Report of the 2011 Independent Review Panel (IRP) on the Implementation of Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria And Plan (OCAP) for State/Federal Water Operations

Prepared for: **Delta Science Program**

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Scope and Intent of Review: This report represents the findings and opinions of the Independent Review Panel (IRP) assembled by the Delta Science Program at the request of the U.S. Fish & Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) to provide scientific advice intended to assist with an annual review of the implementation efficacy of OCAP RPAs from October 2010 through September 2011. After reviewing a required set of written documents (Appendix 1), the IRP convened at a public workshop in Sacramento, CA on 8-9 November 2011. The first day of the 2-day workshop provided a forum for the panel to consider additional and updated information and new research findings and to discuss issues related to the application of RPA actions. On the second day the panel deliberated in a private session beginning at 8:30 am in order to prepare and present their initial findings at the public workshop at 2:00 pm, after which there was an opportunity for agency representatives, members of the public and the panel to comment and otherwise exchange impressions and information. Subsequent panel communication and deliberations were conducted via email and conference call in the course of drafting this final report.

The intent of this annual review is to inform NMFS and the USFWS as to the efficacy of the water operations and regulatory actions prescribed in their respective OCAP RPAs during the 2011 water year. The panel also was encouraged to suggest appropriate adjustments to the RPAs or their implementation in the 2012 water year based on insights from the prior year's water operations and new data from recent and ongoing scientific research findings. Most of the current research presented at the workshop in Sacramento (8-9 November 2011) was not part of an RPA action, and so fell outside the scope of this review, but the panel was free to draw on the findings at its discretion.

The panel was not charged with evaluating the scientific basis or conceptual validity of the process underlying the original RPAs, nor any legal issues related to the development or application of the RPAs.

EXECUTIVE SUMMARY

The review panel appreciates the unique challenges faced by all of the agencies attempting to balance existing commitments and mandated co-equal goals of (1) providing a reliable water supply for California and (2) protecting, restoring and enhancing the Delta ecosystem from which water resources are derived for a multitude of human uses. We commend all of the agencies charged with this daunting task for their efforts to date as they strive to cooperate and integrate activities directed at achieving this goal within the context of persistent change in environmental and socio-economic conditions.

The panel also recognizes that the 2011 Water Year (WY) was classified as wet in both the Sacramento and San Joaquin watersheds. Consequently, most RPA actions that would have constrained water exports under drier conditions were neither triggered nor applied in WY 2011 and a record 6.5 million acre-feet was exported through the pumping facilities. The wet year yielded sufficient water storage capacity in reservoirs to allow most downstream temperature and flow targets mandated in the RPAs to be met with little difficulty. A few physical targets were not met this year, which suggests a low expectation that those specific targets are achievable in the future, especially in drier years. Overall, conditions during the 2011 WY did not challenge water operations with respect to conforming to the physical requirements of the RPAs, but population responses of the listed species remain inadequately articulated. After only two years of operating under the RPA actions, it is still too early to make definitive assessments of long-term effects on listed species populations, but there was little evidence to indicate any change in the status of the listed species even in the short-term. As was observed by the 2010 OCAP IRP, the current panel continues to perceive a distinct focus on achieving RPA objectives in terms of meeting physical targets (i.e., flows and temperatures) without explicitly relating the success or failure in meeting those targets to the biological/ecological responses of the listed species. We reiterate the previous panel's cautionary advice "that the focus on meeting operational targets should not carry over into the planning of data needs and studies necessary to improve what should be very real connections between the RPA actions and their effects on the listed species." (Anderson et al. 2010)

Linking RPA actions to vital rates within life stages (e.g., juvenile survival rate), and ultimately to the population dynamics (e.g., annual changes in population size) of the listed species within the ecosystem remains a key area of concern. The panel was encouraged that some studies aimed at refining tools for the accurate prediction of spatially-explicit variation in physical factors (e.g., temperature, tides, turbidity) and the behavior of fishes are being encouraged, but every effort should be made to speed the pace of progress in this area.

The panel encourages the continued development and future use of real-time sensor arrays linked to an informatics expert system that can track variation in physical and ecological data simultaneously as a means of coupling RPA actions with biological response and informing the management of water operations to meet multiple goals.

Evaluating the effectiveness of RPA actions in meeting the intended objectives in WY 2011 seemed a simple task, at least superficially. Almost all of the operational targets were achieved because water resources were abundant and many RPA actions (e.g., all RPA actions pertaining to delta smelt) that may have constrained water exports were not even triggered in WY 2011. While it is certain that the RPAs only minimally affected water exports, in terms of meeting the intended biological objectives, effects on listed fish species were unknown and only presumed to be minimal. The wet conditions in WY 2011 followed what was very nearly an average water year in 2010, yet the ability to accurately detect effects on the populations of listed species has yet to be demonstrated. The panel remains concerned that many of the temperature and flow targets will not be met in substantially drier years. If positive effects on listed species are not detectable following a series of “good” water years, the Panel has some concerns about the detectability of effects under less favorable conditions.

The technical teams continue to meet regularly – and periodically in response to unexpected developments - to discuss available information and make recommendations. It is difficult to envision how these dedicated groups of experts could be asked to do any more with the information currently available to them. However, near real-time information on fish populations is often based on the collections of very few individuals in the monitoring programs and depressed population levels of the listed species may affect the reliability of this information in terms of assessing even relative abundance at a specific site. Even when near real-time data on listed fish species are available, response times required to adjust water operations are sometimes too slow relative to real-time triggers (e.g.,salmonids at Knights Landing and closure of Delta Cross Channel (DCC) gates) to provide effective protection for some portion of the population at risk. Also, recommendations of the technical teams continue to be based on historical patterns and the expert opinions of the current team members rather than on an objective and transferable template that could be followed and justified in subsequent years.

One suggestion for collectively addressing these issues is the adoption of a comprehensive and accessible web-based data management system that uses real-time data and state-of-the-art predictive models for physical variables (e.g., flows, temperatures, substratum transport) and biological responses under changing flow regimes within a spatially-explicit landscape context. An expert system such as this has potential to improve synchronization of water operation decisions with fish behavior and requirements, as well as providing a basis to promote greater objectivity and transparency in the management process that can carry over to future technical teams. Some ideas and suggestions that were considered and discussed by the IRP are provided in Appendix 3 of this report.

Finally, the panel appreciated the response to the recommendations of the previous IRP to move toward a more standardized format in the technical reports and workshop presentations adopted by some of the technical work groups. The inclusion of geographic orientation to the portion of the system under discussion was especially useful for newer members of the IRP, and discussions of specific reasons for why particular RPAs were or were not applied during the year were generally appreciated. We encourage the continued use of similarly oriented formats in the future. The panel continues to recommend and encourage the inclusion of more known or measured responses of the fish populations or life stages targeted by the RPA actions, particularly as multiple years of observations are developed. Finally, the time allotted at the workshop for panel deliberations (5.0-5.5 hrs) was a much appreciated improvement over the 2-2.5 hrs during which the previous IRP was expected to organize its thoughts and reach consensus prior to presenting its preliminary findings. We encourage a similar time allotment for that purpose for future panels.

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INTRODUCTION

The Sacramento-San Joaquin Delta comprises a complex system of distributaries and human-engineered channels, levees and a mix of agricultural and urban areas that have replaced former wetlands and floodplains. Historically, the Delta (particularly the southern portion) contained more structurally complex aquatic habitats (e.g., smaller and more numerous channels and sloughs) that likely functioned, at least in part, to store water much like a sponge as well as to provide expanded shallow aquatic habitat for certain fish species. Significant structural alterations of the ecosystem date back to the mid-nineteenth century. Many of the anthropogenic changes in the Delta and in its upstream tributaries were designed to store, redirect and convey water to meet human demands within the region, with little consideration for other biotic components of the ecosystem.

Water in the Delta is essential habitat for resident and migratory fishes and an important resource supporting a variety of uses (e.g., agriculture, power generation, drinking water, etc.) that produce goods and services for the human population both within and outside of California. The chronic multi-decadal alteration of the natural ecosystem associated with meeting the demands of an increasing human population in the watershed have contributed to profound changes in the system's aquatic fauna, including a persistent decline in certain species of native fishes. Consequently, some of these jeopardized species have been afforded protection under the Endangered Species Act (ESA).

Within the historical context of engineered water resource management in the Delta, formal legislative recognition that water and other habitats should be managed to restore and enhance the Delta ecosystem as a co-equal goal with providing a reliable water supply to California (SBX7, Nov 2009) represents a novel conceptual approach to water management within the region.

Background on the OCAP RPA review process:NOAA's National Marine Fisheries Service (NMFS) and the US Fish and Wildlife Service (USFWS) each issued Biological Opinions on the long-term Operations, Criteria, and Plan(OCAP) of the Central Valley Project (CVP) and State Water Project (SWP) that included Reasonable and Prudent Alternative (RPA) actions designed to compensate for - or avert - any project-caused jeopardy to listed species or adverse modification of critical habitat for the listed fish species in accordance with section 7 of the Endangered Species Act (ESA). The specific RPA actions in NMFS' OCAP Opinion include both broad and location-specific RPA actions which were recently amended slightly (NMFS' 2009 RPA with 2011 Amendments). The specific RPA actions in the USFWS' OCAP Opinion are organized by delta smelt (*Hypomesustranspacificus*) life stages and are triggered primarily by actual or expected presence of adults, larvae and juveniles in portions of the Delta where flows are influenced by export pumping. The RPA actions in both OCAP Opinions provide specific objectives, scientific rationales, and implementing procedures. The NMFS Opinion primarily addresses issues involving wild winter- and spring-run Chinook salmon (*Oncorhynchustshawytscha*), Central Valley steelhead (*Oncorhynchusmykiss*) and green sturgeon (*Acipensermedirostris*). The USFWS Opinion relates to jeopardy issues involving delta smelt (*Hypomesustranspacificus*).

NMFS' Opinionrequires the U.S. Bureau of Reclamation (USBR) and NMFS to host a workshop no later than November 30 of each year to review the prior water year's operations and to determine whether any measures prescribed in the RPA should be altered in light of information learned from the prior year's operations or research (NMFS' OCAP Opinion, section 11.2.1.2, starting on page 583). Amendments to the RPA must be consistent with the underlying analysis and conclusions of the Biological Opinions and must not limit the effectiveness of the RPA in avoiding jeopardy to the ESA listed species or result in adverse modification of critical habitat. The U.S. Secretaries of Commerce and Interior have directed that this annual review be expanded to include a review of the implementation of the USFWS RPA as well.

Panel charge: The panel was charged with reviewing the implementation of the OCAP RPAs associated with the NMFS and USFWS Biological Opinions for water year 2011 (1 October 2010 through 30 September 2011). The charge addressed five categories: (1) whether implementation of RPA actions met the intended purposes, (2) agencies' responses to recommendations from the previous IRP (2010), (3) the study designs, methods and implementation procedures taken in meeting the objectives of the RPAs, (4) efficacy of coordination of real-time operations with the technical teams, and (5) recommendations for adjustments to implementation of the RPAs actions for meeting their objectives.

Six questions were posed to the panel. These are provided verbatim in Appendix 2 of this report and defined the scope of the panel's charge. Additional questions were presented to the panel by the Technical Working Groups and while the panel was not obligated to address these under the official charge, we attempted to provide some feedback when possible and appropriate.

Acknowledgements: The members of the panel appreciate and acknowledge the efforts of the agency and technical team representatives who prepared the written materials and delivered the workshop presentations that were the basis for this report. We recognize that much of the material had to be compiled, analyzed and organized in a relatively short time. Despite the many competing demands on the workshop participants, the materials were presented professionally, on schedule and often were responsive to the previous IRP's recommendations for format changes. The panel wishes to express a special thanks to the Delta Science Program staff for providing the organization and logistical support to facilitate our task. In particular, Sam Harader (Program Manager) facilitated discussions and maintained a tight schedule at the workshop. Lindsay Correa (Environmental Scientist) expertly attended to a wide variety of technical and provisional details in support of the panel's efforts before, during and following the workshop.

PANEL COMMENTS ON OCAP RPA ACTIONS IN WATER YEAR 2011

Implementation of RPA Actions and the intended purpose of the Actions

General comments and observations. The intended purpose of RPA actions can be viewed from several perspectives. One is to meet some physical or numerical compliance target (e.g., a temperature at a particular location, a maximum negative flow for a given period of time, maximum level of take, etc.). Sometimes the intended purpose is to meet some target determined by a running average through time (e.g., 10 yr running average). Of course, it is impossible to determine whether or not such an intended purpose is being met for an average that cannot yet be calculated (e.g., 2 years into a 10 year running average). A few actions require that additional studies be conducted when critical pieces of information are lacking (e.g., InstreamFlow Incremental Method study on Clear Creek, green sturgeon study associated with Red Bluff Diversion Dam). The initiation or completion of the studies might be viewed as accomplishing the intended purpose, or the studies may be judged to have met their intended purpose only if the information gaps were filled. Ultimately, the intended purpose of all of the RPA actions is to achieve a biological response in the target fish species that improves the survival of one or more life stages or at least minimally results in no additional jeopardy from water operations.

Some of the NMFS RPA actions have yet to be implemented or completed and so the IRP is unable to develop an opinion as to whether or not they will meet their intended purpose. These include:

(1) Action I.1.2. Channel Maintenance Flows from re-operation of the Whiskeytown Glory Hole spills. This action is targeted for implementation in winter 2013.
(2) Action I.1.4. Replacement of Spring Creek Temperature Control Curtain in Whiskeytown Lake. This action was completed in June 2011, but there was no test of its effectiveness that would allow an evaluation of the intended purpose of the action.
(3) Action I.1.6. Adaptively Manage to Habitat Suitability/Instream Flow Incremental Methodology (IFIM) Study Results. The action relates to habitat suitability for salmonids in Clear Creek. While the IFIM Study initiated in 2004 has been completed, the results have not been finalized..
(4) Action I.2.4. Keswick Release Schedule (May 15 – October). Although it appears that temperature compliance points were met this year as far downstream as Jellys Ferry, this action also required Reclamation to employ an independent modeler to review the Temperature Management Plan by March 2010. This has not been done, so it is not possible to evaluate the intended purpose of this portion of the action.
(5) Action I.3.1. Operate the Red Bluff Diversion Dam (RBDD) with gates open all year after May 14, 2012. This action is intended to take place following the construction of the new pumping facility that replaces the water diversion function of the RBDD. While there have been some delays in construction,

the new facility is expected to be completed on schedule (no later than May 15, 2012).

(6) Action I.3.4. Compensation for adverse effects on green sturgeon of interim operation of the RBDD. This action involved the funding of a 3-yr research project on green sturgeon at UCDavis. The research is ongoing, but it is not entirely clear how the genotyping and telemetric studies will be used to compensate for adverse effects of interim operations at RBDD. Interim operations should have ceased by the time that the findings of this research are available. The IRP was asked to comment on this study and address some questions, which we include in a subsequent section of the report

(7) Action II.1 Lower American River Flow Management provides for minimum flow criteria for all steelhead life stages as specified by the Water Forum's Flow Management Standard (FMS). It was unclear how the prescribed flows were intended to affect the different life stages of steelhead or what minimum flow model(s) were linked to the intended biological objectives.

Flows and temperatures outside the Delta. With a few notable exceptions, most of the flow and temperature targets were met in WY2011, but effects on listed species were unclear.For example, Action I.1.1. provides for at least two spring pulse flow releases from Whiskeytown Dam into Clear Creek to attract Chinook salmon to upriver spawning areas. The pulses were delivered but there was no indication that their purpose was served in attracting salmon. Adult salmon populations continued to be low and there was even a suggestion that spring-run Chinook spawning migration may have been negatively affected through some unknown mechanism associated with the pulse flows. The Clear Creek Technical Team's recommendation to continue pulsed attraction flows similar to those applied in 2010 was difficult for the IRP to appreciate given the possible negative effect on spring-run Chinook. Why would the team make a recommendation that could result in an undesirable negative impact on Chinook spawning? Perhaps what was implied here is that pulsed flows have other beneficial ecological outcomes and perceived negative impacts may be balanced by enhancements in other areas (e.g., production of improved spawning habitat that will become apparent in the future). If so, this was unclear. While it may not be possible to separate positive or negative effects of certain pulse flows from other potential stressors affecting Chinook salmon, it is clear that depriving the system of pulsed flows would drastically change fluvial geomorphic processes that drive floodplain systems.

In some cases, temperature compliance is measured as a percent of time within a 10-yr running average that a minimum temperature is maintained at afew (3) locations along the Sacramento River downstream of the Shasta Reservoir. Clear Creek, Ball's Ferry, Jelly's Ferry and Bend Bridge are among the locations in NMFS RPA Action I.2.1. It is not possible for the panel to determine whether most of these locations will meet the temperature compliance points (TCP) on the basis of a 10-yr running average given that this is only the second year that the RPA action has been in effect. However, the TCP at Bend Bridge, which is required to be met only 15% of the time (i.e., 1.5 yrs out of 10), has not been met in either this or the previous year.

If the TCP at this location was not met in WY2011 – one of the least challenging years in terms of available reservoir storage – it seems unlikely that it can be met in any year. Therefore, the panel concludes that the objective of meeting the temperature compliance point at Bend Bridge will not be possible within 10 yrs.

The panel considered how the high resolution forecasts in the NOAA/NASA model might fit into the temperature management. In the 2010 report the panel encouraged further development of the system. However, in reviewing the material this year the panel was concerned with a mismatch between temperature prediction scales and the scales needed to manage river temperature for salmonids. From the perspective of the listed species, effects of temperature need to be projected over prespawning adult, egg, and juvenile life stages, which span 3 to 6 months. Spatial scales are most relevant over the habitat occupied by prespawning adults and redds. It was not clear how the 15 minute resolution of temperature over a 3 day window provides the needed information. Although it was suggested in the presentation that the projection from the NASA model could be extended over months it was not illustrated how these projections would provide meaningful improvements over the long-term temperature projections currently used for making temperature control decisions in the Sacramento River.

In an ideal temperature management system water releases are optimized under constraints of the fish distribution and available or forecasted volumes of cool water. Such a system would need to focus on winter Chinook but multiple stocks and life stages also need to be considered. The current scheme based on temperature compliance points and best judgments made within the season addresses the basic needs of management. However, the effectiveness of the current system in terms of fish measures is not assessable and can be improved; the distribution and response of fish targeted by temperature control actions are only considered in coarse ways. The biological analysis of temperature control operations (Appendix B in Sacramento Temperature Task Groups annual report 2011) was essentially a qualitative assessment based on best professional judgment. The panel suggests that a more quantitative model-based program is needed to efficiently utilize the limited cold water resources in the Central Valley reservoirs.

The panel is aware of NOAA's and others efforts to develop comprehensive life cycle models that would presumably deal with salmonid freshwater stages (Rose et al 2011). However, it was not evident to the panel whether efforts to improve Sacramento River temperature management are being integrated with the life cycle models under development. The panel urges that the agencies take real definitive actions to better coordinate the temperature control programs and commit real resources to developing a more state of the art management system that integrates hydraulic, biological and climatic factors at the appropriate temporal spatial scales of resolution. The NOAA/NASA temperature model is an example of what can be accomplished but even this effort remains too narrowly focused on tool-development with little explicit consideration for how it will be applied to assess the efficacy of meeting the biological objectives intended by the RPA actions.

Flows and turbidity inside the Delta for resident species. No RPA actions were triggered in WY2011 to reduce the risk of entrainment of delta smelt because neither the flow/turbidity triggers nor biological triggers (trawl monitoring of populations and salvage) were reached. For the second year, the turbidity trigger failed to detect the winter first-flush event presumed to stimulate upriver migration of delta smelt toward freshwater spawning sites. This trigger, based on the observation of turbidity of at least 12 NTU for 3 days at 3 stations (Prisoner's Point, Holland Cut and Victoria Canal) – the so called "3 x 3" rule – was not attained in either WY2011 or WY2010. The inclusion of additional turbidity monitoring stations at other locations did not help to detect the "first-flush" event. This seemed to surprise everyone because turbidity has been associated with flows and WY2011 was a high flow year.

For the second year, USFWS has expressed concern about the efficacy of the "3 x 3" turbidity triggerand both the 2010 and 2011 OCAP IRPs have concurred. The previous panel supported the suggestion to study turbidity at different stations in an attempt to find locations that would better match the intent of detecting the winter first-flush turbidity cue believed to be associated with the upriver spawning migration of delta smelt. However, there may be good reasons to consider moving away from a general turbidity trigger for implementation of RPA actions intended to protect pre-spawn and spawning adult delta smelt by predicting their movements. First, turbidity levels in the Delta have declined from historical levels and there are reasons to believe this trend will continue into the future as climate changes during the 21st Century (e.g., Cloern et al. 2011). Second, the findings of recent research conducted during 2010 and 2011 (2011 OCAP workshop presentation by Burau - USGS) demonstrated that upriver movements of adult delta smelt are achieved through a form of tidal rectification, such that fish move toward the center of the channel on rising tides to augment their upriver migration by tidal transport and then move toward the shallow edges of channels on ebb tides to maintain their position. Turbidity gradients associated with tidal movements may be involved in the lateral positioning of delta smelt within the channels, but general large-scale turbidity pulses in the system many not be necessary to trigger upriver migrations.

The observations from the above referenced study of tide and turbidity effects on delta smelt behavior also have potentially important implications for the delta smelt monitoring programs that are the basis for biological triggers for RPA Actions 1 and 2, which depend in part on detecting the presence of delta smelt in areas where they are at risk of entrainment. The principal means of detecting the location and assessing the relative abundance of pre-spawn, spawning and post-spawn adults is via the Spring Kodiak Trawl program which collects monthly samples at 40 stations during January through May. If trawl samples are collected from mid-channel, it is possible that the probability of capturing delta smelt is affected by tidal stage (i.e., captures may be more likely during flood than ebb tides), so the apparent distribution and abundance of delta smelt in a given area may have a tidal component that the current monitoring program may not reflect

A potential consequence of inaccurately assessing the relative abundance of a species at risk of entrainment/salvage mortality in the Delta was demonstrated by the extraordinary number of Sacramento splittail in this year's salvage. Nearly 9 million splittail were among the expanded salvage in WY 2011, with nearly 48% of that number occurring in a 1 week period (16-23 May). Nothing in the available fish survey data at stations in the south Delta even suggested that so many splittail were at risk of being affected by water operations. FMWT samples (September-December 2010) included splittail but almost exclusively at stations on the Sacramento side of the system and reported an abundance index of zero for the species in 2010. The 20 mm survey included no splittail during 25-28 April and contained relatively few individuals even through the peak period of splittail salvage (9-26 May), particularly at stations located nearest to the pumps. Similarly, the summer tow net survey contained few splittail in the vicinity of the pumps. The Spring Kodiak Trawl survey (January-May) targets and reports exclusively on delta smelt. While none of these surveys specifically targets splittail, the relative distribution and abundance of splittail within the Delta is reported for the FMWT, 20 mm and summer tow net surveys (www.dfg.ca.gov/delta/data).

Flows inside the Delta - anadromous species.The RPA for Delta Operations of Salmon and Sturgeon (DOSS) which have a large impact on Delta flows include:1) the Delta Cross Channel (DCC), 2) Action IV.2.3, the Old and Middle River (OMR) flow management, 3) Action IV.2.1, the San Joaquin Inflowto Export (I/E) ratio and 4) Action IV.4.1–IV.4.3, the Entrainment and Salvage (ES) facilities. Implementation of these actions are based on triggers defined by specified numbers of fish passing monitoring locations (Knights Landing for DCC operations, percent take of indicator species for OMR and inflow to export (I/E) ratio operations). The triggers are based on preseason estimates of juvenile run sizes.

These protocols were developed over the past decade and improved and refined as part of the Environmental Water Account and the biological opinion. When the operations were first developed fish routing and survival estimates were based on coded wire tag studies and therefore were imprecise. The water management protocols were designed to complement the level of resolution at which fish movements were understood. In general,the panel views real-time water operations based on fish triggers as efficient and tractable. The high flows in 2011 did not require complex actions and were associated withrelatively low loss rates of salmonids at the pumps, perhaps with the exception of wild winter-run Chinook. Although incidental take of winter-run remained below allowable levels (66%), losses of fry and smolts were the third highest in the past 10 years. Whether this system will provide adequate protection for fish in below average water years is open to question.

The combined interactions of operations of the DCC, OMR and I/E in low flow years and the resulting effect on fish routing and survival through the Delta appears to be unknown. Several issues were evident to the panel. For example, while criteria for closure of the DCC are straightforward and workable under high and average flow years it is uncertain how the operations of the DCC in low flow years will affect water quality in the Delta and the movement of delta smelt. Also, the effect of the DCC operations on the effectiveness of the OMR and I/E actions seems uncertain. In particular, the effect of I/E ratio on survival has not been well established (see VAMP peer review Dauble et al. 2010).

To understand the synergistic impacts of actions in a way that is biologically relevant to the goals of the BiOp requires a level of integration beyond the current protocol based on fish triggers. The effectiveness of the combined Delta actions must be expressed in a common biological measure, which from asalmonid life-cycle perspective is the total survival of fish passing through the Delta. As was emphasized in the 2010 report, the panel encourages the agencies to begin the transition away from the current system of fish triggers and independent water actions and move towards an integrated approach that focuses on the combined impact of flow actions on fish survival. The following section presents a simplified framework illustrating this integration and identifies weaknesses with the current approach. In actual implementation it would involve use of the Delta hydraulic model coupled with fish movement and survival algorithms. The panel is aware that several models of this nature are being developed and certain elements are currently available. Below is a heuristic example of elements required to manage the Delta actions in concert.

Framework for Managing Delta Actions in Real-Time. The passage of fish through the Delta is complex and involves multiple passage routes and fish entering the system from different rivers.The common measure of Delta operations is survival of fish from the Sacramento or San Joaquin rivers to the San Francisco Bay. Consider in this example survival from where the Sacramento River enters the Delta to San Francisco Bay. Designate survival over the entire complex network as S_{04} (Figure 1). Note that fish have many routes from the River to the Bay and for simplicity we identify four primary routes: 1) Route 03 connects the Sacramento River to San Francisco Bay through Yolo Bypass, 2) Route 013 goes through the main stem of the Sacramento River,3) Route 0123 goes into the Delta and out through the San Joaquin River and 4) Route 0125 goes into the Delta and out to the Bay via salvage and transportation at the pumps. The total survival through the system depends on the fraction of fish taking each route and the survival through each segment as

$$S_{04} = S_{34}\left(S_{03} f_{03} + \left(1 - f_{03}\right) S_{01}\left(S_{13}\left(1 - f_{12}\right) + S_{12} f_{12}\left(S_{25} f_{25} + S_{23}\left(1 - f_{25}\right)\right)\right)\right) \qquad (1)$$

where the fraction of fish partitioned to route f_{ij}can be defined in this example in terms of how flow is partitioned at a junction. Survival over route ij is denoted S_{ij}. Note that survival S_{25} involves movement through the Delta, collection at the pumps and transport of the salvaged fish out of the Delta.

Perry et al. (2010) demonstrated that the partition of fish into different routes follows the partition of flow which allow the routing of fish to be defined as

$$f_{03} = \frac{F_{03}}{F_A}$$
$$f_{12} = 1 - \frac{F_{13}}{F_A}\frac{1}{(1 - f_{03})} \tag{2}$$
$$f_{25} = \frac{1}{\frac{F_A}{F_{25}}(1 - f_{03})\, f_{12} + \frac{F_B}{F_{25}}}$$

where F_{ij} are flows, the river segment defined by points *i* and *j,* and F_A and F_B are inflows from the Sacramento and San Joaquin Rivers. In this simplified example, the routing through the Old River to the pumps is ignored so, a negative OMR flow is expressed as a positive F_{25} and a positive OMR flow is expressed as $F_{25}= 0$ and with the resulting flow included in F_B.

These measures can be directly related to the DOSS actions. The opening and closing of the DCC affects F_{13}. Its maximum value occurs when DCC is closed since water only enters the inner Delta through Georgiana Slough and its minimum value occurs when the DCC is open. The negative OMR flow is essentially F_{25}as controlled by water export and F_B/F_{25} is the I:E ratio for the San Joaquin River, while F_A/F_{25} is the Input to Export ratio measured relative to the Sacramento River.

Understanding the routing of flow and fish is only half the issue in implementing actions in the Delta for anadromous fish. Total survival through the system also depends on the reach-specific survival and this in turns depends on both the hydraulic and biological conditions with the segments. The system is further complicated because the pattern of survival depends on whether the flow is unidirectional, as in the upstream reaches, or oscillatory as in the regions of the Delta where tidal influence is strong enough to cause reverse flows. The relationship between water movement and survival in a segment can be expressed as

$$S_{ij} = \exp\left(\frac{x}{\lambda}\sqrt{1 + (w/V)^2}\right) \tag{3}$$

where $V$is the mean segment velocity, which is proportional to the river flow,F_{ij}, w is the root-mean-squared tidal velocity, x is the length of the segment and λ is the mean free path length a fish travels before being captured by a predator (Anderson et al. 2005). The path length depends on the predator density in the segment and environmental factors such as the visual clarity of the water and temperature. The equation can be simplified further. When river flow dominates tidal flow,$V>w$, survival depends on the length of the segmentand survival reduces to $S_{ij} = \exp(-x/\lambda)$. When the segment is dominated by the tidal velocity$V<w$, the survival can be approximated $S_{ij} = \exp(-wt/\lambda)$. Furthermore, if the mean travel through the segment depends on

the mean flow then survival is approximated $S_{ij} = \exp\left(-\frac{xw}{\lambda V}\right)$. These equations indicate that when river velocity has no tidal influence, survival should be relatively independent of flow but when tides influence the segment, survival depends on the ratio of the tidal velocity to the mean velocity which in turn should depend on flow.

This framework has two significant differences from the current protocol used for managing flows in the Delta. First, the current protocol considers three flow points in the system: F_{13}, $F_{25}$and the ratio F_B/F_{25}. However, net survival of emigrating juveniles also depends on the flow into Yolo Bypass and the Sacramento expressed by the ratios F_{03}/F_A, F_{13}/F_A and F_{25}/F_A. Thus, the current flow management does not consider half the flow measures that determine the survival of fish through the Delta. With these omissions the current protocol does not reflect how the general hydraulic conditions in the Delta determine the effectiveness of actions. For example, the fraction of the Sacramento run that passes through Yolo Bypass (an upstream action) affects the effectiveness of OMR flows (a downstream action) for improving survival. In general, the upstream actions diminish the benefit of downstream actions. Also the effectiveness of theI/E ratio for the San Joaquin is affected by the I/E ratio of the Sacramento. While the relationships expressed by Eq. 1 and 2 are nonlinear they are not overly complex and the panel believes that they can be readily incorporated into the Delta management.

The second significant difference is the framework's inclusion of route-specific survivals as expressed by Eq. 3. Estimates of survival over the passage routes are available and more are forthcoming. These can be included into the decision process for flow management. Furthermore, the balance between tidal and river flows in shaping the survival will vary between high and low flow conditions and so the effectiveness of different routes are expected to vary with flow. In general, evaluating the sensitivity of the system described by Eqs. 1 – 3 is tractable and should provide insights into the effectiveness of the Delta flow Actions under differing scenarios. The panel believes that an evaluation of a simple framework would also provide guidance for the development of a more complex analysis involving the hydrodynamic models. The panel notes that work presented in the DOSS report on the volumetric fingerprinting of Old River source waters is very much in the tenor of the framework presented here. An expansion of the work to include fish movement and survival may provide significant advancement in flow management within the Delta.

Habitat modifications. Action I.1.3. addresses gravel augmentation to enhance and maintain degraded spawning habitat for spring-run Chinook and steelhead in Clear Creek. The construction of Whiskeytown Dam has led to a situation whereby perpetual augmentation of gravel for spawning habitat will be required. Maintaining an appropriate mix of gravel sizes is of some concern in providing suitable spawning habitat for both steelhead (smaller gravel) and Chinook (larger gravel). The discussion of meeting the intended purpose of this action was again focused on the amount of gravel injected (potential spawning habitat) into the system and not on its intended realized purpose of improving spawning conditions. Data relating the gravel augmentation efforts to improvements in salmonid spawning success was not provided.

Action I.1.6. Field work on the Instream Flow Incremental Method (IFIM) in support of adaptively managing habitat suitability in order to decrease risk to spring-run Chinook and steelhead populations in Clear Creek has been completed but the findings have not been finalized. The IRP was interested in the findings but had few details on the development of habitat criteria, whether biotic components other than the listed target species were being considered, or how the findings were being analyzed. For example, Gore and Mead (2009) suggested that on-site habitat criteria for all species should be developed, when possible.

The current IFIM analysis can be completed using available habitat suitability curves. Gore et al. (2001) provided criteria for habitat (both low- and high-gradient) streams to maintain maximum community diversity, an indicator of stream integrity. More often than not, macroinvertebrate criteria have become an overriding factor during low flow months for many IFIM evaluations (Gore and Mead 2010). An additional check to the integrity of the IFIM evaluation can be accomplished by analysis of fish habitat guilds (Leonard and Orth 1988, Lamouroux and Souchon 2002). Even though the fish that have been used to create guild curves are primarily from warm water environments, the use of these curves can give an indication of how frequently the appropriate combination of fast-shallow, fast-deep, slow-shallow, and slow-deep criteria are met when compared to similar rivers which are unimpaired.

Ultimately, any IFIM analysis requires some sort of time-series analysis over a period of record, usually 20 or 30 years of previous history (usually in an unimpaired state with comparisons to various existing release schedules). The IFIM analysis should consider that recent research indicates that these historical periods of record cannot be randomly selected. Some over-arching phenomena must be considered. For example, Kelly and Gore (2008) have demonstrated that significant changes in precipitation and resulting river hydrographs as a result of the Atlantic Multidecadal Oscillation (AMO) change the predictions of time-series analysis and demand that dry-hydrograph management strategies (for 30 year periods) and wet-hydrograph strategies (for comparable 30 year periods) be implemented since changes in fish communities independent of anthropogenic alteration can be predicted. Thus, a monthly allocation during wet years to support dominant fish species may not be adequate for different dominant species in dry periods. Indeed, there may be shifts in monthly overriding considerations (e.g., water quality, flushing flows, macroinvertebrates, etc.) (Figure 2). It is reasonable to assume that the Pacific Oscillation has similar impacts on hydrographs and community composition in Clear Creek and the Sacramento River (McCabe et al. 2004,Biondi et al. 2001). The Pacific Oscillation also has been linked to fluvial geomorphic and riparian vegetative response in gravel bed rivers (Whited et al. 2007).

Considering the potential impacts of climate change in the future any IFIM analysis should also consider long-term impacts, regardless of the relative contribution of anthropogenic and oscillatory impacts (Cloern et al. 2011).

Action III.2.1. also addresses the need for improving steelhead spawning habitat on the Stanislaus River through gravel augmentation. Although this action is not scheduled for completion until 2014, some gravel was injected into the system in 2011 at Goodwin Canyon. The IRP notes again the lack of a clear plan for assessing the success or failure of the effort in terms of use of the augmented habitat by spawners and/or an augmentation in juvenile production. Also, the IRP had some concerns regarding the biological effects of artificially and rapidly reducing water levels in the river during the 2-week period required for gravel injection. What were the effects of rapidly reducing flows from 2000 cfs to 500 cfs on resident fish and their food webs (aquatic insects) during the warmest time of the year?

In general, for both Clear Creek and the Stanislaus River, the effects of habitat modifications seem to be very narrowly focused on injecting a target amount (cubic meters) of spawning gravel or altering flow management without consideration of the effects on the overall system that supports fish populations, including macroinvertebrate food resources. The maintenance of the entire community is critical to ecosystem integrity in support of the targeted salmonids.

Routing and migration. Some of the RPA actions associated with migration of anadromous fishes through the Delta and associated watersheds involve the operation of physical barriers that can be removed to facilitate fish passage (e.g., gates at the Red Bluff Diversion Dam) or closed to prevent fish migration into areas where they may be at greater risk for entrainment by the export pumps (e.g., Delta Cross Channel gates and the Head of Old and Middle River Barrier).

Red Bluff Diversion Dam (RBDD): RPA Action I.3.2.is intended to allow the unimpeded passage of green sturgeon and Chinook salmon. The action affects interim operations of the RBDD until construction of the new pumping facility intended to replace the function of the RBDD is completed in May 2012 and requires that RBDD gates be open 1 September through 14 June without exception. Reclamation began opening the gates on 1 September but because the process requires several days, gates were not completely open until 4 September. Perhaps this is considered a minor failure of compliance and no information regarding how the delay affected fish passage was provided, so the IRP is unable to determine the effect on the intended purpose of this action. However, the IRP noted that this was something that was easily predictable (i.e., the time required to open the gates completely was known) and operation of the RBDD could have been in complete compliance if the gate-opening process was initiated on 29 August. However, the IRP saw no need to make a formal recommendation for WY2012 as long as construction of the new pumping facility remains on schedule for completion in May 2012.

Entrainment, salvage and take. Relationships among entrainment, salvage and take of delta smelt continue to be of concern for a variety of reasons. It is generally accepted that entrainment mortality is substantially greater than salvage, but the relationship is not well defined and allowable incidental take refers to the number of fish killed in expanded salvage. Allowable incidental take is estimated as a simple multiple of the Fall Midwater Trawl Index. The multiple (e.g., 7.25 for adults) is based on historical levels of salvage and the FMWT index is assumed to be a reliable measure of relative abundance. The FMWT index is a weighted regional average of the number of delta smelt collected per tow from 100 stations sampled monthly during September to December. So, allowable take is a constant unknown proportion of the estimated population of delta smelt in a given year. Since 2004, the FMWT index as ranged from 26 to 74, but historically has been substantially higher. In WY2011, the FMWT index was 29 and so the level of adult take was set at 210 (29 x 7.25), while the actual level of take in expanded salvage was only 51 delta smelt.

This was interesting because water exports were exceptionally high, accounting for average monthly values of 6.7% to 27% of the volume of water in the system every day during December to May. On average,14% of the inflow to the Delta wasexported through the pumping facilities each day during this period without resulting in negative OMR flows. There is a significant but imprecise (R^2 = 0.31) linear relationship between historical salvage and OMR flows during 1993 to 2005 (Grimaldo et al. 2009), which would have predictedno salvage of delta smelt under these conditions because OMR flows remained positive throughout the period. Exported water is replenished by inflows to the system in a more or less continuous process but fish populations are not replenished on the same scale and the process is more intermittent (i.e., driven by immigrations from outside the system in the case or some species of salmonids, and/or seasonal spawning by both migrant and resident species).

The use of a constant proportion of the estimated relative extant population size (e.g., 7.25 x FMWT Index) to set allowable incidental take levels each year for delta smelt brings up the issue of whether the size of the extant population should be of concern in setting levels of take and in adjusting RPA actions. As a simple exercise to consider the possible effect of current population size on such decisions, one can apply a constant daily loss rate to hypothetical populations of different sizes to determine how many days would be required to extirpate the population. This would be the amount of time available to take some action to either reduce the loss rate or replenish the population. Figure 3 shows the number of days to extirpation for populations ranging in size from 2 individuals to 1 million individuals. Note that much more time is available to take an action to stop or reverse losses at larger starting population sizes. Also, increasing the constant loss rate applied to the populations has the effect of significantly reducing the number of days to extirpation for larger initial population sizes.

As extant populations shrink in size but the area required to sample those populations remains the same, variance associated with population estimates will be affected by the inclusion of a substantially greater number of zeros in samples. It is easy to imagine a relatively large subset of initial population sizes that would be very difficult to distinguish statistically. These are shown encircled by the red oval in Figure 3. Consequently, one may not be able to accurately estimate the amount of time to extirpation over a large range of relative abundance estimates when population sizes are low. In the example provided here, it appears that it would be difficult to know whether there are 7 or 99 days to extirpation at a range of actual population sizes from 2 to 31,250 individuals if the variance characteristics of the population abundance estimates did not allow the differences to be statistically detectable with this range.

This example is only intended to point out the potential for considering adjustments to management decisions when populations are dramatically reduced in size relative to historical levels, as observed for some species of concern in recent years (i.e., the POD years). The panel recognizes that the example is entirely hypothetical and does not account for the fact that fish are unevenly distributed within the Delta nor does it consider any behaviors that would reduce their vulnerability to mortality associated with water diversions or exports. However, average annual water consumption from all sources (17% in exports) in the Delta and its watershed is 52% (BDCP 2010, p.10) and the example in Figure 3 assumes fish loss rates of 10-25%. There are reasons to be concerned that historical levels of salvage related to OMR flows and the imprecision of relative abundance estimates when population size is low may not provide an adequate basis for setting acceptable levels of take.

Perhaps the most important practical reason to be concerned about the size of the extant population of delta smelt (and other listed species with severely depressed populations) is the concept of effective population size (i.e., the minimum population size below which the population cannot maintain itself). This is a key information gap that, if filled, could better inform RPA actions intended to reduce jeopardy for delta smelt. Bennett (2005) noted this critical piece of lacking information and suggested that genetic tools were available to address this issue.

Available genetic tools for estimating the effective number of breeders (or effective population size), exist for either a single sample of individuals or two samples separated by approximately one year or more (or samples from two cohorts). Single sample methods allow estimation of demographic parameters such as the number of parents that produced individuals in a sample either from a single cohort (year class) or multiple cohorts (England et al. 2010). Single sample estimators are as precise and accurate as the two sample estimators (e.g. Antao et al. 2010).

Genetic marker-based approaches allow estimation and monitoring of population abundance and of the number of breeders in a population (Schwartz et al. 2007,Luikart et al. 2010). Genetic estimators of abundance use DNA profiles (‘fingerprints’) as a tag (or ‘mark’) for use in traditional ecological methods such as capture-mark-recapture, which generally require two or more sampling periods separated by approximately one week to a month (Tallmon et al. 2011).

Genetic assessment testing on individual delta smelt collected in the Kodiak Trawl program and/or salvage operations could provide an opportunity to address this fundamental problem and thereby add a measure of biological response to the suite of physical measures used in directing RPA actions.

Implementation of IRPrecommendations from 2010

The 2010 IRP made several general recommendations including: (1) the need to transition from reliance on meeting physical targets to the effects of RPA actions on listed species, (2) the need for development of new models to improve real-time information on flow and temperature for river reaches and behavioral and population level responses of listed fishes and (3) the need to develop more objective and transferrable standards for recommendations in applying RPA actions.

The 2011 IRP notes some progress toward linking the potential or realized effects of RPA actions on the listed species, but much more emphasis is required. There continues to be a real need for developing protocols for linking compliance in meeting RPA physical targets and the relationships to biological responses of listed species and perhaps other biotic components on which they depend (e.g., aquatic insects as primary food resources). It does not serve the species of concern if RPA actions are being met through physical criteria without connecting these with species responses. Without the development of clear protocols for data collection and analysis, species responses to the RPA actions will remain largely unknown. Some of the limited data available, does not paint a promising picture. For example, the pattern of inter-annual decline in the passage of Chinook salmon shown in Figure 8 of the SOG report suggests that – after two years of applying the RPA actions - there is either insufficient information to draw conclusions about whether or not the RPAs are meeting their intended purpose or that altering water operations cannot overcome all the other components that may be impacting fish survival.

The 2010 IRP also made some specific recommendations for changes in the format of reports and presentations at the workshop, as well as a request for setting aside more time for the panel to deliberate before presenting its initial findings.

The current panel noted and appreciated attempts to standardize report formats for the panel review and generally found that the changes facilitated the retrieval of pertinent information within each report. However, only three of the Technical Reports (Smelt Working Group, Clear Creek Technical Working Group and the VAMP Study portion of the Delta Operations for Salmonids and Sturgeon) provided labeled maps to assist with geographic orientation that allowed the panel members to spatially associate RPA actions with the critical habitats and water operations they were intended to influence. The IRP recognizes that the agencies and technical working groups have specific and detailed knowledge of the Delta and its associated watersheds, but the current IRP reiterates the recommendation from the previous year for authors and presenters to recognize that panelists, especially newer members, may not have the same detailed map-level knowledge of the system. We recommend continued improvement in the standardize format of the technical reports presented to future panels and emphasize the importance of including information that facilitates spatial orientation in linking RPA actions, water operations, habitat conditions and life stages of targeted species.

Means of evaluating effectiveness of RPA Actions (indicators, metrics, etc)

For a majority of the RPA actions, unambiguous measure of effectiveness in terms of biological/ecological responses of the listed species continues to be lacking. The focus remains on meeting the physical targets which are presumably linked to responses in vital rates of the biological populations of ultimate interest.

Sometimes, the measurements used to assess or forecast the potential likelihood of meeting physical targets are based on relatively few flow and temperature sensors on the assumption that the gauging locations cover the total range of physical heterogeneity in the system. Water flow and temperature are the primary drivers for the river-delta ecosystem, but it remains unclear how the biological components are responding to physical heterogeneity in the system. Better integration of physical and biological heterogeneity in a spatially-explicit context could be very helpful. The IRP engaged in some discussion of this issue and included a few considerations for how this might be achieved in the future (see Appendix 3). The panel recognized that some of the suggestions are outside the charge and scope of this review, but have provided them in anticipation of potential future improvements in real-time management of the physical and biological resources of the Bay-Delta ecosystem.

Coordination of real-time operations with technical teams

For the most part, coordination between the technical teams and water operators seems to be working as well as it can with the current level of real or near real-time information that is available. It is difficult to imagine requiring the teams to meet more frequently. Coordination and transparency of the decision-making process may still be improved in the future as predictive models or improved monitoring systems become available. There were a few examples of unexpected developments that were touted as successes of coordination. These included the early – albeit delayed – closure of the Delta Cross Channel gates in response to the early appearance of emigrating salmon at the Knight’s Landing rotary screw traps, an emergency situation at a power generating facility that might have resulted in releasing water from the Keswick spillway with predicted negative effects salmon, and continuing flows from Keswick Dam in February to prevent the dewatering of salmon redds at the risk of subsequent storage shortfall in the summer. These situations were all resolved in favor of protecting salmonids, but there was little evidence provided to allow the assessment of the actual impacts of the decisions on their intended objectives. The IRP is mindful that the wet year experienced in 2011 did not provide a rigorous test of the coordination effort and concerns remain about the effectiveness of coordinating real- time operations with the technical teams and NMFS in dry years.

Recommendations of adjustments for meeting objectives

Several of the working groups (Stanislaus River, Sacramento River, American River and Clear Creek) are attempting to manipulate water operations to deal with similar issues related to meeting temperature targets within river reaches, but all seem to be using separate stand-alone temperature models. Perhaps there are good reasons for applying different models, but the IRP recommends that these groups at least adopt a common strategy for constructing projection scenario development. Some guidance can be found in NAS (2010).

The IRP also recognized a risk associated with reliance on temperature models alone, especially when data inputs depend on a limited number of sensors in reservoirs and a few river stations. Environmental data monitoring programs can evolve quickly with the development and availability of improved technology and the panel is aware of progress toward integrated programs under development in California and plans for the participation of a Delta-estuary component (e.g., http://www.swrcb.ca.gov/mywaterquality/monitoring_council/). So, a related consideration would be to solicit, facilitate and encourage input from the technical working groups into these developing data management initiatives. This should insure that future needs for improvements are met in the gathering, processing and availability of integrated physical and biological data that the agencies and working groups consider most useful in implementing RPA actions and assessing the effectiveness of their objectives in terms of biological as well as physical targets.

PANELRESPONSES TO SPECIFIC QUESTIONS/REQUESTS FROM THE TECHNICAL WORKING GROUPS

Smelt Working Group

Feedback Request #1: Any suggestions the panel may have regarding evaluation of the turbidity stations with respect to the implementation of Action 1.

See Section of this report on 'Flows and turbidity inside the Delta for resident species'

Red Bluff Diversion Dam (Green Sturgeon Study)

Question #1 Are there genetic implications of spawning at least 2 female green sturgeon in captivity and eventually releasing their progeny? If so, what could they be?

This is a question for an appropriate expert in population genetics and the current members of the IRP do not have sufficient expertise to address it adequately. However, it seems there should be concerns about the potential of introducing diseases to the wild population of green sturgeon if individuals bred in captivity are released. There should also be some consideration of the normality of the behavior and/or survival of individuals reared in captivity and released into the wild. Individuals bred from such a small parent stock would represent only a subset of the genetic diversity within the wild population and may not express the complete suite of behaviors or survival characteristics in the extant wild population.

Question # 2 Are there scientific implications to the green sturgeon population if 2 female green sturgeon are spawned in captivity, and the juveniles that are not used for research euthanized? If so, what could they be?

The answer to this question would likely be dependent on the size of the current green sturgeon population in the wild. That is, what proportion of the total juvenile population is represented by 2 females? It is difficult for the IRP to understand how this question could be answered with the information currently available. Also, "scientific implications" is a rather broad topic area.

Question #3 Considering the responses to #1 and #2 above, would there be less risk to the green sturgeon population if wild juvenile green sturgeon were captured and utilized for the studies?

Again, the IRP has neither the expertise nor the information required to address this question with any authority. However, it does seem reasonable that using only the number of juveniles required for the study and captured from the wild population may have less impact on the population than removing the whole reproductive output of 2 females, unless of course the number of wild-caught juveniles required for the study exceeds the total reproductive contribution of 2 females to current and future year classes.

Question #4 What are some methods to capture juveniles in the wild for the studies?

This question should be addressed by an expert in the biology/ecology of green sturgeon.

Delta Operations for Salmonids and Sturgeon

Question # 1 What are some suggestions as to which methods would be best to evaluate the effectiveness of the RPA actions within the Delta discussed in this report?

The panel believes that effectiveness of the RPA actions are best evaluated in terms of the effects on survival routing and travel time through specific Delta passage routes such as identified in the example framework for managing Delta Actions in *real-time. Then with a framework the information can be integrated in a process model will provide some measure of total Delta survival, S_{04}. As detailed in the response to question 3 below it is unlikely that effects of actions DCC, OMR and I:E can be directly linked to total Delta Survival.*

Question # 2 What are some suggestions for which biological indicators could be used to measure performance of the RPAs.

Evaluate effectiveness of actions in terms of fish routing through segments as well as fish survival and travel times.

Question # 3 What would the Panel recommend as a statistical approach to separate out the actions in the Delta from hydrological variations due to flow, tides, DCC gate operations, etc.?

For question 3 the panel considered the potential of separating effects of actions through two approaches: 1) statistical analysis and 2) process modeling.

1) Statistical Analysis

Although some historical data is available, in a statistical analysis approach to assess that RPA's effect the DOSS group will have to rely mainly on comparisons of fish statistics before, versus after, implementation of an RPA, or by statistically evaluating the effectiveness of an action over a range of the variable in questions.

For example consider the RPA that controls the Inflow:Export (I/E) ratio in the San Joaquin River (SJR). To assess this RPA's effect, the general strategy would be to count fish before and after the RPA is implemented, and, at the same time, measure all factors that affect fish counts (I/E, migration timing, temperature, etc). Then use multiple regression analysis to model the effects of all these factors, including the RPA status (switched "on" versus "off") and I/E ratio, on the fish counts. Unfortunately, we believe that such statistical modeling strategies have little chance of success, regardless of how much data is collected. There are several reasons for this.

First, because the RPA is mandated, its implementation status ("on" or "off") is strongly correlated with other factors (timing, temperature) that affect fish. This confounding will make it very difficult to separate out the RPA's effects, using statistical models based on uncontrolled observational data.

Second, the RPA potentially affects fish through the I/E ratio. However, the RPA requires that I/E be tightly controlled to have values only greater than 4:1 (table on p. 32, DOSS report. We also note the inability of the VAMP study to implement experimental export levels (Appendix B)). Statistically, the effect of I/E is defined as the observed change in fish count due to a change in I/E. But if I/E is not allowed to change and, in particular, not allowed to drop below 4:1, then one cannot estimate the effect of I/E and hence of the RPA. This problem (lack of ability to vary the driving factors) will plague the statistical estimation of effects for any RPA. To quote Donald Ludwig (1994, p.519): "... any policy that seeks to stabilize certain aspects of a system's behavior thereby prevents us from obtaining information about the validity of the policy."

Additionally, past studies using multiple linear correlations of I/E ratios with Delta survival have been unsuccessful (see Dauble et al 2010). Although the VAMP 6-year survival study will likely provide improved estimates of fish survival the effects of multiple interacting factors and the RPA constraints on varying Delta conditions *will limit the ability of the studies to identify the contributions of specific factors to Delta passage and survival.*

For these reasons, the panel believes that classical statistical analyses will be unable to separate the effects of individual actions on Delta survival.

1) Process Modeling Approach

The panel believes that process modeling will likely play a major role in the assessment of RPA effects. A process approach describes the routing of fish through the Delta (e.g. Figure 1) and expresses the effects of changes in flows on fish movement and survival. The Delta flow models are a starting point for developing process modeling. The movement and behavior of fish can be approached through differing degrees of complexity from making assumptions that fish routing is in proportion to flow routing or that fish routing involves small scale flow characteristics such as is modeled with the ELAM approach (Goodwin et al. 2006). The panel recommends taking both simplified and detail approach in developing process models as described in Rose et al. (2011)

Sacramento River Temperature Task Group

Feedback Request #1 The RPA actions dealing with temperature criteria in Clear Creek could be improved by developing a model for Whiskeytown Reservoir that includes alternative operations like seasonal shifts in Trinity River diversions to maintain cold water moving through the reservoir to the Sacramento River.

The IRP believes that a model for management of Whiskytown Reservoir would be valuable. The panel encourages development of a model be coordinated with regionally improved temperature models in other Central Valley reservoirs. Measuring and reporting real-time water column temperatures in the reservoirs and possibly additional stations in the Sacramento River and tributaries that impact water temperature has the potential to not only improve the decision-making process for water operations as affected by implementation of RPA actions, but also provide input to the models. Models without data for validation and calibration are not useful.

Feedback Request #2. An evaluation of the effectiveness of the new Spring Creek temperature curtain (i.e., before and after repairs were made) should be conducted to improve the model above.

At the workshop in Sacramento, the IRP wondered why an evaluation of the new temperature curtain was not conducted in conjunction with its installation. The information provided was that the new temperature curtain simply replaced a similar previous curtain and the effectiveness of the technology was not in question. So, the IRP wonders why the SRTTG would now see a need to test the new curtain.

Feedback Request #3. Real-time operational decisions concerning the EOS carryover storage in Shasta Reservoir (e.g., reducing fall flows to conserve storage) would benefit from the use of long-term (6-8 month) hydrologic projections.

The IRP concurs. Furthermore, the panel supports efforts to address issues of carryover storage under future climate scenarios in which drought patterns may become more extended.

Feedback Request #4. The Decision Criteria document for the Sacramento River Water Temperature Management should be updated to be consistent with the NMFS 2009 BiOp.

The IRP is not versed in the legalities and requirement for how closely the SRTTG Decision Criteria must comply with the NMFS 2009 BiOp. However, as the panel notes in the report, the protocol based on the temperature compliance points is inefficient and its impact on listed species is difficult to assess. The panel urges development of a more comprehensive system for temperature management.

Stanislaus Operations Group

Question #1. What studies or monitoring data would improve our ability to adaptively manage within the flexibility of the RPA actions or improve our ability to assess the effectiveness of our implementation of the RPA actions?

Perhaps the most important immediate need for the Stanislaus operation is implementation and maintenance of real-time gauging stations. It is not possible to implement RPA actions when stream gauges are not working as was the case this past year.

Question #2. What advice can you provide regarding the implementation (in timing or shaping) of particular pulses in the flow RPA, specifically the winter "storm" pulses, the spring pulse (which partially coincided with the VAMP pulse flow) and the October pulse flow?

Timing of pulsed dam releases is by necessity tied to the availability and input of water but the shape should also be related to reservoir inflows, particularlythose associated with natural events (e.g., precipitation and snow melt). Essentially the closer to normative flow conditions that can be achieved for the pulsed releases, no matter what time of year they occur, conditions will at least approximate those to which the fish species are adapted.

Question #3. Do you have suggestions for any specific sort of analysis that would be most appropriate to use when implementing temperature management throughout the year (e.g., addressing impacts to water supply and all beneficial uses)? Are there particular data gaps (e.g., outlet temperatures at New Melones and Tulloch and reservoir temperatures at Goodwin) that you recommend filling in order to substantially improve the effectiveness of our implementation of Action III.1.2., including the exception procedure?

A first step could be to implement the NOAA flow routing model approach coupled with a climate component that could estimate probable conditions 6 months or longer, if this type of forecasting is possible. Adding river monitoring MET (meteorological) stations for both New Melones and Tulloch outlets and water depth *temp buoys in the Goodwin dam reservoir may also be advisable. The river MET stations should be in appropriate locations in the Stanislaus River as well as other tributaries of the San Joaquin River. Data from this RIVERNET system needs to feed real-time into the model of forecasted conditions and be used to monitor effects of implemented cold water flow releases.*

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FIGURES

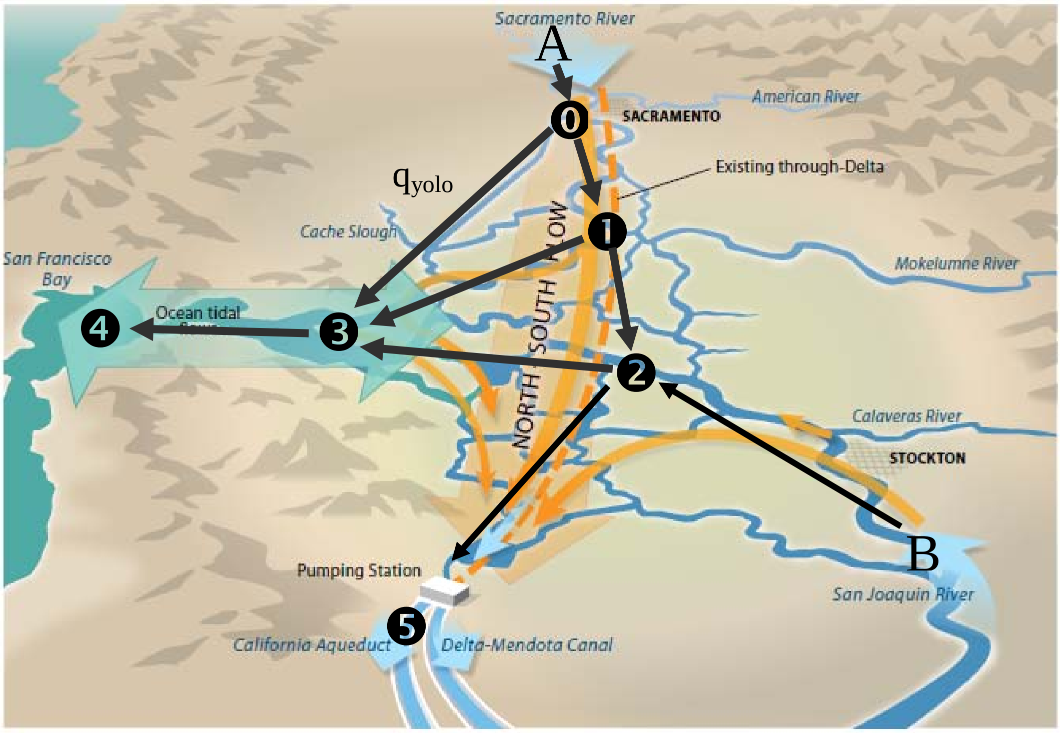

Figure 1. Schematic for modeling routing of fish and water through the Delta.

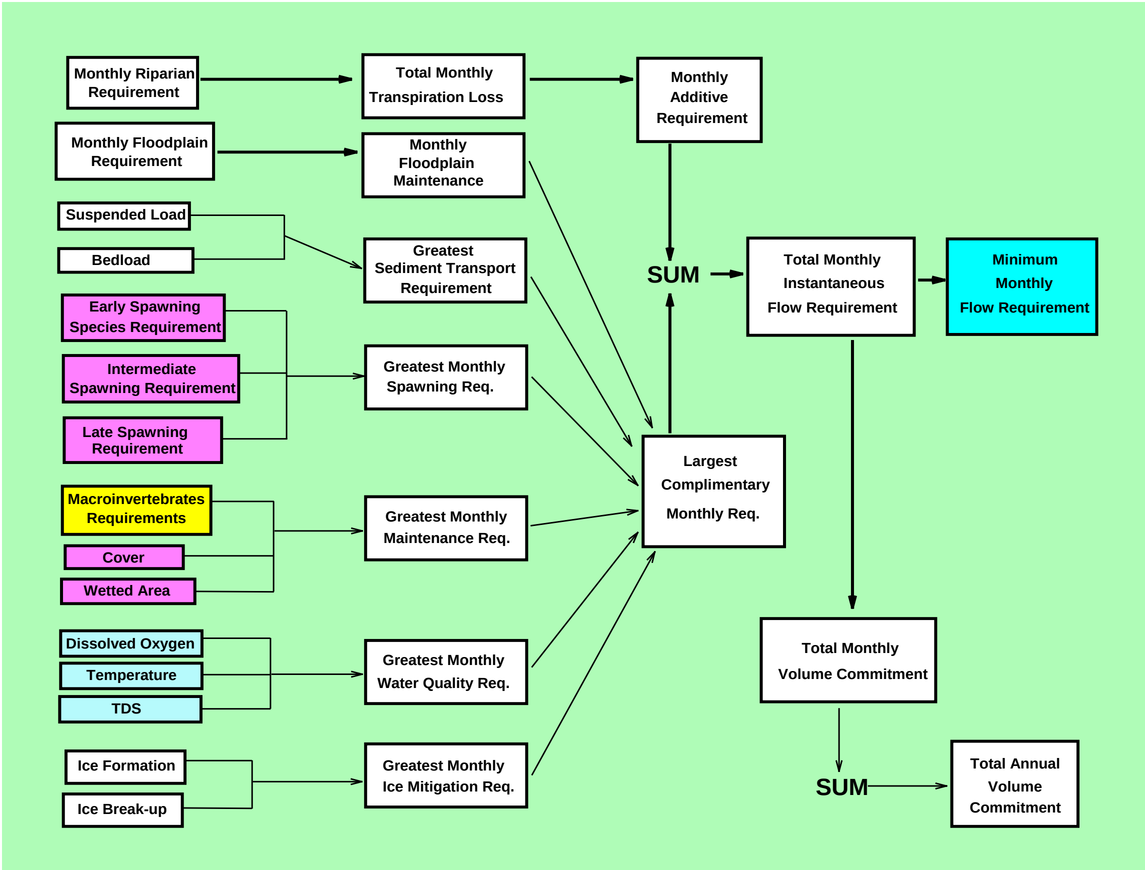

Figure 2. A decision tree for examination of the overriding consideration for assuring minimum flow allocations that allow major physical and biological processes to be maintained. [Adapted from Bovee et al. 1978].

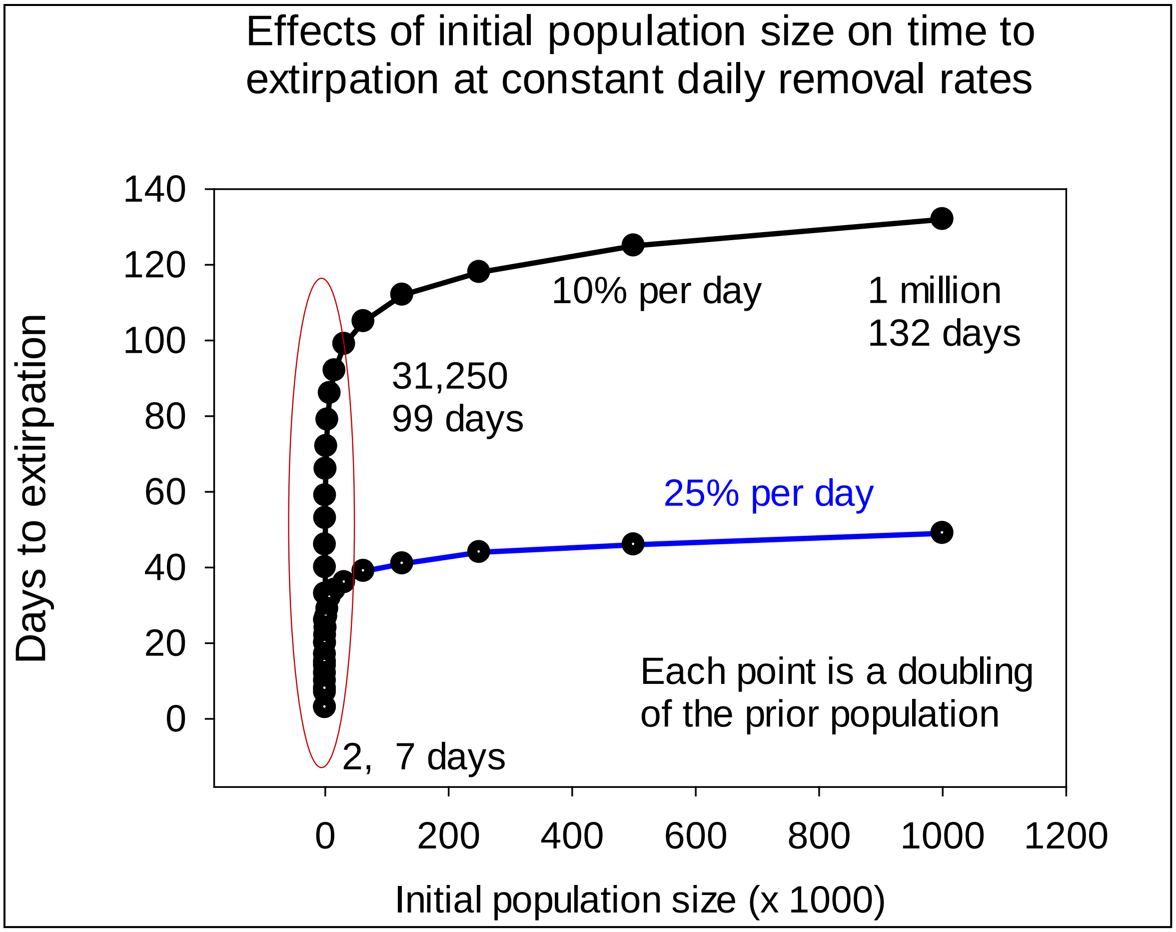

Figure 3. Number of days before populations of different initial sizes are extirpated (number falls below 1 individual) at constant daily loss rates of 10% and 25%. Initial hypothetical population sizes range from 2 individuals to 1 million individuals. The population sizes toward the left and enclosed in the red oval would very likely be impractical to distinguish from one another. For example, a population of 31,250 individuals, which has 99 days to extirpation may not be statistically distinguishable from a population of 2 individual with 7 days to extirpation depending on the variance characteristics of the population size estimates.

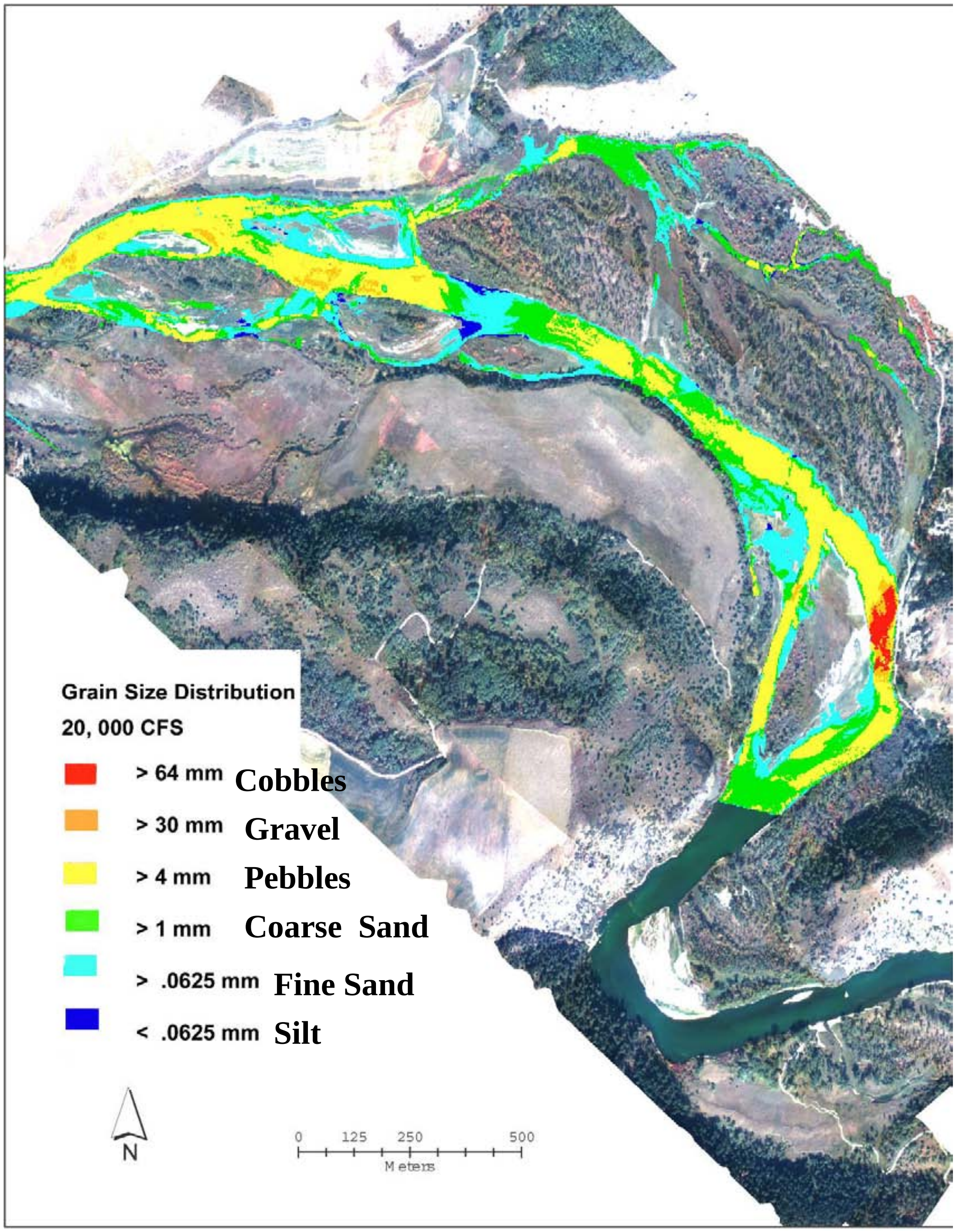

Figure 4. A map of predicted sediment mobility at a specific discharge determined from the classification of airborne remote sensing imagery (Hauer and Lorang 2004). Maps like this could be made for a range of discharge levels from base flow to flood conditions and for specific key areas where spawning and rearing of target species occurs. This provides an example of how flow releases and gravel augmentation procedures could be assessed.

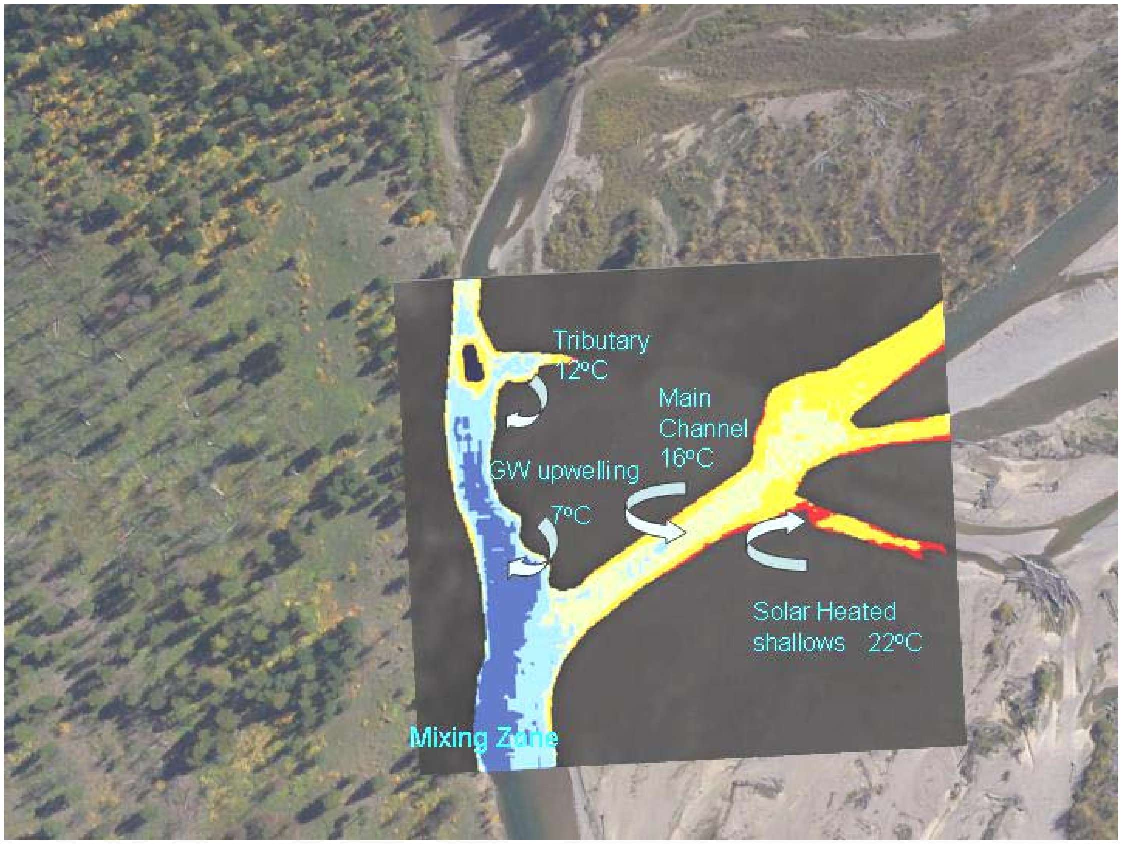

Figure 5. An example of thermal imagery (panel) overlain on traditional color aerial photograph showing the large spatial heterogeneity of temperature over even small scales typical of gravel bed rivers(Hauer and Lorang 2004). This underscores the importance of sensor location as a gauge to determining RPA goals related to flow releases from a reservoir.

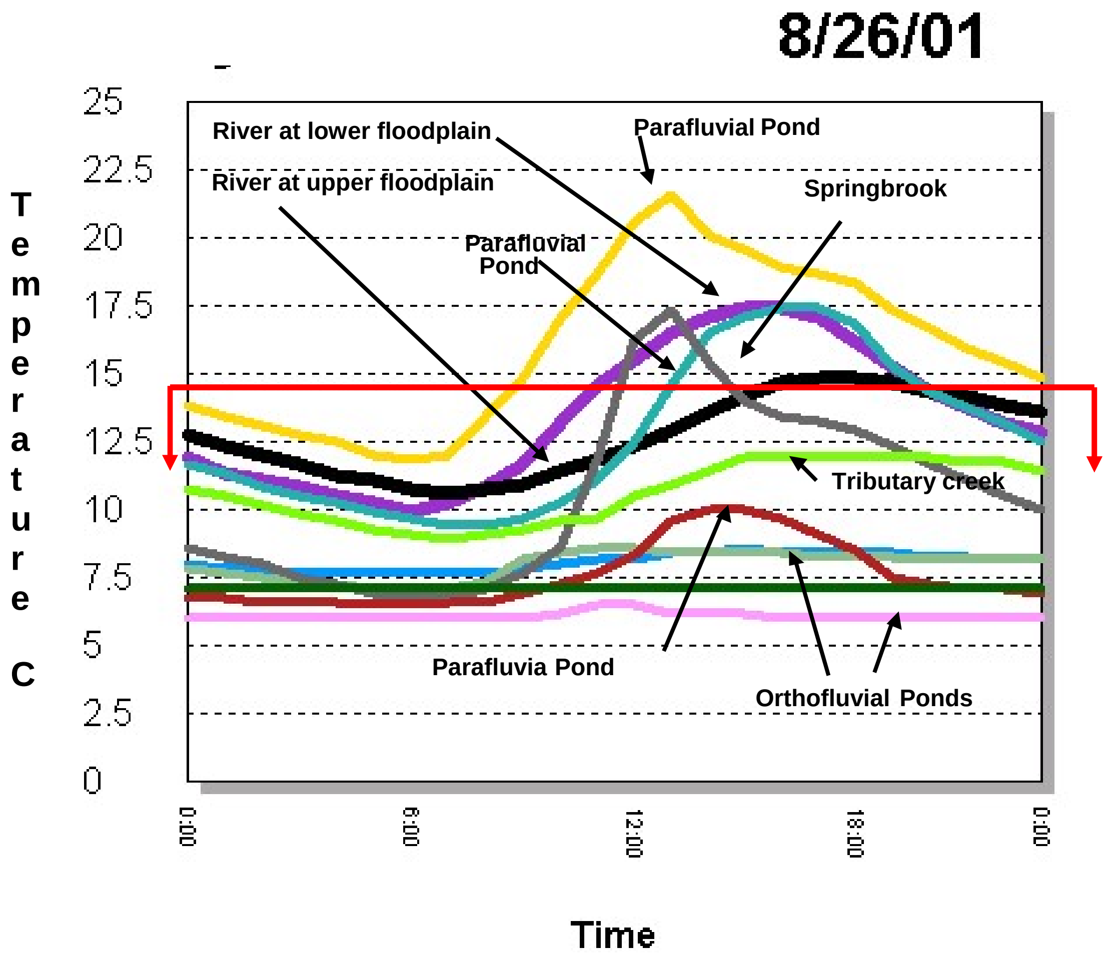

Figure 6. A plot of water temperature measured in the area shown in Figure 5 with red arrows indicating temperature below 56^{o} F. The terms para and orthofluvial refer to scoured vs vegetated areas in the image respectively. The take home value here is the large spatial and temporal variability of aquatic temperatures. Daily averages might not be meaningful and where you measure is very important. Overlaying known spawning and rearing habitats is crucial to knowing if RPA's are helping target species. This simply cannot be assessed by comparing to single or even multiple main channel temperature gauges.

APPENDIX 1

Review Materials Available to the 2011 OCAP Independent Review Panel

I. The following documents were provided in electronic format as required reading by the panel prior to the 2-day workshop in Sacramento, CA on 8-9 November 2011:

- Clear Creek Technical Working Group (CCTWG) Annual Review Report
- Interagency Fish Passage Steering Committee (IFPSC) Annual Review Report
- Sacramento River Temperature Task Group (SRTTG) Annual Review Report
- Red Bluff Diversion Dam Technical Team (RBDDTT)Annual Review Report
- American River Group (ARG) Annual Report
- Stanislaus Operations Group (SOG) Annual Review Report
- Delta Operations for Salmonids and Sturgeon Group (DOSS)Annual Review Report
- Smelt Working Group Annual Review Report
  - Attachment 1 - Delta Smelt Risk Assessment Matrix
  - Attachment 2 - Smelt Working Group Notes for June 1, 2010

II. The following additional reports were made available in electronic format for supplemental use in providing historical context for the panel:

- Report of the 2010 Independent Review Panel (IRP) on the Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria and Plan (OCAP) for the State/Federal Water Operations
- Joint Department of Commerce and Department of the Interior Response to the Independent Review Panel's (IRP) 2010 Report of the Reasonable and Prudent Alternative (RPA) Actions Affecting the Operations Criteria and Plan (OCAP) for the State/Federal Water Operations
- NMFS' 2009 RPA with 2011 Amendments
- USFWS Biological Opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the Central Valley Project and State Water Project (pages 279-282 and 329-356)
- RPA Summary Matrix of the NMFS and USFWS OCAP Opinion RPAs
- National Academy of Science's March 19, 2010, report
- VAMP peer review report
- State Water Board's Delta Flows Recommendations Report
- NMFS RPA, Appendix 2-B, Task 4: Green Sturgeon Research
- 2010 OCAP Annual Review Web Page
- Kier Associates: An Alternative Technique to Quantify the Incidental Take of Listed Anadromous Fishes at the Federal and State Water Export Facilities in the San Francisco Bay-Delta Estuary. Prepared for National Marine Fisheries Service, Central Valley Office, July, 2011

III. Additional written materials provided to the panel after the 8-9 November 2010 workshop (there was no implicit or explicit obligation on the part of the panel to consider these materials in its review):

- Vermeyen, T.B. (1995) Use of Temperature Control Curtains to Modify Reservoir Release Temperatures. Proceedings, ASCE's First International Conference on Water Resources Engineering. San Antonio, Texas, August 14-18, 1995.

- Vermeyen, T.B. (1997) Modifying Reservoir Release Temperatures Using Temperature Control Curtains. Proceedings of Theme D: Energy and Water: Sustainable Development, 27th IAHR Congress, San Francisco, California, August 10-15, 1997.

APPENDIX 2

Verbatim questions as presented in the panel charge defining the scope of this review (from Exhibit A, Attachment 1 of the Charge to the Delta Science Program Independent Review Panel for the OCAP Integrated Annual Review):

1) How well did implementation of the RPA Actions meet the intended purpose of the actions

2) Where the 2010 Independent Review Panel made recommended adjustments to implementation of the RPA actions,
(a) Were the adjustments made?
(b) How well did these adjustments improve the effectiveness of implementing the actions?

3) Howeffective was the process for coordinating real-time operations with the technical teams' analyses and input as presented in the OCAP Opinions? [NMFS' 2009 RPA with 2011 amendments (pages 8-9) and USFWS' OCAP Opinion (page 280)]

4) (a) Were the scientific indicators, study designs, methods, and implementation procedures used appropriate for evaluating the effectiveness of the RPA actions?
(b) What scientific indicators, study designs, methods, and implementation procedures might be more appropriate for evaluating the effectiveness of the RPA actions?

5) How can the implementation of any of the RPA actions be adjusted to more effectively meet the objective of the RPA actions (or in some cases a Suite of actions)?

6) How should multi-year data sets on OCAP RPA action implementation be used to improve future implementation of the RPA actions?

APPENDIX 3

A3.1 Considerations for RPA Assessment Related to Flow Releases from Dams

Rivers and their accompanying floodplains form landscapes composed of patches or mosaics of biophysical space that are used by a wide variety of different species (Stanford et al., 2005,Tockner et.al, 2010a&b,Lorang et al. 2011). This complex biophysical system produces a shifting habitat mosaic that is a fundamental feature of river ecosystems and provides a theoretical framework to underpin restoration activities associated with flow releases from dams (Stanford et al. 2005).

Maintaining the biogeomorphic functioning of river systems requires hydraulic processes that form new channels and bars while enabling recruitment of riparian vegetation as well as the establishment of inundation-temperature patterns that define the quality of aquatic habitat for target species (e.g., salmonids and their invertebrate prey resources). Understanding the effects of hydraulic processes and variation is crucial to developing successful approaches to river management ranging from flow regulation to gravel augmentation. Temporal variation in the pattern and composition of downstream floodplain habitat (e.g., vegetation cover type, channels, bars) in relation to the spatial distribution of water temperature is a fundamental metric that can be tracked as part of a monitoring protocol by employing readily available airborne remote sensing tools.

Remote Sensing Tools and Applications

Airborne and satellite remote sensing is a rapidly evolving tool for accurate landscape-scale analyses of riverine ecosystems which improves our ecological understanding by greatly expanding the spatial scale at which ecosystems can be analyzed (Lorang et al. 2011, Tonolla et al. 2011, Whited et al. 2011, and references therein). High-resolution satellite and airborne remote sensors are becoming increasingly available for measuring aquatic landscape pattern and processes as well as for studying functional relationships and causal linkages between spatial landscape patterns and biota. For example, flow competence patterns (the ability of the river to transport sediment of various size fractions) over a range of discharges were evaluated using airborne remote sensing techniques (Figure4) (Hauer and Lorang 2004; Hauer et. al. 2004 and 2006). These techniques not only allow the prediction of geomorphic change (e.g.,future location of spawning beds and rearing habitat)related to flow release but also the temperature regime of those aquatic habitats (Fig. 5).

Temperature is a fundamental trigger for the dispersal of ectothermic organisms including fishes (Buisson et al. 2008,Tiffan et al. 2009). However, temperature gradients across river floodplains have extreme spatial and temporal variability (Figures5 and 6),whichaffects biology, behavior and survival of many stream fishes (Buisson et al. 2008,Pörtner and Farrell 2008,Jonsson and Jonsson 2009, McCullough et al. 2009,Tonolla et al. 2010 & 2011). Many fish species can detect small differences in water temperature over short distances and respond to these fine-scale gradients in both space and time by moving to more favorable areas (Mather et al. 2008); such responses have been particularly well studied in salmonids (Ebersole et al. 2001,Madej et al. 2006).

Thermal IR imaging also may detect thermal patterns and gradients that influence ecosystem processes and distributions of aquatic biota and otherwise influence ecosystem. This tool has been successfully used to monitor spatial heterogeneity of stream and river temperature (Faux et al. 2001,Torgersen et al. 2001,Cristea and Burges 2009) in order to map and analyze groundwater discharge processes (Love et al 2005,Loheide and Gorelick 2006,Deitchman and Loheide 2009), to calibrate and validate stream temperature models (Loheide and Gorelick 2006,Cristea and Burges 2009), and to monitor restoration projects (Shuman and Ambrose 2003,,Loheide and Gorelick 2006). Thermal IR imagery has been used to analyze relationships among stream temperatures, aquatic habitat, and fish assemblages as well as for locating hot and cold patch patterns within lotic systems (Torgersen et al. 1999, 2006;Madej et al. 2006, Tonolla et al. 2010 & 2011).

Thermal patchiness is an important consideration in floodplain community dynamics because it provides ectothermic organisms the opportunity to select sub-habitats at multiple temporal scales (i.e., local diel variation to inter-decadal climate-driven variation). Such choices have been related to optimization of energy intake relative to physiological costs, which is reflected in growth and survival (e.g., Olden and Naiman 2010). The broad spatial scale overview gained with thermal images can be used to decide where to concentrate the most detailed and time-consuming in situ investigations or to manage processes that generate thermal patch diversity and its effects on different life stages of targeted species (e.g., egg survival in salmon redds).

Given the expected spatial variability in riverine temperatures (e.g., Figs. 5 and 6), monitoring flow releases from dams using only a few temperature gauges, may not be sufficient to predict thermal impacts on species of concern. Moving to upstream gauging stations only allows RPA’s to meet some main channel flow temperature target at a single point. This does not provide sufficient information to assess whether or not an RPA meets the goals of improving survival during the early life stages of listed species. Several approaches could be considered to improve the spatial resolution of thermal data with the aim of better matching it to spatial variation in the biological data (e.g., distribution of redds). For example, deployment of more inexpensive temperature loggers within key reaches of some systems (e.g., Clear Creek and Stanislaus River) could provide a cost effective means of gathering the data necessary for retrospect analysis of both models and RPA actions. Alternatively, airborne collection of remote sensing imagery has become relatively inexpensive. Where possible, the location of fish occurrence, adults, juveniles, redds, etc. can be overlain on maps (e.g. Figs. 4 & 5) to provide better spatially explicit links between variation in physical variables and fish responses, as well as predicting the effects of water operations (e.g. rapid changes in flows from reservoirs) on habitat patch dynamics (e.g., thermal or substrata patches) affecting downstream biotic components of interest (e.g., eggs and embryos in redds or spawning site selection by adult salmonids).

A3.2 Considerations for Integrated Data Management

The IRP understands that the BiOps were not intended to improve regional data monitoring, but linking the physical RPA targets to fish biology and population dynamics continues to be a recommendation. One means by which this long-term goal could be achieved is by drawing on existing as well as developing resources at the national and regional levels. Consequently, the IRP considered thepotential for using an integrative, cyber-enabled informatics system to facilitate the acquisition, management, distribution, and utilization of environmental data currently being collected by many different agencies, research institutions, NGO's and consulting firms within and outside the Delta and throughout the Central California Valley. Such a system would allow real-time sharing of and visualization of available information, analysis of data, modeling forecast and RPA decision outcomes as they are affected by conditions and operations in the reservoir-river-Delta system.

In the long-term, implementing a fully functional system would likely require developing critical partnerships with industry and national leaders in supercomputing. One such example is a project directed by the non-profit Planetary Skin Institute (PSI) (http://www.planetaryskin.org/challenges/water_skin/). This is an infrastructure optimization approach to monitor changes in water demand and supply at the river basin level. Their aim is to harness the power of information technology and networks to help decision-makers effectively manage scarce resources.

Currently there are several initiatives supported by the National Science Foundation (NSF) that are seeking to use an integrated data management approach to understand environments, from watershed to global scales. NEON (National Ecological Observatory Network) will have a primary emphasis on terrestrial and climatic processes. STREON (STReam Ecological Observatory Network) is a research proposal within NEON aimed at examining food web and ecosystem dynamics in single reaches of predominantly small streams. GLEON (Global Lake Ecological Observatory Network) is a grassroots, international endeavor to deploy a network of buoys equipped with sensors to examine metabolism in lakes and develop simple ecological models. SaRON (Salmon Rivers Observatory Network) is a private foundation funded endeavor composed of permanent and mobile remote field sites on large rivers around the Pacific Rim investigating salmon productivity. WATERS (WATer and Environmental Research Systems network) is primarily focused on existing hydrologic datasets. The Consortium of Universities for the Advancement of Hydrologic Science(CUAHSI) along with WATERS has developed the Hydrologic Information System (HIS) to manage and provide access to disparate sources of hydrologic data. Each of these efforts has made significant contributions, conceptually or programmatically, to advancing ecological data management and analysis.

Integrated data management, analysis and distribution programs with a more regional focus (e.g. the Columbia River Basin) have applied this approach specifically for applications to salmonid fisheries, and include Data Access in Real Time (DART, http://www.cbr.washington.edu/dart/dart.html), StreamNet (http://www.streamnet.org/links.html) and the Fish Passage Center (FPC, http://www.fpc.org/).

Many of the developing efforts in integrated data management and distribution are informed by recent enhancements in capability and reduction in the size and cost of environmental sensors, which allows for high frequency measurements to be gathered at many points within regional landscapes. Wireless communication, satellite uplinks and internet connectivity can be integrated to move large, sensor-streamed datasets from field-hubs to computer centers and/or into national high performance computing (HPC) environments. The flow of data from field or remote sensors (e.g., surface-, aircraft-, and satellite-based imaging sensors) can be used to parameterize simulation models that forecast system responses to real or potential environmental, demographic, economic and policy changes. The means of collecting ecological data include deployed lake, river and meteorological sensor systems.