Orsi and Mecum 1996, Kimmerer and Orsi 1996, Kimmerer 2005, Winder and Jassby 2011)
2. (1) At around the same time abundance indices of several fish species declined, notably anchovy, longfin smelt, and striped bass (Kimmerer 2002, 2006, Kimmerer et al. 2009), indicating an overall response of estuarine fish populations to the decline in food abundance. The decline in anchovy abundance in brackish waters (but not in high salinity) was particularly sharp and closely tied in time to the 1987 decline in phytoplankton biomass.

Delta smelt

3. (1) Gut fullness of delta smelt larvae was positively related to copepod density (Nobriga 2002). This suggests that when there is more food the smelt larvae eat more.
4. (1) Feyrer et al. (2003) found that delta smelt guts averaged about 40% full in Suisun Marsh before *Potamocorbula* arrived. This was similar to the gut fullness of most other fish species. It suggests that if there were more food the fish would have eaten more, or that there is some other limit to gut fullness.
5. (1) The functional response of larval delta smelt from laboratory experiments shows that the feeding rate saturates at a prey concentration well above that seen in any zooplankton samples in the smelt habitat during May –July of 1993-2011 (L. Sullivan, SFSU, unpublished; see Figure A7.1).

6. (2) Glycogen was depleted in 30% of fish in summer and 60% of fish in fall of 1999 (Fig. 28C in Bennett 2005) which could be interpreted as evidence of poor nutrition either because of a food shortage or because of some toxic effect; however the frequency of toxic damage was <10% in these fish.
7. (2) Mean lengths declined in either 1989 (Bay Study) or 1993 (FMWT study; Fig. 29 in Bennett 2005). The latter year is when the copepod *Pseudodiaptomus forbesi* shrank back from the LSZ in summer-fall, presumably because of the combined effects of clams and the introduction of other copepods. Bennett (2005, Figure 30) also showed positive relationships between mean length of delta smelt and copepod density (Bennett Fig. 30).
8. (3a) Copepod biomass is correlated with an index of survival from summer to fall (Kimmerer 2008).
9. (3a) Abundance data show evidence for density dependence between summer and fall when the early years are included (Bennett 2005 Fig. 17). A likely cause of density dependence is food limitation, although other mechanisms are also possible.
10. (1-4) Several model analyses show strong effects of food supply on the population rate of increase (Maunder and Deriso 2011, Rose et al. 2013a, b, Kimmerer and Rose, in prep). Note, however, that these models are incomplete and can only show effects based on what is in them.
11. A multivariate autoregressive (MAR) model (Mac Nally et al. 2010) showed weak support for a positive link between calanoid copepod abundance and delta smelt abundance index.

Longfin smelt

12. (1) Longfin smelt prey mainly on mysids after summer (Feyrer et al. 2003). Mysids declined sharply after 1987 (Orsi and Mecum 1996, Winder and Jassby 2011).
13. (Overall) Abundance of longfin smelt declined sharply after the introduction of *Potamocorbula*, when the strong effect of freshwater flow is taken into account (Kimmerer 2002, Kimmerer et al. 2009). Striped bass, which also feed on mysids (Feyrer et al. 2003), also declined at that time.
14. A multivariate autoregressive (MAR) model (Mac Nally et al. 2010) showed weak support for a positive link between calanoid copepod abundance and longfin smelt abundance index.

Evidence that does not support food limitation or is missing

15. The abundance of delta smelt did not change when *Potamocorbula* arrived or 1993, which were the two times of greatest change in calanoid copepod abundance in the low-salinity habitat of delta smelt

16. A changepoint model (Thomson et al. 2010) showed no link between abundance of various zooplankton and abundance indices of either smelt species.
17. Sampling for zooplankton is at too coarse a scale to represent the prey abundance that the smelt perceive, and the spatial distribution of prey cannot be replicated in the laboratory. Therefore it may be misleading to extrapolate functional responses from the laboratory to the field.
18. There is no direct evidence for effects of food on survival, maturity, or fecundity.

Appendix E: Model of plankton subsidy from marsh to estuary

Here we assume that the restored areas will actually produce an excess of phytoplankton or zooplankton over adjacent waters, and ask what additional level of food availability to the smelt would result. This is based on a very simple model and some calculations using data from IEP monitoring, as noted below. These calculations are unpublished except where a citation is given; details of calculations are available on request.

The additional zooplankton biomass available to the open-water areas as a result of production in restored shallow subtidal areas depends on the excess production in the restored areas, the resulting gradient in biomass, the tidal exchange rate between the restored areas and open waters, and the net population growth rate of the zooplankton in the open waters. The benefit of that additional supply to the smelt species depends on the proximity of the restored area to the population centers of the smelt (Fig. 7.2).

A simple model of this subsidy is:

$$F = (B_R - B)V_R X / BV \qquad (1)$$

where F (d^{-1})is the subsidy as a daily proportion of plankton biomass in the receiving water, B is biomass per unit volume, V is volume, B_R and V_R are biomass and volume in the restored area, and X is exchange rate as a daily proportion of the volume of the restored area (d^{-1}). Biomass and volume units cancel out.

It is clear from Equation 1 that the subsidy is maximized when the restored area is large, the zooplankton biomass in the restored area is well above that in the open water, and exchange rate is high. However, there is an the interplay among biomass B_R, volume V_R, and exchange rate X. First, water depth has three competing effects: 1) Phytoplankton growth rate is highest in shallow water where light penetration is high; 2) For a given area of restoration, volume is inversely related to water depth; 3) any bivalve grazing consumes phytoplankton and zooplankton in inverse proportion to depth. Second, as the exchange rate X increases, net population growth rate within the restored area decreases as organisms are removed by the exchange. If there is no exchange there is no subsidy, but at high levels of exchange there is also no subsidy because the zooplankton are being mixed rapidly compared to their internal growth processes (see Figure 7.3). Cloern (2007) showed that the efficiency of conversion of phytoplankton to zooplankton in a linked shallow-deep system was maximized when the tidal exchange rate X was equal to the net population growth rate of the primary consumers.

It is beyond our scope to model explicitly the growth and other processes and consequent biomass levels. However, it is possible to constrain the total phytoplankton and zooplankton biomass within a marsh using available data. During strong blooms nutrients are converted to phytoplankton biomass, but conversion is incomplete because some is lost to other foodweb components such as detritus, bacteria, and zooplankton. Thus, the total amount of dissolved inorganic nitrogen (DIN, comprising nitrate, nitrite, and ammonium) can set an upper limit to total phytoplankton biomass.

We used data from the IEP water quality and zooplankton monitoring programs from 1975-2012. Data used were from May to October to avoid the high variability of winter flows, and to focus on the dry season when the smelt species may be most constrained by food supply. Data were taken from the low-salinity zone, extended to a salinity of 0.5 – 10, about the range of salinity where delta and longfin smelt are abundant in their first summer, and averaged by year and month.

Chlorophyll was converted to phytoplankton C using a carbon:chlorophyll ratio of 50, under the assumption of high light availability. To examine bloom conditions, we used only data for which phytoplankton biomass exceeded 200 mgC/m^3. From these data, we determined the zero-intercept of a linear model of phytoplankton carbon vs. dissolved inorganic nitrogen (DIN), under the assumption that this represented the maximum conversion of DIN to phytoplankton biomass. This corresponded to about 900 mgC/m^3 (about 40% of the sum of phytoplankton C and DIN converted to C using a molar ratio of 6.6:1). We used that value as the upper limit for phytoplankton C in a marsh. Calanoid copepod C for adults and copepodites was estimated to be about 2.5% of actual phytoplankton C, and we assumed that this proportion would apply to the maximum phytoplankton C, or about 23 mgC/m^3. Using the same data the median phytoplankton and calanoid copepod C in the open water during 1994 – 2011 were 73 and 3 mgC/m^3 respectively.

The optimum exchange rate was calculated separately for phytoplankton and for zooplankton. For calculation we assume a mean depth of 2m and an area of 1000 ha (2500 ac) in the restored area. From Lopez et al. (2006) the growth rate of phytoplankton in a shallow area can be modeled as

$$\mu_P = -0.09 + 1.91/H, \qquad (2)$$

where H is water depth. At a water depth of 2m, this evaluates to 0.86 d^{-1}, which we use although a similar model using data from the LSZ in 2006-2007 gave a growth rate that was about 25% lower. We assume that benthic grazing in the restored area is negligible, but cannot neglect grazing by microzooplankton. This can be modeled either as:

$$g = \max(0, 0.93\ \mu_P - 0.3) \qquad (3)$$

based on experimental results from the Low-Salinity Zone in 2006-2007 (York et al. 2011), or

$$g = 0.6\ \mu_P \qquad (4)$$

from a review of microzooplankton grazing estimates, using values for estuaries (Calbet and Landry 2004). These yield growth rates of 0.5 and 0.35 d^{-1} respectively. The latter value is probably more generally representative of a wide range of conditions and for this analysis gives a higher net phytoplankton growth rate.

Using an exchange coefficient X set to be close to the net phytoplankton growth rate less grazing of 0.35 d^{-1} and using the volume of the LSZ of 0.5 km^3 as V in Equation 1, we get:

$$F = (B_R-B)V_RX / BV = (900-73)\ (1000 \times 10^{-2} \times 2 \times 10^{-3})\ 0.35 / (73 \times 0.5)$$

or about 0.16 d^{-1}. This is about half of phytoplankton growth, and about twice the (negative) net of growth less grazing by microzooplankton and clams in the LSZ based on field measurements during 2006-2008, which is now subsidized by mixing from other areas of the estuary. Thus, the extremely ideal conditions proposed above would lead to a substantial subsidy of phytoplankton to the LSZ. However, this assumes nearly perfect tuning of the exchange, ideal growth of the phytoplankton with no benthic grazing within the restored area, and perfect mixing of the discharged phytoplankton into the LSZ, which is unlikely because of its tidal movement in relation to the outlet of any marsh.

For calanoid copepods the equivalent calculation to that above is

$$F = (23 - 3)\ (1000 \times 10^{-2}) \times (2 \times 10^{-3})\ 0.1 / (3 \times 0.5)$$

or about 0.03 d^{-1}. As before, this represents an upper limit of the likely subsidy to LSZ zooplankton. This corresponds to a turnover time of about a month, considerably longer than the population turnover time of the copepods. As with phytoplankton, this is an upper limit of the potential subsidy of copepods, which would be reduced by behavioral resistance to movement such as vertical migration, and by excess predation in the marsh compared to the adjacent open waters. Both of these reductions are likely to be very large.

Zooplankton export from Suisun Marsh

One of the proposed restoration areas is in the northern end of Suisun Marsh. Biomass of calanoid copepods in the southern part of the marsh was about 2× that of the adjacent Grizzly Bay, based on a short-term field study and long-term monitoring data (Kimmerer and Marcal 2004). Biomass in the smaller sloughs to the north is apparently higher although nothing has been published on that (J. Durand, UC Davis, pers. comm.).

We used output from the UnTRIM hydrodynamic model (MacWilliams et al. in prep., Kimmerer et al. in press) and the FISH-PTM particle tracking model (Kimmerer et al. in prep.) to examine the residence time of particles within Suisun Marsh during the dry season. The hydrodynamic model simulates the entire estuary including marsh channels and bathymetry, but is not specifically set up to replicate flows in the marsh and therefore the results should be considered preliminary. For the entire network of channels it should give acceptable results, but to model the smaller sloughs would require a finer grid for that area.

The PTM was run for 45 days in a dry period in the historical data set (starting 1 July 1994) to examine the influence of vertical movement on retention in the estuary. The model was started with particles released throughout the northern estuary in a pattern similar to the distribution of the copepod *Eurytemora affinis*, the most abundant LSZ resident zooplankton species before *Potamocorbula* was introduced. Over 9000 particles were released for each run at approximately the same number per unit volume throughout the marsh. Residence time was estimated as the rate of decline of the log of total particles remaining in the marsh.

For neutrally-buoyant (i.e., passive) particles, the residence time of the marsh was about 28 days, and particles continuously left the marsh during the 45-day run. Particles that either sank or migrated tidally (down on the ebb and up on the flood) had a more complex pattern but generally the particles in the northern part of the marsh did not leave the marsh during the 45-day run.

Taking the passive case first and using available bathymetric data for the volumes of the marsh and Suisun Bay, Equation 1 can be reduced to the following:

$$F = (B_R / B - 1) \times V_R /(RT \times V) = (B_R / B - 1) \times 0.07 /(28 \times 0.11)$$

$$= 0.02 (B_R / B - 1)$$

Based on the existing data cited above for Suisun Marsh, this flux would provide an additional 2%/d of copepods to Suisun Bay if the copepods behaved as passive particles. This is unlikely to produce a noticeable increase in copepod biomass, as their population growth rates are on the order of 10%/d. Any tidal migration or tendency to remain near the bottom (which can be common among zooplankton in shallow, well-lit waters) would greatly reduce or even eliminate the net flux from the marsh to the open waters.

Appendix F: Effects of floodplain inundation

This Appendix explores available data on the response of phytoplankton and zooplankton biomass to flooding of the Yolo Bypass. This is to provide a basis for anticipating effects on the estuarine foodweb from floodplain inundation at lower flows in the Sacramento River.

One assumption underlying BDCP plans for increased inundation of the Yolo Bypass is that it would provide a source of phytoplankton and zooplankton to the open waters of the estuary. If so, the much larger floods that occasionally inundate the Bypass now should produce measurable increases in phytoplankton and zooplankton at monitoring stations in the estuary.

The basis for this analysis was to use the IEP monitoring data to try to detect an influence of inundation of the Bypass on phytoplankton biomass as chlorophyll concentration, and zooplankton biomass calculated from abundance. IEP data were obtained from six stations in the western Delta to eastern Suisun Bay.

Chlorophyll concentration has been determined since 1976 in the zooplankton survey. Abundance of zooplankton has been determined since 1972 by species and gross life stage. We used data on adult and juvenile calanoid copepods, which are common in the diets of delta smelt and other fishes. Abundance data were converted to biomass using carbon mass per individual by species and life stage (see Kimmerer 2006 for details; carbon estimates have been updated).

Neither chlorophyll nor copepod biomass showed any effect of inundation of the Bypass. This lack of response is clear for copepod biomass in Fig. F.1, which shows that under high flows in the Bypass the biomass was generally lower than when flows were lower. The data have been stratified by groups of years separated by the time that the clam *Potamocorbula amurensis* was introduced. During both periods biomass was generally higher when the Bypass was dry than when it was flowing at a low rate (< 500 $m^3 s^{-1}$). Biomass increased slightly in a handful of times when the Bypass was flowing at a higher rate, but even with this increase biomass still did not match that at the lowest flows. The difference in biomass between the pre- and post-clam period is notable at low Bypass flows.

Most of the high flows in the Bypass occurred during winter when zooplankton biomass is at its seasonal low. Inundation of the Bypass later in spring at a lower stage of the Sacramento River than is now necessary might provide conditions for higher productivity, but the lack of response of the current system at lower Bypass flows is not promising.

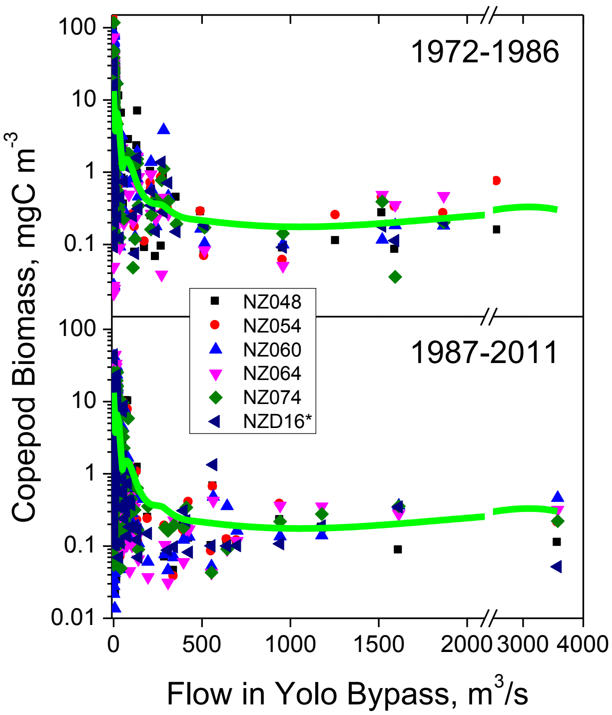

Figure F.1. Copepod biomass as a function of flow in the Yolo Bypass for two time periods. Symbol shapes and colors show the sampling stations from the IEP zooplankton monitoring survey. Green line is from a generalized additive model with a loess (locally-weighted) smoothing function applied to the pre-1987 period and shown in the lower graph for comparison.

Appendix G: Can incidental take permits be issued to water contractors?

Do the federal Endangered Species Act and the California Natural Community Conservation Planning Act allow the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, and the California Department of Fish and Wildlife to issue incidental take permits to the Central Valley Project and State Water Project contractors?

This question is significant, because the draft BDCP provides that the Authorized Entity Group shall be comprised of the Director of the California Department of Water Resources as operator of the SWP, the Regional Director of the U.S. Bureau of Reclamation as operator of the CVP, and one representative each of the CVP and SWP contractors if the contractors are issued permits under the Plan. BDCP 7-8. If we correctly understand the premise of this question, it is that only the owners and operators of the two projects—the U.S. Bureau of Reclamation and the California Department of Water Resources—are eligible to hold the incidental take permit that would govern construction and operation of the facilities authorized by the BDCP.

Although there is no definitive answer to this question, we conclude that the CVP and SWP contractors may receive incidental take permits. We base this conclusion on four factors: (1) There is nothing in either the federal Endangered Species Act or the California Natural Community Conservation Planning Act that prohibits the fish and wildlife agencies from issuing incidental take permits to entities such as the CVP and SWP contractors who receive water service from (and therefore are beneficiaries of) the permitted project operators. (2) The text of both statutes allows for the grant of incidental take permits to persons or entities other than the owners and direct operators of the projects governed by an HCP and NCCP. (3) There is precedent for the inclusion of both government entities and private landowners and resource users within a single HCP/NCCP. (4) There are good reasons both for the CVP and SWP contractors to seek the protections of an incidental take permit and for the fish and wildlife agencies to include the contractors within the management structure of the BDCP. It is therefore likely that the courts would defer to the agencies' decision to issue incidental take permits to the contractors.

The incidental take permitting and HCP provisions of section 10 of the federal ESA authorize the taking of individual members of a listed species that otherwise would be prohibited by section 9(a)(1)(B) of the Act. 16 U.S.C. § 1538(a)(1)(B). The take prohibition of section 9 applies to "any person subject to the jurisdiction of the United States." *Id.* § 1538(a)(1). The statute defines "person" as meaning

> an individual, corporation, partnership, trust, association, or any other private entity; or any officer, employee, agent, department, or instrumentality of the Federal Government, of any State, municipality, or political subdivision of a State, or of any foreign government; any State, municipality, or political subdivision of a State; or any other entity subject to the jurisdiction of the United States. [*Id.* § 1532(13).]

This definition expressly includes the CVP and SWP contractors, which are comprised primarily of instrumentalities of the state (and, in the case of the CVP, includes some individuals). The statute thus extends eligibility for (limited and conditional) exemption from the take prohibition of section 9 to the project contractors, and it contains no exclusion from this eligibility based on the fact that the contractors do not themselves own or operate the project.

The California Natural Community Conservation Planning Act addresses this question even more directly. In its articulation of the purposes of the statute, the Legislature stated:

> Natural community conservation planning is a cooperative process that often involves local, state, and federal agencies and the public, including landowners within the plan area. The process should encourage the active participation and support of landowners and others in the conservation and stewardship of natural resources in the plan area during plan development using appropriate measures, including incentives. [California Fish & Game Code § 2801(j).]

The Act also declares that "Any person, or any local, state, or federal agency, independently, or in cooperation with other persons, may undertake natural community conservation planning." *Id.* § 2809.

Indeed, the fish and wildlife agencies approved this type of multiparty, multijurisdictional, cooperative approach in the Orange County HCP/NCCP for the protection of the coastal gnatcatcher, other target species, and their habitat. The cooperating and individually permitted entities include the County of Orange, the cities of Anaheim, Costa Mesa, Newport Beach, Irvine, Laguna Beach, Orange, and San Juan Capistrano, as well as other participating public and private landowners and water users, such as Southern California Edison, the Metropolitan Water District, Irvine Ranch Water District, the Irvine Company, UC Irvine, the California Department of Parks and Recreation, and transportation corridor agencies. COUNTY OF ORANGE, FINAL NATURAL COMMUNITY CONSERVATION PLAN AND HABITAT CONSERVATION PLAN, CENTRAL AND COASTAL SUBREGION (1996), document available at http://www.naturereserveoc.org/documents.htm. Although this situation does not precisely mirror the relationship between the CVP and SWP and their contractors, it does serve as precedent for creation of an HCP/NCCP that includes both land and resource management agencies and public/private land and resource users as incidental take permit holders.

Finally, it makes sense for the CVP and SWP contractors to seek the protections of the incidental take permits governing operation of the facilities authorized by the BDCP, as it is their uses of project water that would potentially violate the federal and state take prohibitions. The contractors thus would benefit both from the security provided by the incidental take permits and from participation in the decisions that would shape implementation and compliance with the terms and conditions limiting coordinated CVP/SWP operations set forth in the BDCP. Concomitantly, it is in the fish and wildlife agencies' interest to have the contractors participate as permittees so that disputes between the contractors and USBR and DWR as project operators may be resolved within the forum of the Authorized Entity Group, rather than outside the purview and procedures of the BDCP. Under these circumstances, we believe that it is likely that the courts would defer to the fish and wildlife agencies' reasonable interpretation of the statutes as authorizing the grant of incidental take permits to the CVP and SWP contractors. *See Chevron U.S.A. v. Natural Resources Defense Council,* 467 U. S. 837 (1984); *American Coatings Ass'n. v. South Coast Air Quality Dist.*, 54 Cal.4th 446 (2012).

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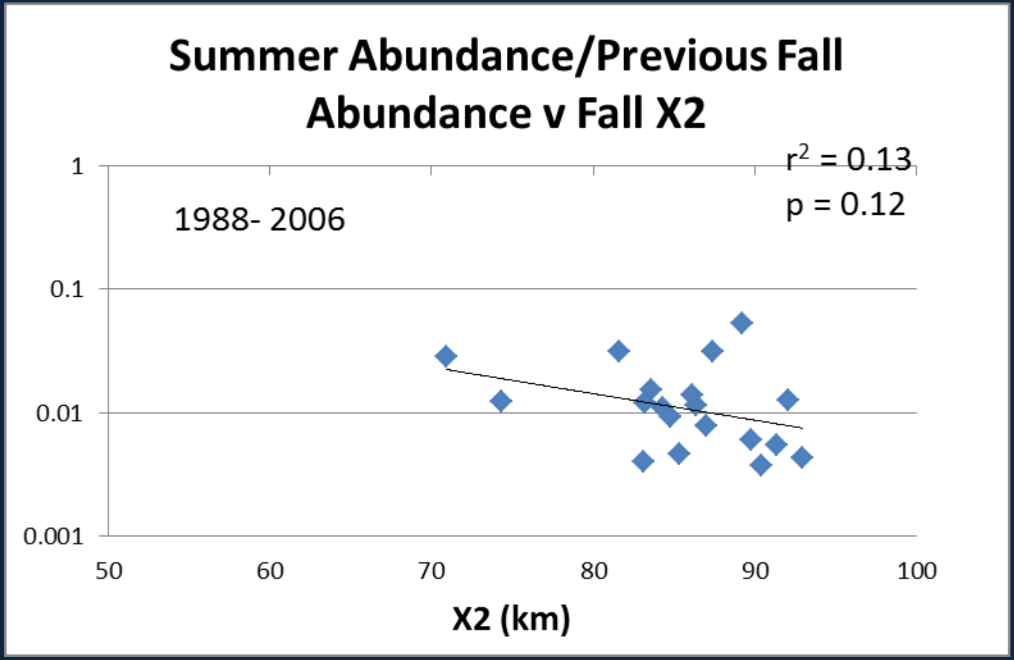
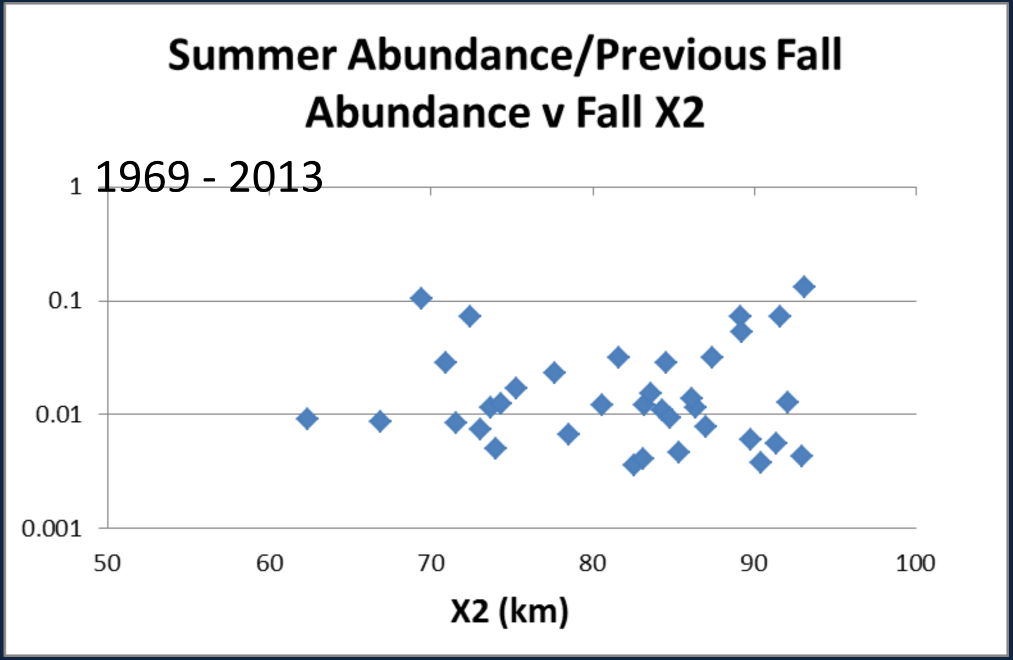
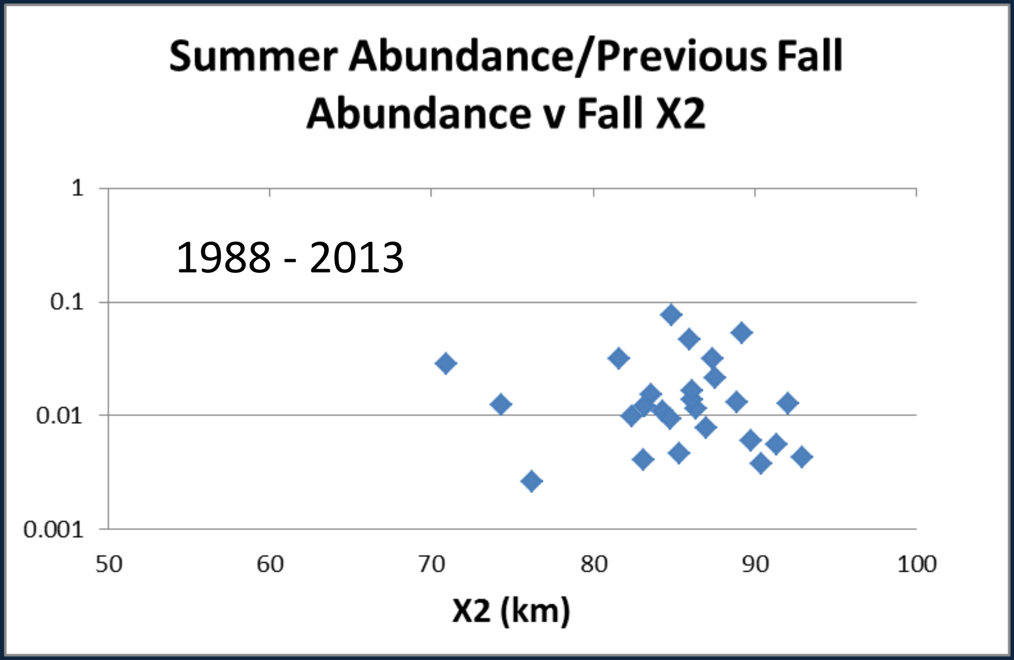
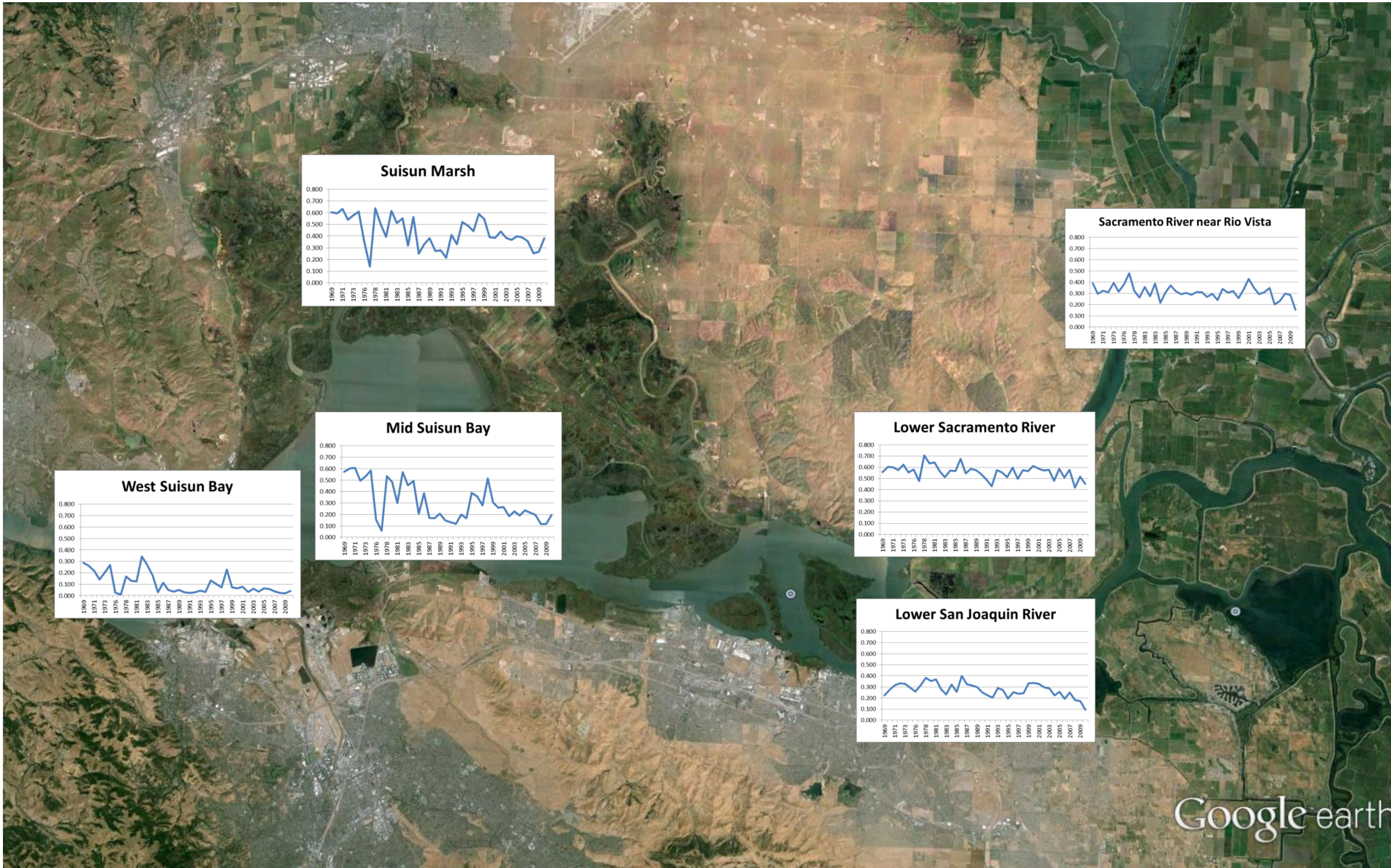

Summer Abundance/Previous Fall Abundance v Fall X2
r2 = 0.13
p = 0.12
1988- 2006
1
0.1
0.01
0.001
50
60
70
80
90
100
X2 (km)

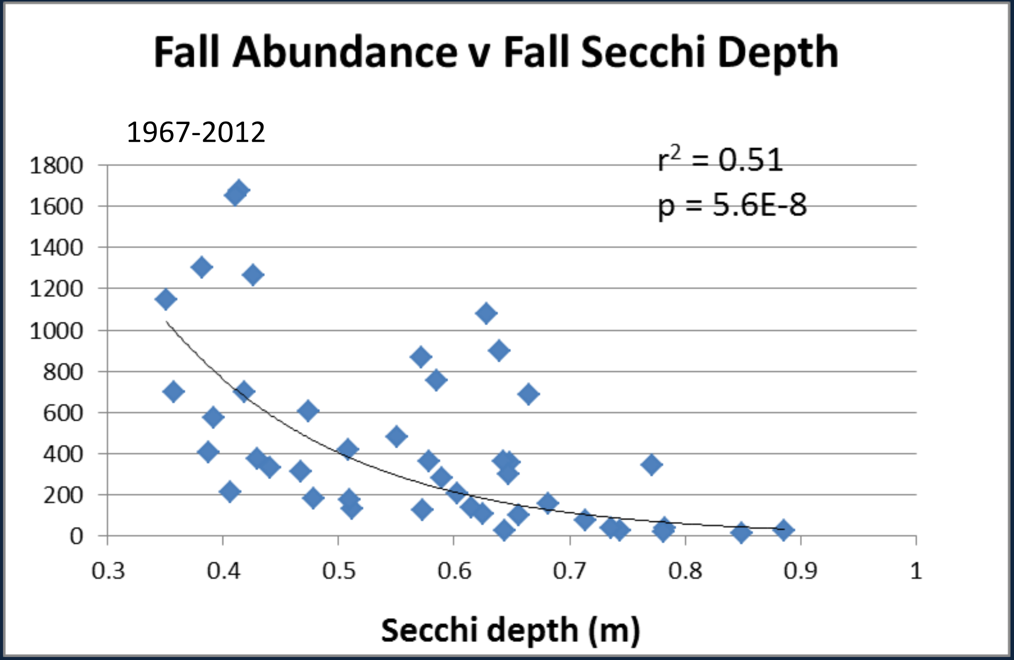


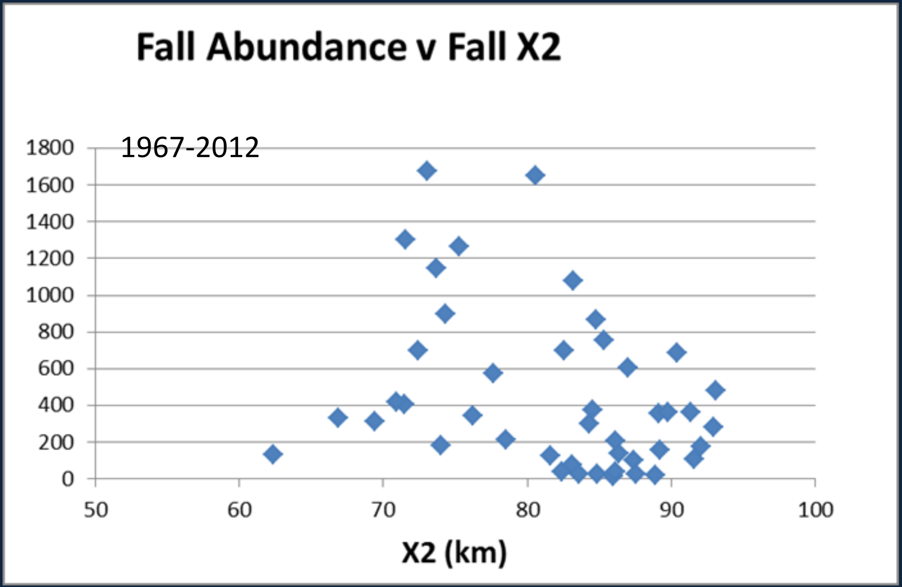
Summer Abundance/Previous Fall Abundance v Fall X2
1969 - 2013
1
0.1
0.01
0.001
50
60
70
80
90
100
X2 (km)



Summer Abundance/Previous Fall Abundance v Fall X2
1988 - 2013
1
0.1
0.01
0.001
50
60
70
80
90
100
X2 (km)


Suisun Marsh
Sacramento River near Rio Vista
Mid Suisun Bay
Lower Sacramento River
West Suisun Bay
Lower San Joaquin River
Google earth


Fall Abundance v Fall Secchi Depth
1967-2012
r2 = 0.51
p = 5.6E-8
1800
1600
1400
1200
1000
800
600
400
200
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Secchi depth (m)



Fall Abundance v Fall X2
1967-2012
1800
1600
1400
1200
1000
800
600
400
200
0
50
60
70
80
90
100
X2 (km)