NMFS Science Center Evaluation of the Peer Reviews of the Long-Term Central Valley Project and State Water Project Operations Section 7 Consultation.

25 May 2006

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Background

We have been charged with reviewing the peer reviews of NMFS' biological opinion (BiOp) on the Biological Assessment (BA) of the long-term Central Valley Project and State Water Project Operations, Criteria, and Plan (OCAP) in California. One review was implemented by the California Bay-Delta Authority's Science Program (Cal-Fed), resulting in a consensus report of a group of six independent scientists. A second set of reviews was implemented by NMFS through the Center of Independent Experts (CIE). This resulted in reports from two reviewers. The Cal-Fed and CIE reviewers were instructed to assess whether the BiOp used the best available scientific and commercial information, but not whether the BiOp reached the correct conclusion regarding jeopardy.

The three reports identified a number of perceived shortcomings of the BiOp, and the Cal-Fed reviewers concluded that the BiOp was not based on the best available scientific information. In this report, we evaluate the major criticisms in the reviews and assess whether future BiOps of similar large scope and complexity could do a better job in these areas, and whether improvements could be made in the near term or long term. Specifically, we were asked to address the following issues and questions raised by the Cal-Fed and CIE reviews (throughout this report, sans-serif 10-point font indicates quotes from the Statement of Work):

1. The feasibility and need to address global climate change, changing ocean conditions, and role of hatchery fish.
2. Are the technical tools used in the NMFS OCAP biological opinion (e.g., modeling, calculations, analytical and assessment techniques) able to determine impacts to the individuals and to the populations?
3. Are the independent reviewers criticisms of uncertainty founded and if so how do you suggest NMFS approach their recommendations in the short and long term?
4. Is the Cal-Fed review's recommendation for an explicit conceptual framework (life cycle approach) feasible for application in management settings? Can such a framework be developed to apply generically to salmon-bearing river systems and can the framework be developed and applied in the short or long-term?
5. What constitutes a complete analysis of Viable Salmonid Population (VSP) characteristics in a management document? Is a qualitative analysis adequate or could some scientific tool be developed to ensure each characteristic is given the proper weight and level of analytical rigor?

We read the Cal-Fed and CIE reports closely, and delved into the BiOp and BA in lesser detail but as necessary to fully understand the comments of the reviewers. A teleconference was held to review each of the five questions as a group, and subsequent work was done by telephone and e-mail.

Summary of our findings and recommendations

We found the comments and criticisms of the peer reviewers to be generally valid. In general, future large-scale Section 7 consultations could be improved significantly by incorporating some of the suggested approaches and considerations identified by the peer reviewers of the OCAP consultation. The fundamental improvement would be a better-developed conceptual framework for analyzing the impacts of large-scale actions. The Cal-Fed reviewers suggest a "life-cycle" approach. NMFS has in hand a general life cycle approach outlined by the Viable Salmonid Populations (VSP) report (McElhany 2000). VSP is accepted by NMFS as best-available science, and is being used by the NWR in consultations. Technical Recovery Teams have produced numerous documents that develop the generic VSP concepts for application to specific populations and ESUs, many of which were available in 2004 in draft form. These too are or will be accepted as best available science, and should be particularly useful for guiding Section 7 consultations. We see no reason why these tools could not be used immediately in future consultations in the 135 day period for consultation preparation, because VSP is not a model and does not require any particular kind of data.

Within the framework provided by VSP, further improvements could be made by systematically examining all of the important linkages between project effects and VSP parameters, addressing climate variation and climate change, accounting for uncertainty, and making the connections between data, assumptions, analyses, and conclusions more transparent. Scientists in the NWC and SWC are actively working to reduce critical uncertainties that may hinder application of VSP-related concepts, and this work will likely continue for the coming decades. In the meantime, biologists in the Regional Offices could make better use of what is available in their consultations, bearing in mind the uncertainties and accounting for them in a thorough and transparent way.

Specific findings

The committee agreed that question 4, dealing with the need for a clear conceptual framework, was fundamental: the other issues arise at least in part because of the inadequacy of the conceptual framework used in the BiOp. Because VSP provides an appropriate framework and is the best developed one available for such applications, we follow with consideration of question 5. The remaining questions are dealt with in their order in the Statement of Work.

Questions 4 and 5

Question 4: Is the Cal-Fed review's recommendation for an explicit conceptual framework (life cycle approach) feasible for application in management settings? Can such a framework be developed to apply generically to salmon-bearing river systems and can the framework be developed and applied in the short or long-term?

The Cal-Fed Review recommended an explicit conceptual framework and that NMFS should include a life cycle-based approach. They referenced a paper by Bottom et al. 2005 which contains the beginning of such a framework.

Question 5: What constitutes a complete analysis of Viable Salmonid Population (VSP) characteristics in a management document? Is a qualitative analysis adequate or could some scientific tool be developed to ensure each characteristic is given the proper weight and level of analytical rigor?

The Cal-Fed review indicated that NMFS did not adequately address the genetic and spatial diversity in the ESUs. Their review highlighted that some dependent populations are a valuable resource because they exist in marginal environments and may contain genetic attributes (e.g., high temperature tolerance) and may serve as links with other populations in ways that increase the viability and resiliency of the ESUs over long time scales.

In their review of the 2004 Central Valley BiOp, the Cal-Fed reviewers state that the BiOp would have benefited from a clearly articulated conceptual framework . The Cal-Fed reviewers further state that although there was an underlying conceptual framework in the BiOp, it was obscure, not explicitly identified, and needed to be assembled by the reader. We agree that the Central Valley BiOp would have benefited from an explicit conceptual framework. Moreover, we believe that the conceptual framework should have two major components. First, a biological conceptual framework is necessary to provide a context for integrating diverse types of scientific information into overall assessments of viability and risk at the population and ESU level. Second, a legal/policy conceptual framework could facilitate relating the biological conclusions regarding risk/viability to the legal concept of jeopardy in the context of the Cal-Fed BiOp.

The legal/policy framework is outside the scope of our committee to comment on, but the outline of the Central Valley BiOp was prepared pursuant to existing procedural regulations and guidance concerning interagency Section 7 consultations under the ESA, including the Service's 1986 Section 7 Interagency Cooperation implementation regulation (50 CFR §402) and 1998 Endangered Species Consultation Handbook. Existing implementing regulations and guidance require that BiOps prepared by NMFS present a description of the proposed action, the status of affected endangered species, the environmental baseline within the action area, and the effects (direct, indirect, interrelated and interdependent, beneficial, and cumulative) of the proposed action on listed populations. Taken together, these descriptions and effects analysis constitute the underlying legal/policy framework for a BiOp.

This underlying legal/policy framework of the BiOp can have many limitations, however, and may not lend itself to a clearly articulated and explicit risk analysis. The National Research Council (NRC) concluded in 1995 that spatially explicit frameworks in ESA decision making are "badly needed" and that despite major advances in models existing methods of risk analysis in ESA have "substantial limitations"(NRC 1995). NRC (1995) proposed decision analysis as an example of a structured problem solving method and stressed the merits of using such tools as conceptual frameworks. The purpose of decision structuring is to provide a more rational, transparent decision, the basis for which is fully revealed to the decision maker and other observers. Structuring decisions facilitates problem solving in complex situations.

It is our opinion that the overall decision analysis of the BiOp, while consistent with current NMFS guidance, lacked temporal and spatial resolution and omitted important linkages between the project effects and salmon survival, reproduction,

abundance, distribution, and diversity. Prominently, population growth rates were generally not expanded to the endpoint of the analysis (year 2020) and spatial analysis of distribution was inconsistent at best over the timeframe of the analysis. It was also not clear how summed individual-level effects were expected to affect population sizes, growth rates, diversity or spatial and temporal distribution. The use of a conceptual framework with an explicitly defined analytical framework in the Central Valley BiOp would have facilitated a consistent analysis of project effects on salmonid reproduction, abundance, diversity and distribution.

The Cal-Fed reviewers suggested that incorporating the framework presented by Bottom et al. (2005) would have yielded a more transparent and coherent BiOp. Bottom et al. (2005) considered the complex problem of assessing the role of the Columbia River estuary in the decline and recovery of Pacific salmon. They concluded that the traditional "production" framework (which considers the estuary merely as a physical locality through which salmon have to pass and, perhaps, suffer mortality) is inadequate and what is needed instead is an ecological framework that "emphasizes the geographic structure of habitats, populations, and diverse salmon life histories that contribute to salmon resilience and productivity" (Bottom et al. 2005, p. 185).

We agree that such an ecological framework is needed and directly relevant to the Central Valley BiOp. However, the ecological framework outlined by Bottom et al. (2005) for the Columbia River estuary can perhaps best be viewed as part of a larger, more comprehensive framework for salmon viability and recovery such as Viable Salmonid Populations (VSP; McElhany et al. 2000). Bottom et al. (p. 190) acknowledged this close relationship: "This expanded view of population status is consistent with the performance criteria recently proposed by NOAA Fisheries Service to determine salmon recovery needs … (McElhany et al. 2000)". A subsequent NOAA Technical Memorandum (Fresh et al. 2005) makes this link more explicit by considering how estuarine processes affect the four VSP factors for salmon populations and ESUs: abundance, productivity, spatial structure, and diversity.

Although both the Bottom et al. (2005) and Fresh et al. (2005) documents contain valuable information and insights relevant to the Central Valley BiOp, we believe that VSP represents a broader and more general biological framework for considering the effects of proposed actions on salmon viability and recovery. VSP is able to accommodate virtually any type of scientific information, yet flexible enough that lack of any particular type(s) of data does not preclude doing a viability assessment. VSP underwent extensive peer review and has been used as an organizing framework for formal ESA salmon recovery planning in the Northwest and Southwest Regions since 2000. Furthermore, the basic VSP framework has been adopted (provisionally) more broadly within the agency, as it forms the basis for the draft interim procedure for conducting ESA status reviews[1] (circulated by NMFS for internal comment in Fall 2005 and currently under revision). This interim guidance document was prepared by NMFS policy staff in response to a recommendation by the Quantitative Working Group (Demaster et al. 2004), which evaluated ways to improve consistency and quantifiability of NMFS' ESA listing determinations for all species. While no formal link between VSP and Section 7 jeopardy determinations has been established, consideration of basic VSP principals will help form an explicit conceptual framework for a BiOp.

[1] An Interim Procedure for Conducting Endangered Species Act Status Reviews

We agree with the Cal-Fed reviewers that the BiOp did not adequately address the impacts of the project on genetic and spatial diversity within ESUs. The use of VSP as a conceptual framework would facilitate assessment of how project impacts might influence these important components of species viability. What represents a reasonable application of VSP principles in a salmon recovery context in both the short and long term? These are key questions, as outlined in the charge to our Committee:

> The committee's evaluation will consider the most pertinent findings of the peer reviews and make recommendations to NMFS on the need for short and long-term actions on:
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> 1. The scientific importance and feasibility of addressing *in the short term* (3-6 months) peer review findings in Section 7 consultations; and
> 2. The need to implement other scientifically important actions for which implementation would require *longer-term* research or modeling, and would lead to an enhanced ability to address issues such as climate change and ocean variability in future consultations.

Short-term VSP considerations

The limited amount of time provided for Section 7 consultations rarely allows for the collection of new information or conducting new analysis. While new information or models may help make the analysis more transparent and rigorous, it is not required and many times is not realistic given the limitations on time and resources. Nevertheless, VSP principles can be incorporated into short-term ESA considerations in two ways. First, Technical Recovery Teams in each recovery domain have already put a great deal of effort into VSP evaluations for every listed Pacific salmon and steelhead ESU. These evaluations include, but are not limited to, identification of populations within ESUs, assessment of the four VSP factors at the population and ESU level, and development of alternative scenarios that will lead to ESA recovery. These analyses constitute "best available scientific information" that should be reviewed as appropriate in every Section 7 consultation. Second, although there may be no existing VSP analyses that exactly match the spatial scale and/or complexity of a proposed action covered by a specific BiOp, VSP still provides a unifying framework for considering the biological consequences of proposed actions, even if only in a qualitative fashion. Therefore, even in data-poor situations VSP provides a useful organizing framework for considering risks to salmon populations and ESUs, and clear references to this framework in future Biological Opinions will enhance their transparency as well as their scientific credibility. At a minimum, actions proposed in a BiOp should be evaluated with respect to their effects on the four VSP viability criteria, and there should be a process to map these VSP evaluations to the overall decision regarding jeopardy. Such a four-criteria evaluation would constitute a structured decision process with all the benefits described above, but it would not require new information and could be conducted within the time frame of a typical Section 7 consultation. Note that while VSP would provide a conceptual framework, an analytical framework will still need to be assembled to assess the impacts of specific projects on VSP parameters.

Long-term considerations

In the longer term, the VSP framework can accommodate a wide range of new quantitative analyses, thus incrementally improving the rigor and repeatability of management decisions related to viability. It is important to recognize that VSP is not a

life-cycle or population model, although it incorporates life-cycle and population thinking. Rather, VSP is a conceptual framework that can incorporate and provide a context for interpreting results from many different types of models, both quantitative and qualitative.

Question 1

The feasibility and need to address global climate change, changing ocean conditions, and role of hatchery fish.

> One report responded that NMFS did not use the best available scientific information because it did not consider the effects of climate change in its analysis. It also faulted the analysis, or lack thereof, of the risks associated with hatchery-released fish and variable ocean conditions.

The reviewers all point out that a number of factors that are likely to affect focal populations are not fully accounted for in the analysis of project impacts. Ignoring important risk factors would tend to underestimate the impacts of the project. The Cal-Fed reviewers suggest that where data is not available, conservative (i.e., protective of the fish) guesses about effects should be made and included in the synthesis of effects in a clear way. We broadly agree with the reviewers, and offer further justification and suggestions for doing more on these topics below.

Climate change

Both the Cal-Fed consensus review and the Maguire review claim that assuming that future climate will be like the recent past is unreasonable, because of the likely effects of global climate change on temperature and precipitation regimes in the Central Valley. We agree with these reviewers that the best available scientific information indicates that the global climate is warming (e.g., Oreskes 2004, Karl et al. 2006), that temperatures in the Central Valley are expected to rise (Hayhoe et al. 2004), and that this will likely cause hydrologic changes due to decreased snow fall and earlier snow melt (VanRheenen et al. 2004). These trends are increasing the risk to protected populations, which suggests that the risk assessments in the BiOp are optimistic.

The obvious impacts of climate change include direct effects on the fish. For example, as temperatures rise, suitable summer habitat will shift towards higher elevations. In many cases, populations will not be able to track this shift because of impassable barriers (e.g., populations below dams). In other cases, suitable habitat will disappear from the basin (e.g., some spring chinook streams that are relatively low-elevation such as Butte and Cottonwood creeks). Also, the relatively modest increases in temperature-related mortality that are predicted under future project operations as described in the BA are contingent on "critically dry" water-year types remaining rare, and "wet" years remaining common. Regional climate forecasts for the Central Valley suggest that critically dry water-years will become the most common water-year type within this century (VanRheenen et al. 2004). According to the OCAP BA, temperature-related mortality of winter-run chinook eggs in wet years is about 2%, but in critically dry years, it may exceed 40% (pg. 9-32).

Perhaps less obvious impacts may come from the high likelihood that it will become impossible for the project to satisfy all of its operational targets (various flow,

storage, temperature and water delivery targets) in the future (Frederick and Gleick 1999, Poff et al. 1999, VanRheenen et al. 2004). For example, Shasta Dam is operated to meet criteria that optimize flood control, coldwater storage, water deliveries, and fish and wildlife objectives. The BiOp assumes that the project will be able to meet these criteria about as well in the future as it has done in the past, yet it is more likely that only some of these criteria may be routinely met when the most common water-year type is "critically dry" rather than "wet". Because the system will have to be operated in a different but unspecified way, there is a substantial source of uncertainty that is not addressed in the BA or BiOp. It is our conclusion that the failure of the BiOp and BA to address the probable or likely effects of global climate change is a serious flaw in the BA and the BiOp.

The BiOp could easily be modified to include a review of the reports cited above and the references within them, because they contain directly relevant analyses. More might be possible: according to Frederick and Gleick (1999), "Data and modeling uncertainties are not justifications for delays in taking specific actions and for planning for altered climatological conditions. Water managers already have a wide variety of tools available for dealing with hydrologic risk and uncertainty". It is hard to reconcile this statement, made in 1999, with the BA, which does not contain a single reference to "climate change", and only mentions the word "climate" once in the text.

The Cal-Fed reviewers suggest developing a series of scenarios that represent a range of possible future climates and water demand situations. We feel this would significantly improve the BiOp and that it could be done available information in a timely manner.

Changing ocean conditions

The Cal-Fed reviewers also noted that assuming that very recent ocean conditions will hold into the future was untenable. The BiOp correctly notes that at least part of the recent upturns in abundance of chinook salmon is due to favorable conditions in the ocean. In spite of this recognition, the BiOp argues that populations will be able to bear long-term increases in mortality caused by the project because they have recently experienced short-term increases in abundance. The BiOp should have evaluated whether the populations will be able to bear the increased mortality under the full range of ocean conditions, which will include periods of poor survival as well as good periods. The literature is rich with examples of how ocean survival of salmon varies over time, and what kinds of oceanographic variables might be useful indices of this variation. Furthermore, the recent status review update for Pacific salmonids attempted to incorporate considerations of climate variability in status assessments (Good et al. 2005, but available in 2003). Unfortunately, it would not be easy to incorporate the analyses suggested by the Cal-Fed reviewers in the short term, although ongoing research at the NMFS science centers may be useful in future BiOps. In the short term, BiOps should avoid arguing that anticipated impacts are sustainable on the basis of recent population performance, especially when that performance is suspected to be partly the result of favorable climatic conditions.

Hatchery fish

The OCAP BiOp does review the effects that artificial propagation can have on naturally-spawning populations, and recognizes that hatcheries are part of the project, but doesn't attempt to assess their actual impacts because of time limitations (pg 169).

The Cal-Fed reviewers urge that the effects of hatchery fish be analyzed concurrently with the other project impacts (which is consistent with advice from the Salmon Recovery Science Review Panel (RSRP) to stop analyzing individual "H-factors" independently; RSRP 2001). According to the BiOp, hatcheries are "interrelated and interdependent actions" of the project that are intended to mitigate for habitat losses caused by the project. It therefore seems appropriate for the BiOp to address the full range of impacts that hatcheries might impose on protected populations. In the Central Valley, hatcheries cause two kinds of problems for naturally-spawning populations.

One problem arises from the fact that the major purpose of most Central Valley hatcheries is to support high harvest rates in mixed-stock ocean fisheries. Harvest rates that are easily withstood by hatchery populations are likely too high for naturally-spawning populations, especially those using less productive habitats. The hatchery-natural harvest management dilemma does not appear to be mentioned in the OCAP opinion.

The other problem, according to the best available science, is that hatcheries may be degrading the ability of natural populations to reproduce in the wild, at least where there is significant exchange between natural populations and hatcheries (i.e., steelhead, winter chinook, and Feather River spring chinook). Of particular concern are the genetic impacts, which are cumulative over time, or are rather slow to reach equilibrium (Ford 2002). A key concern is that as a result of cumulative losses of fitness in the wild, populations that once were viable, albeit depressed, can become dependent on hatcheries for survival. Furthermore, hatchery operations can promote the loss of genetic diversity among populations by increasing gene flow (Waples and Drake, 2004). Even if the project operates as it has into the future, the status of populations may continue to decline. The BiOp could do a better job of reviewing the available information on this topic, and in explaining how it is factored into the synthesis. This is an area of active research and rapidly evolving understanding, however, and any predictions at this point in time will be uncertain. This uncertainty should be accommodated.

The Central Valley TRT, recognizing both the high risk posed by hatchery operations, and the large uncertainty in assessing particular situations (where typically the necessary data are lacking), has adopted simple rules that specify how many hatchery-origin fish may spawn in areas used by natural populations without raising extinction risk beyond acceptable levels. These criteria suggest that the existing hatcheries place directly associated natural populations (i.e., those in the same river) at high risk of extinction and continued operation will prevent them from achieving a low-risk status. ESUs may be able to achieve a low risk status with continued hatchery operation, but only if there are enough viable populations that are essentially isolated from hatchery strays, and the indirect effects of hatchery operations on the populations are low enough such that all other viability criteria are met.

Other factors likely to be important but that received inadequate treatment
The reviewers noted a number of other factors that they felt were important to consider but had been given insufficient treatment in the BiOp. The Cal-Fed reviewers listed 11 impacts that the BiOp identified but failed to adequately quantify or assess. Of these, perhaps the most significant are effects of elevated temperature beyond those on early-life-stage mortality which include alteration of the timing of life-history events, especially emergence and outmigration, changes in the abundance, distribution and activity of predators, especially non-native warm-water game fish, and mortality or sublethal effects on other life stages such as smolts and adults. A number of papers were identified by the Cal-Fed panel that would be useful to consider in the BiOp.

McMahon highlights spawning gravel as an important but ignored factor. Certainly, the project has a large effect on the input, distribution and quality of sediments, including gravels, but it is not clear to this committee (which does not include a geomorphologist) that the proposed operations will significantly change sediment dynamics relative to the baseline used in the analysis. It is possible, however, that the system has not reached its new equilibrium and that the adjustments of stream channels and riparian areas to hydrologic conditions and reduced sediment inputs will reduce the quantity and quality of spawning habitat into the future even under baseline operations. A review of the relevant literature would be worthwhile.

Conclusions
Comprehensive assessment of the risks posed by management actions that are of large scale, long duration and that may have significant effects on protected species must address climate change, ocean conditions and hatchery fish. In general, there are not yet generic quantitative models that allow for predicting how these risk factors will interact with a project to influence species persistence. Much background information is available, however, that could be used to develop plausible scenarios that would be helpful in assessing whether protected populations will be likely to persist in the future. We do not suggest that *all* Section 7 consultations must address these issues. Where the expected impact is small or of short duration (e.g., a dredging project in a small harbor), or more generally, where the project impacts will not directly exasperate the impact of climate change, it may be appropriate to ignore climate change in risk analyses.

Question 2

Are the technical tools used in the NMFS OCAP biological opinion (e.g., modeling, calculations, analytical and assessment techniques) able to determine impacts to the individuals and to the populations?

The Cal-Fed review found NMFS dependence on existing off-the-shelf models, especially for quantitative analyses, resulted in less quantitative results and more qualitative-based assessments than is desirable and faulted the use of a temperature-mortality model (LSalmon-2) as not producing credible estimates of temperature-induced mortality.

One CIE reviewer argued that the modeling used in the BO was a collection of ad hoc procedures that had been developed independently, and were used in various combinations at various times, as each independent model evolved, to provide results. He suggested that comprehensive ecosystem modeling should be undertaken such that

> all species can be looked at simultaneously with up-to-date information and techniques, including predator-prey relationships.
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> The other CIE reviewer answered affirmatively and argued that two main analytical tools used to assess impacts at the individual and population level are the Salmon Mortality and Delta Loss models. He found that both allow quantitative measurement of the relative impacts of various project operations under a range of potential hydrologic and water management scenarios.

The three reviews approached this question differently. The Cal-Fed review took a broad scale approach that pointed out a number of issues with specific methodologies. Notably, they correctly identified serious flaws in the temperature-mortality model, which was the basis for much of the quantitative assessment. This finding, among others, led the Cal-Fed reviewers to conclude that the best available scientific information was not used. In contrast, the McMahon (CIE) review was specific both in terms of comments about the models as well as the application of the models. It focused on the ability of the models to address the impact of the project on individual fish and supported the technical tools used. Finally, the Maguire (CIE) review was even more broad-based than the Cal-Fed review, recommending ecosystem modeling including predator-prey interactions and adaptive management. The reviewers reached different conclusions according to how they approached the question, but overall, the BiOp does not appear to address population-level impacts adequately.

We agree that there are problems with some of the technical tools used in the OCAP biological opinion. For example, the monthly time step in CALSIMII was too large and did not treat the variability in daily temperature correctly and the L-Salmon2 model did not use the best available data (and in fact uses seriously flawed data). We disagree that an ecosystem model that incorporates all aspects is an appropriate method for Section 7 consultations because the wide gaps in current knowledge prevent a single holistic model from capturing all important features. Instead we recommend the approach used in the BiOp, i.e., multiple models for specific questions. However, the results from the separate models must be brought together in a manner that makes them comparable. The lack of a conceptual framework in the BiOp led to use of inconsistent measures for different aspects of the analyses. Using different life stages that were not adjusted to a single point in the lifecycle prevented combining impacts from separate sources correctly. The lack of a conceptual framework also led to the BiOp focusing on certain aspects for which models were readily available, such as temperature effects on juvenile survival, but essentially ignoring other aspects, such as impacts on the supply or quality of spawning gravel. We recommend an explicit conceptual framework be used in all Section 7 consultations to ensure that all aspects of a project are considered and added together, even if only qualitatively. The Central Valley Recovery Team has conducted VSP analyses, which could have been adapted for use as the conceptual framework for this BiOp.

Overall, the most difficult issue expressed by the reviewers is how to deal with the "salami" problem: no individual slice of salami is a problem but eventually the salami is gone. The classic cumulative effects (salami) problem is exacerbated by the moving baseline problem whereby each project is compared to the current situation instead of to a fixed historical baseline that is known or assumed to be viable. In the context of Section 7 consultations, this means that it is extremely difficult to measure the population- or

ESU-level impact of specific current actions against a baseline that is far from undisturbed. The major changes in habitat accessibility and river flow caused by the many dams and water diversions already far outweigh the potential impacts of any particular proposed action in the OCAP on the future viability of salmon. These difficulties may be moot, however, because by regulation, an Environmental Baseline in a Section 7 consultation "includes the past and present impacts of all Federal, State, or private actions and other human activities in the action area, the anticipated impacts of all proposed Federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process" (50CFR 402.02).

Short-term improvements

In the short term, we recommend using a conceptual framework, such as a VSP analysis, for all Section 7 consultations. The conceptual framework should be explicitly stated and summarized in a table to allow easy comparison of impacts from wide ranging sources, even if only qualitatively. This does not mean the creation of new models or analyses, but rather an explicit consideration of all possible impacts of proposed actions. In general, there will need to be some work done by biologists writing BiOps to apply VSP concepts and TRT products to assessments of particular actions. A useful approach might be the risk matrix approach developed by salmonid biological review teams, were a quantitative or qualitative risk score is assigned to each VSP element. Such tools, once developed, could be reused on or adapted for other assessments. Additionally, more communication between the Science Center representatives, such as Recovery Team members, and the Regional Office would ensure that the best available scientific information is used in Section 7 consultations.

Long-term improvements

Continued development of assessment tools for all species will benefit future Section 7 consultations. In particular, there is a need for developing and improving quantitative tools that predict how alterations to fish habitat impact populations. The Office of Protected Resources may wish to consider maintaining a library of these tools as they are developed, so that they would be readily available to biologists in future consultations.

Question 3

Are the independent reviewers criticisms of uncertainty founded and if so how do you suggest NMFS approach their recommendations in the short and long term?

> One CIE report found that uncertainties were not adequately considered in the BO. He found that past observations, even though they may not be representative of future ones, because of global climate change, show considerably more variations and cyclicity than predicted values from the models used.

The second CIE reviewer argued that the BA would benefit from more uncertainty analysis relative to several key life history periods.

The independent reviewers' criticisms of the treatments of uncertainty in the BiOp and its associated BA are well founded. Definitions of uncertainty need to be clarified here before the reviewers' comments can be organized and understood. The term, uncertainty, has two broad meanings in the context of the reviews. The remedies available to improve the treatment of uncertainty depend on what type of uncertainty it is.

The first meaning, called here 'statistical uncertainty,' refers to the precision of measurements. In this case uncertainty may be described by well known statistics (i.e. variance, standard deviation, coefficient of variation). It appears that a lack of standardization of statistical terminology for describing the precision of estimates among the contributors to the BiOp and BA was a source considerable concern to the reviewers. To take an example provided by a reviewer, an estimate of a critical demographic attribute of the salmon populations, the Juvenile Production Estimate (JPE), was not qualified according to its precision. The JPE is appropriately described as an "unbounded point estimate" meaning that its statistical uncertainty is unknown, although recent work indicates that any prediction of juvenile outmigration that is based on adult returns will have a coefficient of variation in excess of 100% (Newman and Lindley, in press).

The reviewer's concern is that the lack of knowledge of the variability in a critically important demographic attribute has not been acknowledged. Statistical uncertainty grows multiplicatively in the estimation of population abundance by a chronological sequence of such demographic parameters; hence the reviewer judges it to be important that the degree of uncertainty in each parameter be acknowledged. Please note that the reviewer does *not* criticize the logic and biological facts behind the JPE, which lies in the domain of the second broad type of uncertainty identified by the reviewer.

The second meaning of uncertainty, called here 'biological uncertainty,' refers to the degree to which the logic and assumed biological facts surrounding the control of the basic processes of birth, growth and death correspond to reality. An explicit statement is needed regarding current understandings of the dependence of birth, growth and death processes of salmon populations on biotic (i.e. food and predators) and abiotic (i.e. climate, flows, oxygen, spawning substrates) factors. For example, one of the reviewers calls for "*A more detailed uncertainty analysis of what are likely key limiting factors/time periods for juveniles would help better define the upper and lower bounds of likely juvenile abundances under varying abiotic (e.g., water temperature, entrainment) and biotic conditions (e.g., predation levels).*" (McMahon).

The reviewer's concern is that lack of understanding of the relative importance of fundamental aspects of the biology in relation to the environment is limiting the ability to understand what controls salmon populations, and hence the ability to effect recovery. Putting concerns about statistical uncertainty aside, models of salmon abundance through time are only as good as their fidelity to the actual circumstances of birth, growth, and death processes that determine the abundance of the population. Biological and model uncertainty may only be decreased through careful analysis of scientific observations in the laboratory and the field and ongoing testing and refinement of models.

Near Term Points of Criticism to be Addressed

Addressing reviewer's concerns about the treatment of statistical uncertainty may be accomplished in the near term through editorial and procedural mechanisms that could be implemented within the time frame of the Section 7 consultative process. Reviewer's concerns about statistical uncertainty were driven in large part by lack of standard nomenclature and by organizational issues, both of which are related to how critical parameter estimates are presented. Leaving aside issues of biological uncertainty, values of parameters need to be uniformly and invariably identified as 1) actual measurements with known measurement error, or 2) unbounded point estimates with unknown measurement error. For example this basic nomenclatural issue might be approached editorially by using different type faces unique to each category of parameter estimate, bounded or unbounded. Bounded estimates might be further distinguished based on how the measure of uncertainty was obtained.

Organizationally, all of the parameters could be placed in a table conveniently and consistently located near the front in both the BiOp and BA. Tables would contain symbols, definitions and type of statistical uncertainty, bounded or unbounded. When a parameter estimate is the product of calculations that include bounded and unbounded estimates of other parameters, it would be so identified.

Uncertainty could further be incorporated into BiOps through the use of scenarios, both best and worst case, to examine the robustness of the analysis results. The scenarios would by necessity be a subset of all possible combinations of parameters, but still could provide indications of whether or not proposed actions would put the stock in jeopardy. As more information becomes available, these scenarios could be transformed into a more formal Bayesian analysis.

The specifics of the preceding examples are meant primarily as suggestions to motivate near term actions. The actual remedies applied to the concerns of the reviewers regarding the treatment of statistical uncertainty could take other forms.

Longer Term Points of Criticism to be Addressed

Addressing reviewer's concerns about biological uncertainty will require an iterative process of 1) collecting interdisciplinary scientific observations, 2) building and re-building models of the populations within their environments, and 3) running the models in data assimilation mode to advise the content and design of data collection programs, hence back to step 1. Repeating these three steps (observe-model-test) consistently would eventually provide the types and quality of information requested by the reviewers. The process of data assimilation not only tests the logic and parameters of the model against reality, but it can also be used to identify which variables are most critical, and the minimum frequency or density of observations necessary to estimate a given parameter.

It appears that the concerns of the reviewers regarding biological certainty could only be addressed in the longer term through the systematic gathering and testing of data that is the scientific process. As such the amount of time necessary to complete it lies outside the time constraints of the section 7 consultation. Nonetheless these are valid concerns that if addressed could substantially contribute to the salmon recovery efforts.

Conclusions

The three external reviews offer generally valid and helpful critiques of the science underlying the Central Valley BiOp. Future BiOps could be improved in the near term through the use of an explicit conceptual model, such as that provided by VSP and related works, comprehensive consideration of all significant sources of risk and effects on all stages of the salmonid life cycle, and adequate accounting of uncertainty through the use of scenarios of future conditions and the response of salmonids to these conditions. In the longer term, the conceptual framework provided by VSP will allow improved information and analytical methods to be incorporated into biological opinions as they become available.

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