UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

Rob Thomson
Environmental Planning and Permitting Compliance Manager
Sites Project Authority
122 Old Highway 99 West
Maxwell CA, 95955

Re: NMFS Comments in the Site Reservoir Draft Environmental Impact Statement

Dear Mr. Thomson,

We are writing in response to the August 14, 2017, request for public review of the Sites Project Authority and U.S. Bureau of Reclamation Draft Environmental Impact Report/Environmental Impact Statement (EIR/EIS) for the Sites Reservoir and associated facilities (Project). NOAA's National Marine Fisheries Service (NMFS) has reviewed the relevant portions of this draft and we are providing technical assistance comments on the analysis as it relates to anadromous fishes under our jurisdiction. As a Cooperating Agency under the National Environmental Policy Act (NEPA), we have proposed to work closely with you in evaluating key sections of the Final Environmental Impact Statement prior to release. In this, our response to the request for public comment, NMFS staff provide feedback regarding the level of analysis in the Draft EIR/EIS and identify those elements of the project that will need further scrutiny during the development of a Biological Assessment and initiation of consultation pursuant to section 7 of the Endangered Species Act (ESA). As such, we view the analyses presented in the Draft EIR/EIS as foundational for any additional analysis necessary to support the ESA consultation for the proposed action.

In our review of the sections of the Draft EIR/EIS most pertinent to species under our jurisdiction, NMFS staff have compiled a number of comments, a complete log of which is included with this letter (Enclosure 1). Our comments are also summarized here and we anticipate that a continued dialogue will allow us to build on our understanding of the Project and its potential impacts. Our comments relate to the following broad topics:

Final Operations

While NMFS understands that Final and Annual Operations are expected to be developed following the WSIP determination, the concept of how Operations will "interface with the preparation of the annual Temperature Management Plan for the Sacramento River, consistent with WR 90-5 and applicable RPAs" (pg. 102 of Ch. 3) needs further development. An explanation of the process by which Annual Operations will be set, consistent with WR 90-5 and applicable RPAs, and how the Ecosystem Enhancement

Storage Account (EESA) priorities will be determined (or modified) will be critical in an analysis of Project Operations. It will also be important to consider how baseline conditions might change based on the demands of other projects that are either under construction or have received approvals and permits.

Bypass Flows and Weir Spill Analysis

NMFS recommends greater scrutiny be applied to the relative impact of reduced river flows caused by diversions along the Sacramento River so that the consultation analysis is able to answer the questions related to the biological impact of diversions and the proposed bypass flows. The SacEFT analysis (Appendix 8B) describes significant loss of rearing habitat in the Sacramento River, but the WUA analysis (Appendix 12L) for the Sacramento River is limited to the reach between Keswick and Battle Creek (upstream of all Sites diversions). We would like to see an assessment of the bypass flows that includes a WUA analysis downstream of the diversions. For the Sutter and Yolo bypasses, a few biologically-significant metrics are acknowledged (e.g., “Sutter Bypass flows greater than 4,000 cfs for at least 21 days,” and for “Yolo Bypass, there is a rapid increase in the inundated area up to around 40,000 cfs and […] only marginal […] increase up to modeled flows of 200,000 cfs”) but it is not clear if these metrics are applied to the weir spill analysis. NMFS recommends that an additional "acre-day" analysis be conducted for the lower Sacramento River and bypasses that compares alternatives and the change in the number of acre-days of inundation. An analysis of this type can be further divided by water-year type and month. Where channel geometry information is known, inundated acres can be separated into bankfull channel and floodplain inundation, with the assumption that shallower/lower velocity habitat in the floodplain is more beneficial to salmonid rearing.

Water Quality Analysis (Temperatures)

For the section 7 ESA consultation, NMFS recommends a more thorough analysis of the Project’s impacts to water quality, in particular associated temperature effects. The stated assumption that only a violation of a particular water quality standard would indicate a potential water quality impact oversimplifies and discounts the extent of effect. NMFS will be concerned with the effect to water quality regardless of the magnitude relative to a water quality standard. Greater resolution and detail is needed in the modeling and assessment of temperature impacts below the new Delevan intake/outfall, as well as in the analysis of thermal changes in the GC Canal, Holthouse Reservoir, and TR Reservoir. Further, we recommend analysis of potential temperature stratification within Sites Reservoir and assessment of the benefit of the proposed temperature-control device.

Pulse Protections (and Monitoring)

Details regarding **Mitigation Measure Fish-1f** are too vague to determine to what extent operations would minimize entrainment. Additional information regarding a number of operational definitions (e.g., “rapid increase in juvenile salmon […] migration,” “naturally occurring, storm-induced pulse flows,” etc.), as well as the intended use of existing and new environmental data collection, will be critical in determining the efficacy of the mitigation measure. Understanding that these Project elements are intended to be developed cooperatively with CDFW and NMFS, we look forward to working with the Authority, Reclamation, and CDFW to help refine the proposed pulse flow protection rules and to develop the associated anadromous fish monitoring program. To that end, we suggest identifying bypass flows, not only for the pulse protections but also during periods of diversion, that are biologically supportive and specific to river reach. We provide Enclosures 2 and 3 ("Comparison of Proposed BDCP Operational Scenarios Based on Frequency of Achieving Specific Salmonid and Sturgeon Flow Needs" and the "Preliminary late-fall Chinook salmon smolt outmigration analysis for SIT team, December 2016 meeting") as examples of fisheries-agency efforts to identify Sacramento River and Delta flow criteria that are beneficial to listed species. The recommendations in these documents require review and potential updating for new information and therefore are not a final recommendation; however, they represent multi-agency approaches to evaluating flow-survival needs of species and should be useful in identifying an approach to and starting point for bypass flow criteria.

Fish Screens and Fish Screen Interactions

NMFS recommends further analysis to assess the effect of fish screens and fish screen interactions. In particular, baseline information regarding the efficiency of existing screen performance under current operations will need to be contrasted with expected performance during proposed Project operations, which include intake use at different times of the year than is permitted for current operations. As noted in the EIR/EIS, the interaction of potential stressors, such as the interaction between fish screens and predators and the efficacy of predator refugia, will need to be assessed.

We appreciate the opportunity to comment on this important document and for continued engagement. If you have any questions regarding our input, please contact myself and/or Evan Sawyer at evan.sawyer@noaa.gov and (916) 930-3656.

Sincerely,

Cathy Marcinkevage
Branch Chief

Cc: California Central Valley Office
Division Chron File: 151422-WCR2017-SA00363

Michael Dietl
Project Manager
Planning Division
U.S. Bureau of Reclamation
2800 Cottage Way, MP–720
Sacramento, CA 95825

Brian Hughes
Project Manager
Planning Division
U.S. Bureau of Reclamation
2800 Cottage Way, MP–720
Sacramento, CA 95825

Comment #	Comment	Page #	Associated sections	Keywords
WSIP1	Operations presented in the WSIP proposal are described as "flexible and adaptable to meet a wide range of water supply and environmental needs" and those presented in the application have been "deemed to be most-responsive in providing water to the highest priorities." There is also acknowledgement that "over the life of the Sites Reservoir, these priorities may need to change and the Sites Project has the flexibility to adapt to a changing future," so what is the process for changing priorities and what organizations would be involved?	6 of 26		Governance
WSIP2	The Water Operations Committee will be comprised of investors and stakeholders that include "the state and federal resource agencies delegated the responsibility to have management control over the investment by the state and/or Federal government, respectively." When is that responsibility delegated and by whom?	6 of 26		Governance
WSIP3	Further explanation of the development and timing of the annual operating plans is needed. Annual operating plans are initiated in the spring of the prior year and completed and approved no later than the Authority Board meeting in August of the prior year. Is this realistic? CVP initial allocations are developed in February should the Sites annual operating plans coordinate more closely or along similar timelines as those of the SWP & CVP? How will "Sites Project annual operating plans [...] interface with the preparation of the annual Temperature Management Plan for the Sacramento River, consistent with WR 90-5 and applicable RPAs?"	7 of 26		Governance
WSIP4	What are the model products and assumptions? "The operations analyses conducted for the Sites Reservoir Project utilized the model products and assumptions described in section 6004(a)(1) of the California Code of Regulations"	9 of 26	Section 6004(a)(1) of the California Code of Regulations	Assumptions
WSIP5	Clarification: "equal proportional share"	9 of 26		Clarification
WSIP6	"Several existing and additional proposed bypass flow criteria were assumed at specified locations" What are they or where are they?	10 of 26		Assumptions

WSIP7	Pulse flow protection period proposed from October - May. What are the criteria associated with this?	10 of 26	Cross ref with section describing pulse protections (?)	
WSIP8	Unclear what is meant by "Provide (via upstream actions) **incidental** Delta water quality improvements in the summer and fall"	11 of 26		Clarification
WSIP9	"Operations in any given year will be a function of the current year hydrology, as well as a function of the system conditions resulting from the previous year's hydrology and operations." I Understand this as a concept but what is the "**function**?" (i.e. what is the process by which operations are developed? is that function/equation defined?)	11 of 26		Clarification
WSIP10	two public benefits are listed as possible uses of EESA water during wet years (Yolo bypass/delta outflow improvement and supply for refuges), could there be others? Also if EESA water is not used can it be "stored/banked?" are there rules for storage/banking?	11 of 26		Clarification, Governance
WSIP11	why is it in above normal year types that by 2070 average diversions are expected to be greater (770 TAF) than wet year types (715 TAF)?	12 of 26		Clarification
WSIP12	Similar to other questions about the EESA is there an average year allocation of EESA water that maximizes the benefit? Understanding that it is based on "current priorities"	13-14 of 26		Assumptions
WSIP13	The "adaptive management process" is described as having 6 steps, suggest a closer association/coordination with the AM program for CVP/SWP & CWF ops and/or the DSP's nine step AM framework.	18 of 26		Clarification
WSIP14	"monitoring is only initiated if opportunities for management change exist" that doesn't include compliance monitoring?	19 of 26		Clarification

WSIP15	"Monitoring for 12 years is recommended to assess increase in spawning by quantifying increasing trends of the first four consecutive cohorts. Monitoring will begin immediately after completion of Sites Reservoir." For the BA NMFS would expect monitoring to begin before the completion of the reservoir to help establish baseline conditions. shouldn't be a problem because table ADF-1 doesn't propose any new monitoring? --> Conflicts with Mitigation Measure 1F which proposes additional monitoring.	19 of 26		Assumptions
Universal comment	What are the bypass flows? And what are the pulse protection criteria/rules?	NA	See Chapter 3 for bypass flows	Universal comment
EIS1-1	In describing roles and responsibilities Reclamation is involved in the action to provide the "coordinated operations of the CVP" but the same responsibility is not identified for DWR and SWP?	1&2 of 35		Clarification
EIS1-2	Operating criteria are defined/explained in... Chapter 3 (?) Description of Project Alternatives	6 of 35	Chapter 3, Sections 3.2(?), 3.3, 3.4 and 3.5(?)	Clarification, cross-reference
EIS1-3	What is the benefit or significance of being a CALFED project? Is it only that the full development of alternatives has already been considered in the CALFED EIS/EIR and ROD?	10 of 35	www.calwater.ca.gov/content/Documents/ROD.pdf	Clarification, cross-reference
EIS1-4	Is WaterFix considered? "Applicable reasonably foreseeable plans, projects, programs, and policies that may be implemented in the future but that have not yet been approved, are included as part of the analysis of cumulative impacts in Chapter 35 Cumulative Impacts. Potential impacts associated with climate change are addressed separately in Chapter 25 Climate Change and Greenhouse Gas Emissions."	15 of 35	Chapter 35, Chapter 25	Clarification, cross-reference
EIS1-5	What is (or would be) the timeline for Reclamation's ROD? This would be after ESA consultation correct?	16 of 35		Clarification
EIS1-6	An example of the difference between the Secondary Study area and the Extended Study Area would be useful. It is unclear the difference considering they both seem to be based on the use of CVP/SWP water?	22 of 35		Clarification

EIS1-7	Does the "Project Area" the same as the "Primary Study Area" or is there some difference? For the ESA consultation NMFS will consider the "Action Area" which seems likely to be the Secondary Study Area.	26 of 35		Clarification
EIS3-1	Operation and efficiency of the fish screens at the RB pumping plant (TC canal) is unclear/not identified	54 of 118		fish screen, operations
EIS3-2	Is there additional information on the operation of the additional pumps at the RB pumping plant?	54 of 118		capacity
EIS3-3	The GCID intake fish screen facility is expected to operate similar to current operations but year-round. What kind of analysis is there for current operations and why are the screens expected to perform the same during different periods/seasons of operations? NMFS would likely need to see baseline operations and compare them to future operations.	64 of 118	Would need similar analysis of TC Canal fish screens operations as well.	fish screen, operations
EIS3-4	unclear if dredging (outside the canal) would occur year-round?	64 of 118		dredging
EIS3-5	Bypass flow at Delevan would be 4,000 cfs. Does this conflict with Wilkins Slough navigation requirement?	71 of 118	not listed in section 3.3.1.2	bypass flow
EIS3-6	Not sure how a final operation plan will be influenced by the findings of the Water Commission (WSIP)?	102 of 118		operations
EIS3-7	Section 3.3.1.1 "flow conditions needed to maintain and protect anadromous fish survival" is vague and ambiguous. Is this a new requirement? a specific existing requirement?	105 of 118		flow, operations
EIS3-8	Bypass flows: 3,250 cfs @ RBDD (TCCA); 4,000cfs @ Hamilton City (GCID); 5,000cfs @ Wilkins Slough (regardless of hydro conditions???); Freeport flow of 15,000 in January, 13,000 December and Feb - June, and 11,000 all other months (July - November). Are these bypass flows adequate? Is there a timing element of operations for the different diversions? Could there be a situation where Sites is releasing water at Delevan but diverting water at TCCA and GCID? Should there be rules for that? For ESA consultation it would be important to consider what conditions these bypass flows would create.	106 of 118		bypass flow, operations

EIS3-9	Maximum release from Delevan pipeline is 2500 cfs? It's stated elsewhere that it's only 1500 cfs?	107 of 118		clarification
EIS3-10	Is there more information from the Sac River Flow Regime Tech Advisory Group? specifically about increasing the reliability of Sutter and Yolo inundation?	110 of 118		Yolo
EIS4-1	Would the FWCA govern the coordination and use of the EESA water? what is the process for determining how the EESA water is 'spent?'	11 of 27		
EIS4-2	Does the water right filing define an amount of water or is it just that water would be diverted?	15 of 27		
EIS4-3	The regulatory setting for aquatic Biological resources is presented in Appendix 4A "Environmental Compliance"	NA	Appendix 4A, and Chapter 12 Aquatic Biological Resources	
EIS7-1	The characterization of RPA action I.2.3 in the EIS is inaccurate where it states that "water temperatures are to be **maintained at** 56°F between Ball's Ferry and Bend Bridge." The RPA actually directs Reclamation to "maintain a temperature compliance point **not in excess** of 56 degrees".	14 of 84		Shasta, Temperature
EIS7-2	On August 2, 2016, Reclamation has requested the use of the adaptive management provision of the Shasta RPA to address new science and considerations related to the RPA action where it is expected that temperature compliance will soon be managed differently (e.g. location, timing, metric and temperature). In a separate letter, also on August 2, 2016, Reclamation has requested reinitiation of consultation on the long-term operation of the CVP and SWP; meaning that additional changes will need to be considered.	NA		Shasta, Temperature, CVP & SWP
EIS7-3	Table 7-4 identifies WQ objectives for temperature as being > 56 degrees when it should be < (less than).	14 of 84		correction
EIS7-4	Significance criteria and thresholds do not sufficiently identify the extent of environmental impact. Actions that do not violate a particular water quality standard may still have a significant impact. this is not described by the analysis.	29 of 84		Impact analysis, assumptions

EIS7-5	(understanding the limitations of monthly time-steps) Quantitative changes between 5 and 10 percent are considered to be "less than significant"	30 of 84		Impact analysis, assumptions
EIS7-6	Existing conditions should not be assumed to be the same as the future, No Project/No Action Condition which has been stated to include the demands of projects under construction and those that have received approvals and Permits (CWF?).	33 of 84		Impact analysis, assumptions
EIS7-7	Sites Reservoir Discharge Temperature Model: "Significant warming is not expected within the Delevan Pipeline." it is unclear if the analysis of thermal changes includes changes at the GC Canal, Holthouse Reservoir, TR Reservoir, or even Sites itself?	34 of 84		Impact analysis, assumptions, temperature, modeling
EIS8-1	Is there any protection of Geomorphic flows? Are high flow events protected given Sacramento River channel migration "starts" at flows in excess of 55,000 cfs.	7 of 30		flow, channel migration,
EIS8-2	More detail is needed in the analysis of suspended sediment changes that were modeled at Red Bluff, Hamilton City, and Colusa. Much of the detail and potential significance is lost by making annual comparisons. Further, a description of the relative change in sediment entrainment between alternatives would reach very different conclusions.	20 of 30	Appendix 8A	flow, sediment
EIS8-3	The average amount of suspended sediment that was modeled to be entrained at the Tehama-Colusa Canal Authority Red Bluff Pumping Plant Intake annually under the Existing Conditions/No Project/No Action Condition is 40,000 tons, however in Appendix 8A (Sedimentation and River Hydraulics Modeling) this figure is 4,000 tons/yr.	20 of 30	Appendix 8A	flow, sediment
EIS8-4	The Reclamation meander study uses a threshold of 30,000 cfs as the threshold for "substantial geomorphic river changes." Is this inconsistent with the 1999 CalFED study that identifies 55,000 cfs as the flow where channel migration "starts?"	21 of 30	Appendix 8A	flow, channel migration

Ch8-5	More detail should be carried through from the analysis to the conclusions of the river meander study. The analysis in Appendix 8A indicates that there is large variability in the potential for river meander depending the river mile examined such that for the entirety of the river impacts may be less than significant but for certain small sections of the river there will be significant increase or decrease of erosion.	21 of 30	Appendix 8A	flow, channel migration
EIS8-6	Appendix 8A notes that reach 10 (where the new Delevan Pipeline would be located) experiences the most notable aggradation and that periodic dredging may be required. No mention of this is mad in the conclusions regarding the maintenance impacts in the primary study area.	22 of 30	Appendix 8A	flow, sediment
EIS12-1	Focused on Alternative D, as it was identified by Sites JPA as the preferred alternative	N/A		
EIS12-2	Surface water conditions are not considered upstream of Vernalis (the San Joaquin River). Could or should changes and effects be considered in the San Joaquin? Is there a reason that the use of EESA water could not or would not affect storage on the San Joaquin?	2 of 118		Definitions, Action area, San Joaquin,
EIS12-3	SR Killer Whales are identified as "species of special management concern" This should be endangered. NMFS would want clarification the status and analysis of effects to killer whales.	2 of 118		
EIS12-4	What is the status of the Winter-run Shasta re-introduction? What would be the interaction with Shasta Lake conditions?	8 of 118		
EIS12-5	Cold water pool is essentially a function of the volume of water in the reservoir. --Reclamation has (at times) argued that this is not the case. At a minimum this is a tenuous assumption.	10 of 118		Cold water, storage
EIS12-6	"Existing screens at the pumping plants are designed to prevent entrainment of Chinook salmon and steelhead into the canals" This does not negate effect, NMFS criteria are that screens are expected to be 95% effective (this goes for existing facilities as well). For the consultation NMFS would need further analysis of the fish screens (new and existing) and the effect of operations on the screen efficiency.	50 of 118		fish screens, assumptions

EIS12-7	Evaluation Criteria and Significance Thresholds	51 of 118	Appendix G	Definitions
EIS12-8	Pulse flow protection period is assumed Oct - May, "Further detail on the diversion limitation assumptions is included in Chapter 5 Guide to the Resource Analysis."	53 of 118	Chapter 5, Mitigation measure 1f (pg. 117-118 of 118)	Pulse Flow Protection
EIS12-9	A more detailed description of the rationale and indicators used to assess the potential impacts of ongoing hydrologic changes associated with SWP and CVP Operations is provided in Appendix 12B Fisheries Impact Assessment Methodology.	56 of 118	Appendix 12B	assumptions
EIS12-10	"flow and storage changes of 5 percent or less are generally considered within the standard range of uncertainty associated with model processing; therefore, flow changes of 5 percent or less were considered to be similar to the Existing Conditions/No Project/No Action Condition flow levels in the comparative analyses using CALSIM II conducted in this EIR/EIS. Changes in flow exceeding 10 percent were considered to represent a potentially meaningful difference." What about differences between 5% and 10%? are they "similar" or "potentially meaningful"	58 of 118		assumptions, definitions
EIS12-11	How was Sites incorporated into the models (CALSIM II, Reclamation Water Temp. ?)	61 of 118	Appendix 6B, Appendix 7E	tools, analysis, assumptions
EIS12-12	For the Sutter and Yolo bypasses alternatives are analyzed based on the frequency of inundation flows of particular size (cfs) and duration (days). Does this analysis provide enough resolution to discern differences in alternatives? For the consultation NMFS would want to see an analysis of the 'raw' data.	62 and 63 of 118	Appendix 12N	Yolo, Sutter,
EIS12-13	"The frequency of events during which flows into the Sutter Bypass of greater than 4,000 cfs were maintained for at least 21 days was used as an index of floodplain habitat availability." What does this mean? or what does this index represent?	62 of 118	Appendix 12N	Sutter, assumptions

EIS12-14	Recent work for the Central Valley Flood Management Planning Program (California Resources Agency and DWR, 2016) confirms that as flows increase in the Yolo Bypass, there is a rapid increase in the inundated area up to around 40,000 cfs and then the inundated area increases only marginally as flows increase up to modeled flows of 200,000 cfs. Does this mean that higher flows are less important? Does the analysis consider flows up to 40,000 cfs (don't think it does).	63 of 118	Appendix 12N	Yolo
EIS12-15	"Of particular importance is the frequency of events during which the floodplain is fully activated for a duration that provides rearing opportunities. Therefore, the frequency of events during which flows into (and through) the Yolo Bypass of greater than 8,000 cfs are maintained for at least 21 days was used as an index of floodplain habitat availability." What does the index represent? and does the 8,000 cfs "fully activated" conflict with "a rapid increase in the inundated area up to around 40,000 cfs" ?	63 of 118	Appendix 12N	Yolo
EIS12-16	Existing TC Canal Connections and existing GCID Main Canal Facilities are not analyzed but should they be? For the consultation NMFS would need further analysis of the fish screens (new and existing) and the effect of operations (timing and fish presence) on the screen efficiency.	65 of 118		fish screens, assumptions
EIS12-17	"Because fish screens would be designed to meet NMFS and CDFW design criteria, no further evaluation of direct fish screen mortality is conducted in this EIR/EIS. However, while the fish screen associated with the Delevan Pipeline Intake/Discharge Facilities would be designed to meet all NMFS and CDFW criteria, and diversions would occur at flow rates that would allow adequate approach and sweeping velocities, potential indirect impacts on fish migrating past the screens could occur." Fish Screen/Predation interaction.	71 of 118	Vogel et al. 1988	fish screens, predation

EIS12-18	In discussions regarding bypass spill and inundation, 'how' the bypasses (particularly Yolo) are inundated is important to realizing the benefit to the species. Flows spilling from the mainstem would also transport fish on to the bypass but flows released from Colusa Basin Drain, through the Knights Landing Ridge Cut, would not provide the same transport nor the same benefit.	75 of 118		yolo, bypass, flow
EIS12-19	Conclusions regarding the impact of operations to (WR) salmon focus almost entirely on the potential benefit of operations, mostly in the drier year types. It is not clear that there is acknowledgement of the impact of temperatures below Delevan, changes (increases) to temperatures in the GC Canal, Holthouse Reservoir and TR Reservoir; or stratification of temperatures in Sites.	75&76 of 118	Chapter 7 Surface Water Quality	
EIS12-20	It is stated that "Most Central Valley hatchery fall-run Chinook salmon are released directly into San Francisco Bay, and thus bypass potential impacts from project operations." I don't know that this is correct.	82 of 118		killer whales, fall-run, prey base
EIS12-21	Further explanation of Mitigation Measure Fish 1f is needed: What monitoring is being proposed what are the specific triggers for "fish presence"	117 and 118 of 118		

Technical Memorandum

To: Carl Wilcox, CA Department of Fish and Wildlife

Maria Rea, NMFS, West Coast Region, CA Central Valley Area Office

From: Cathy Marcinkevage, NMFS, West Coast Region, CA Central Valley Area Office

Chad Dibble, CA Department of Fish and Wildlife

Copied: Pat Brandes, USFWS; Russell Perry, USGS

Re: Transmission of joint agency "Comparison of Proposed BDCP Operational Scenarios Based on Frequency of Achieving Specific Salmonid and Sturgeon Flow Needs"

Date: January 13, 2015

In July 2014, a team of inter-agency staff convened to review the best available information linking Delta flow to the abundance, distribution, survival and recruitment of covered salmonids and sturgeon. In reviewing this information, the team was able to compile specific Delta flow criteria that have been identified as providing suitable conditions for salmonids and sturgeon.

The attached document describes those criteria and their scientific support. The document also compares the BDCP No Action Alternative, Alternative 4:H1-H4 operational scenarios, and Combined Scenario 5 (CS5) according to the likelihood of meeting the identified flow needs.

Additional analyses in the document reviewed life-cycle model escapement results from the BDCP Chapter 5 Effects Analysis (EA) to indicate the relative effects of different operating scenarios (i.e., changes in flow and temperature) on winter-run Chinook salmon population size.

To address uncertainties due to limited data and incomplete understanding of mechanisms, the document also identifies research and monitoring efforts and model development that would solidify the understanding of flow-related effects on these species.

Comparison of Proposed BDCP Operational Scenarios Based on Frequency of Achieving Specific Salmonid and Sturgeon Flow Needs

Final Draft
1/13/2015

Introduction

The BDCP proposed project includes a range of Delta outflow scenarios described in the draft document as Alternative 4: H1-H4. These scenarios were developed based on the flow needs of longfin and delta smelt, but they are also intended to provide favorable conditions for the abundance, distribution, survival and recruitment of salmonids and sturgeon in the Delta. In order to determine which of the proposed outflow scenarios would be most likely to provide these conditions, a team of agency staff (see participant list below) convened to review the best available information linking Delta flow to the abundance, distribution, survival and recruitment of covered salmonids and sturgeon. In reviewing this information, the team was able to compile specific Delta flow criteria that have been identified as providing suitable conditions for salmonids and sturgeon. These flow criteria were used to compare the no action[1] and proposed BDCP operational scenarios to determine which scenarios could be expected to achieve the beneficial flow conditions most often. The comparisons among the proposed operational scenarios also include results from the operational scenario known as Combined Scenario 5 (CS5), which has been proposed as a potential "upper adaptive range"[2]. This upper adaptive range could be partially or fully implemented through the adaptive management process should other elements of the plan's conservation strategy fail to produce the assumed benefits they were designed to achieve.

The comparison includes an additional analysis that uses the results from the BDCP Chapter 5 Effects Analysis describing upstream conditions (based on salmonid life-cycle model results) to compare some of the operational scenarios as they relate to modeled winter-run Chinook salmon adult escapement.

This summary document includes three main sections. The first section describes the flow criteria that were compiled from existing literature and monitoring data and explains why and how the criteria are expected to provide suitable conditions for salmonids and sturgeon. The references cited for these criteria include the original research papers as well as subsequent documents that provide specific flow recommendations based on the findings in the original research papers. The second section includes the comparative analysis of the different scenarios including both upstream conditions and in-Delta flow criteria. The third section describes the uncertainty that is inherent in these analyses and proposes research and monitoring activities that should be implemented in the near term, prior to operation of the new north Delta intakes. Results from the research and monitoring would help reduce uncertainty and inform the final decision on the appropriate initial operating criteria for the new facilities.

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[1] Any use of "No Action Alternative" or "NAA" in this document refers to the Federal baseline scenario Existing Biological Conditions 2 (EBC2).

[2] While acknowledging that the components of the adaptive management program are still being discussed, the team assumed that Combined Scenario 5 (CS5), which was developed with input from the fish agencies, was a suitable modeled bookend to the range of conditions within the adaptive management scheme.

Section 1
Salmonid and Sturgeon Flow Needs Described in Available Literature and Previous Recommendations

Chinook Salmon

Expanded rearing habitat improves spatial and life history diversity

- Fall-run Chinook salmon populations can migrate soon after emergence and rear in brackish estuaries (Hatton 1940, Healey 1991, Williams 2006). Rearing in San Francisco Bay appears to be related to high Delta outflow tempering salinity and creating conditions that expand the habitat available for fry rearing (Kjelson *et al.* 1982).
- Recent studies have shown the notable contribution of estuary-rearing fall-run fry to adult returns. A recent otolith microchemistry study of fish caught in the Oregon ocean troll fishery found that ~20% of the sample of the adult population from the Central Valley had left freshwater as fry (< 55mm FL), and likely during Feb-March (Miller *et al.* 2010). These fry were likely naturally produced and otolith signatures suggested they resided in brackish habitat for some period before entering the ocean (Miller *et al.* 2010).
- Fall-run fry abundance in the San Francisco Bay increases with increased February Sacramento River flow at Freeport as shown in Figure 1 (from Dekar *et al.* (2013) and supported by Brandes *et al.* (2006) and Brandes and McLain (2001)) and increased Jan-Mar Delta outflow as shown in Figure 2 (Redler *et al.* 2010). See FLOW 1.
- Fall-run fry are present in San Francisco Bay when mean daily outflows for Jan-Mar are greater than approximately 35,000-50,000 cfs (Figure 2 (Redler *et al.* 2010)). The wide flow range is due to lack of data for flows between 35,000 cfs and 50,000 cfs. See FLOW 4**.**

Increased distribution, abundance, and survival of migrating and rearing salmonids

- Juvenile winter-run Chinook salmon start to migrate into the Delta when flows at Wilkins Slough increase to approximately 14,000 cfs or more (del Rosario *et al.* 2013). Flow pulses in excess of 20,000 cfs in the fall, with similar peaks continuing past the first of the year, have been recommended to support winter-run Chinook salmon juvenile emigration (Allen and Titus 2004, Wilson and Dibble 2010).
- SWRCB has recommended that juvenile salmon require Nov-Jan flows of 15,000 to 20,000 cfs at Wilkins Slough to facilitate migration into the Delta (State Water Resources Control Board 2010).
- Decreased frequency of bidirectional flow in the Sacramento River near its junction with Georgiana Slough will likely increase survival of outmigrating salmon by reducing the risk of entrainment into Georgiana Slough and the central Delta (Perry 2010, State Water Resources Control Board 2010, Wilson and Dibble 2010). See FLOW 2**.**
- Spring flows in the 20,000 to 30,000 cfs range at Rio Vista results in higher juvenile Chinook salmon abundance at Chipps Island as shown in Figure 3 (California Department of Fish and Game 2010, Wilson and Dibble 2010). See FLOW 3**.**

Sturgeon

- IEP Bay Study otter trawl survey data provide a decades-long database of white sturgeon Year Class Indices (YCI) that can be used to relate annual juvenile production to Bay-Delta flow conditions. These data, as well as more recent unpublished CDFW data, suggest that greater year class index values correspond with higher winter-spring outflows (Fish 2010, Gingras *et al.* 2013).
- Green sturgeon show similar trends, though sample sizes are much lower for this rare species. The mechanisms underlying the flow-production relationship for white sturgeon are believed to be largely applicable to green sturgeon.
- Agency staff familiar with the data concluded that it is most likely that high flows potentially act on sturgeon production by facilitating adult migration, improving spawning and egg incubation habitat, and enhancing larval/ juvenile downstream migration and transport survival. It is unclear whether Delta outflow itself or upstream flows, and their associated mechanisms, have a greater effect on YCI.
- Previous analysis of sturgeon recruitment showed that mean April-May Delta outflow exceeded 25,000 cfs in years of relatively strong recruitment (USFWS (1995) and Kohlhorst (1991)). This has been corroborated by more recent studies as shown in Figure 4 and Figure 5 (Fish 2010, Gingras *et al.* 2013). Additional analysis of Gingras *et al.* (2013) YCI data and April-May Delta outflow suggests that a much greater YCI is more likely to occur when outflows are at least 44,000 cfs (Figure 6 and Figure 7). See FLOW 7.
- Occasional high Sacramento River flows at Grimes/Wilkins Slough and Verona are recommended by USFWS (1995) to improve spawning and rearing conditions for sturgeon. See FLOW 5 and FLOW 6**.**
- Specific San Joaquin River spring flows in wet and above normal years are recommended by USFWS (1995) to promote attraction, migration, and spawning of adult sturgeon and for rearing and transport of larvae and juveniles. See FLOW 8.
- The importance of providing flows adequate for strong recruitment is reflected in recent fishery conditions. During the last 30 years, a substantially-diminished recreational fishery has been primarily characterized by catch from three modest or strong cohorts (1982-1983, 1995-1998, 2006); each cohort was smaller in size than the previous (Figure 8 and Figure 9).

Identified Flow Needs for Salmonids
Needs are listed by location from upstream to downstream.

FLOW 1: Mean Feb flow downstream of NDD > 44,000 cfs in wet and above normal years (W, AN).
Source: Dekar et al. (2013), pp. 32, 137; Brandes and McLain (2001), pp. 50-51.
Benefit: Provide suitable rearing conditions in San Francisco Bay for fall-run Chinook salmon fry rearing.

FLOW 2: Mean flow in each month Nov-Jun downstream of NDD >= 13,000 and 17,000 cfs (flow need is applied to each individual month).
Source: Perry (2010); for flow at Freeport: Wilson and Dibble (2010), p. 46, table p. 61; SWRCB (2010).
Benefit: Reduce entrainment of outmigrating juvenile salmon into Georgiana Slough and the central Delta due to advection of juvenile salmon into Georgiana Slough on flood tides.

FLOW 3: Mean Apr-Jun period Rio Vista flow = 20,000-30,000 cfs (flow need is applied to the three-month average).
Source: U.S. Fish and Wildlife Service (1987); Brandes and McLain (2001); Brandes *et al.* (2006); Dekar *et al.* (2013); Wilson and Dibble (2010), p. 45, table p. 61; CDFG (2010).
Benefit: Increase abundance of juvenile salmon at Chipps Island.

FLOW 4: Mean Jan-Mar period Delta outflow > 35,000 to 50,000 cfs (for W, AN) (flow need is applied to the three-month average).
Source: Redler et al. (2010).
Benefit: Provide additional and expanded rearing habitat for fall-run fry in San Francisco Bay**.**

Identified Flow Needs for Sturgeon
Needs are listed by location from upstream to downstream.

FLOW 5: Mean Feb-May period Sacramento River flow at Grimes > 17,700 cfs (for W, AN) (flow need is applied to the four-month average).
Source: USFWS (1995), p. 3-Xh-7.
Benefit: Provide conditions for successful adult migration from the estuary or ocean to spawning grounds, spawning, and downstream transport of larval and juvenile sturgeon.

FLOW 6: Mean Feb-May period Sacramento River flow at Verona > 31,100 cfs (for W, AN) (flow need is applied to the four-month average).
Source: USFWS (1995), p. 3-Xh-7.
Benefit: Provide conditions for successful adult migration from the estuary or ocean to spawning grounds, spawning, rearing and downstream transport of larval and juvenile sturgeon.

FLOW 7: Mean Mar-May period Delta outflow > 25,000 cfs (for W, AN) (flow need is applied to the three-month average).
Daily Apr Delta outflow* > 20,000 cfs (for W, AN).
Daily May Delta outflow* > 15,000 cfs (for W, AN).
Source: USFWS (1995), pp. 3-Xh-43-44.
Benefit: Provide conditions for successful adult migration from the estuary or ocean to spawning grounds, spawning, rearing and downstream juvenile transport.

Mean Mar-May period Delta outflow > 44,000 cfs (for W, AN) (flow need is applied to the three-month average).
Source: Analysis of 1980-2011 data provided in Gingras *et al.* (2013).
Benefit: Provide conditions for successful adult migration from the estuary or ocean to spawning grounds, spawning, rearing and downstream juvenile transport.

* These recommendations cannot be evaluated for scenarios because daily values are not calculated by CalSimII for Delta outflow.

FLOW 8: Mean Feb-May period San Joaquin River flow at Vernalis > 14,000 cfs (for W, AN) (flow need is applied to the four-month average).
Flow at Newman > 7,000 cfs.
Source: USFWS (1995), pp. 3-Xh-32.
Benefit: Provide flows for sturgeon attraction, migration, and spawning of adults and for rearing and transport of larval and juvenile sturgeon.

Section 2
Comparison of Operational Scenarios

Table 1 provides a comparison of the four proposed operational scenarios (Alternative 4: H1-H4), along with the No Action Alternative (NAA) and CS5, to show how frequently each scenario achieves each of the flow criteria described in Section 1[3]. The comparison shows that the two scenarios that include high spring outflow (H2 and H4) generally achieve the criteria more frequently than those without high spring flows. This is logical as the majority of the flow needs identified for salmonids and sturgeon occur in the spring. It is also important to note that flow conditions under the No Action Alternative (i.e., no north Delta diversions) achieve several of the identified flow needs for salmonids and sturgeon more frequently than any of the proposed action scenarios. This is an indication that the plan will need to rely on the benefits of reduced south Delta pumping along with the successful implementation of the other conservation measures in order to achieve the plan's biological goals and objectives, even if the higher spring flow options are adopted. Flow conditions under CS5 generally achieve the criteria more frequently than the proposed action scenarios and are approximately equal to the NAA scenario in achieving the identified flow needs. These flow benefits of CS5 along with several other beneficial components of this scenario (upstream storage improvements, south Delta operational criteria, etc.) make it a good option for guiding adaptive management. This scenario could be implemented if other elements of the conservation strategy, such as habitat restoration, do not provide the level of benefits necessary to achieve the plan's biological objectives.

Table 1. Fulfillment of Identified Flow Needs by NAA, Alt 4: H1-H4, and CS5
Needs are listed by species and location from upstream to downstream

Identified Flow		Metric	Months	WYT	Value (cfs)	Percent Fulfillment in Applicable Years (ELT) NAA	H1 LOS Low Spring Low Fall	H2 High Spring Low Fall	H3 ESO Low Spring High Fall	H4 HOS High Spring High Fall	CS5 Scope 3
Salmonids	**FLOW 1:**	Mean Sacramento Flow below NDD	Feb	W, AN	44,000	74	55	55	55	55	53
	FLOW 2:	Mean Monthly Sacramento Flow below NDD	Nov-Jun	All	17,000	48	36	42	35	42	44
		Mean Monthly Sacramento Flow below NDD	Nov-Jun	All	13,000	67	53	56	51	56	56
	FLOW 3:	Mean Sacramento Flow at Rio Vista	Apr-Jun	All	20,000	24	17	20	17	20	24
		Mean Sacramento Flow at Rio Vista	Apr-Jun	W, AN	20,000	50	37	42	37	42	50
	FLOW 4:	Mean Delta Outflow	Jan-Mar	W, AN	35,000	95	89	89	87	87	97
		Mean Delta Outflow	Jan-Mar	W, AN	50,000	76	76	76	76	76	79
Sturgeon	**FLOW 5:**	Mean Sacramento Flow at Grimes	Feb-May	W, AN	17,700	18	18	18	18	18	18
	FLOW 6:	Mean Sacramento Flow at Verona	Feb-May	W, AN	31,100	66	53	61	55	61	63
	FLOW 7:	Mean Delta Outflow	Mar-May	W, AN	25,000	84	79	97	79	97	97
		Mean Delta Outflow	Mar-May	W, AN	44,000	45	42	45	42	45	50
	FLOW 8:	Mean San Joaquin Flow at Vernalis	Feb-May	W, AN	14,000	21	21	21	21	21	21

[3] Only early long-term (ELT) scenarios are evaluated.

The following tables (Tables 2-5) show results from the IOS salmon life-cycle modeling conducted for the BDCP Effects Analysis. IOS results are influenced directly by flow, but also by water temperature values. In upstream locations, IOS characterizes egg maturation, egg mortality, and fry mortality as functions of temperature; these temperature values are related to flow. The mortality functions for eggs and fry are especially sensitive to small changes in temperature, so changes in flow can manifest as notable effects on egg and fry mortality. In model mechanisms that depict other life-history stages, direct effects of flow result from the flow-related survival relationship that characterizes survival of smolts migrating through the Delta.

Table 2 shows IOS-generated winter-run Chinook salmon escapement estimates for the early and late long-term time periods. Tables 3 and 4 use the data from Table 2 to clarify the differences in escapement estimates between the various operational scenarios in the early long-term (ELT; Table 3) and the late long-term (LLT; Table 4). Considering mean model results, Table 3 shows that at ELT for the low outflow scenario (LOS), the model predicts 3,858 fewer winter-run Chinook salmon spawners than the No Action Alternative (NAA), and 4,213 fewer spawners than the high outflow scenario (HOS). Median results for the same scenarios show 2,040 fewer winter-run Chinook salmon spawners for LOS than NAA, and 2,116 fewer spawners for LOS when compared to HOS. Table 4 shows similar results for the LLT; LOS would result in 230 fewer spawners than NAA and 3,362 fewer spawners than HOS when comparing mean values. LOS would result in 245 fewer spawners than NAA and 2,063 fewer spawners than HOS when comparing median values.

Table 5 shows similar results for winter-run Chinook salmon from the OBAN model. OBAN incorporates flow effects via two covariates that are used in the model: water temperatures at upstream locations, which affect alevin survival, and flow rates at upstream locations, which affect fry survival. Table 5 shows that HOS provides larger escapement numbers than LOS in both the ELT and LLT timeframes.

Table 2. Summary statistics for IOS escapement estimates for NAA, H3 ESO, H2 LOS, and H4 HOS scenarios over the early long-term and late long-term time horizons.

Parameter	NAA_ELT	H1 LOS_ELT	H3 ESO_ELT	H4 HOS-ELT	NAA_LLT	H1 LOS_LLT	H3 ESO_LLT	H4 HOS_LLT
Mean	6,665	2,807	4,443	7,020	2,800	2,570	1,703	5,932
Max	41,801	15,486	34,921	44,177	17,901	17,746	8,385	41,337
75th %	9,126	3,235	5,795	8,689	3,535	3,234	2,306	7,833
Median	3,622	1,582	2,834	3,698	1,697	1,452	1,151	3,515
25th %	1,435	751	1,224	1,975	703	755	620	1,344
Min	7	1	13	30	1	0	0	11

Table 3. Comparison of IOS escapement estimate summary statistics for H4 HOS and H1 LOS to H3 ESO and NAA for the early long-term.

ELT	Mean	Median	75th %	25%
H4 HOS minus H3 ESO	2,577	864	2,894	751
H4 HOS minus NAA	355	76	-437	-437
H1 LOS minus H3 ESO	-1,636	-1,252	-2,560	-473
H1 LOS minus NAA	-3,858	-2,040	-5,891	-684
H1 LOS minus H4 HOS	-4,213	-2,116	-5,454	-1,224

Table 4. Comparison of IOS escapement estimate summary statistics for H4 HOS and H1 LOS to H3 ESO and NAA for the late long-term.

LLT	Mean	Median	75th %	25%
H4 HOS minus H3 ESO	4,229	2,364	5,527	724
H4 HOS minus NAA	3,132	1,818	4,298	641
H1 LOS minus H3 ESO	867	301	928	135
H1 LOS minus NAA	-230	-245	-301	52
H1 LOS minus H4 HOS	-3,362	-2,063	-4,599	-589

Table 5 (from BDCP Table 5.G-12). OBAN results for mean and median of annual adult escapement (predicted median) for NAA, H4 HOS, and H1 LOS[1].

	NAA_ELT	NAA_LLT	H1 LOS_ELT	H1 LOS_LLT	H4 HOS_ELT	H4 HOS_LLT
Mean	1,514	358	833	107	1,394	508
Median	755	91	393	65	496	88

[1] Because of assumptions made in the OBAN model, only relative comparisons of escapement among scenarios should be used.

Conclusions

The comparative analysis provided above shows that several desired flow-related criteria that have been recommended to provide suitable conditions for survival and recruitment for salmonids and sturgeon are expected to be achieved more frequently under the BDCP proposed operational scenarios that include higher spring outflows (i.e., H2 and H4) as compared to those scenarios that do not include the spring outflow requirements (i.e., H1 and H3). The analysis also shows that implementation of the full suite of CS5 criteria would result in achievement of the recommended flows more frequently than any of the BDCP proposed scenarios, and would be approximately equal to conditions of the No Action Alternative with respect to providing flow-related benefits. The salmon life-cycle modeling conducted by ICF for the BDCP Chapter 5 Effects Analysis further indicates that the high outflow scenario (H4 HOS) is expected to result in higher adult winter-run Chinook salmon escapement than the other analyzed scenarios, including the No Action Alternative; however, IOS and OBAN modeling was not executed for the CS5 or H2 scenarios.

These results, based on a compilation of the best information currently available and previous recommendations by other entities, indicate that the high outflow scenario, and particularly the high spring outflow criteria, will be needed to reduce the effects of operating the new north Delta diversions. The uncertainty of the other conservation measures, and the variable effect of those measures on different species, advocates for the scenario that is most likely to provide suitable hydrologic conditions. By altering flow, the diversions are affecting an identified key driver of species condition, especially for some species (i.e., sturgeon) that may not benefit as much as others from the habitat-related conservation measures. However, even with these higher outflow criteria in place, the plan will likely need to rely on the successful implementation of other conservation measures to provide additional benefits to achieve the BDCP biological objectives for salmonids and sturgeon.

These conclusions are based on a relatively small number of studies, incomplete understanding of mechanisms responsible for the relationships observed, and limited data. As described in the following section (Section 3), an extensive research and monitoring effort, along with development and refinement of species-specific life-cycle models, is needed to solidify our understanding of flow-related effects on these species and the mechanisms behind those effects. Early implementation of the research, monitoring, and model development recommended in Section 3 is needed to assure a better informed decision on appropriate Delta flow criteria to be implemented upon initiation of the north Delta diversion operations.

Section 3
Research and Monitoring Needs

Past studies have provided useful information regarding the influence of flow on the survival, abundance, and spatial and life-history diversity of salmonids and sturgeon. However, there are many uncertainties about the underlying mechanisms by which flow contributes to these population attributes. Further studies will contribute toward reducing existing uncertainties and allow for better informed management decisions in determining appropriate operational criteria under the BDCP. The following sections provide identified areas of uncertainty and potential study questions, but they are not a comprehensive list of Delta-wide study needs.

Salmonids

- Acoustic tracking of juvenile salmonids past the proposed North Delta Diversion intakes and through the Delta are needed to provide additional baseline survival estimates prior to construction of the facilities, as well as to inform survival estimates once the intakes become operational. Understanding these flow-survival relationships will be critical to inform initial operating criteria, real-time operational adjustments, and adaptive management.
- Many studies have observed the benefits that flow provides to salmonids and sturgeon. However, the specific flow mechanisms associated with these relationships (e.g., magnitude, timing, duration (pulses versus sustained), etc.) warrant additional studies.
- In an effort to reduce the number of juvenile salmonids entering Georgiana Slough, continued studies are needed to determine if, and with what efficiency, fish can be kept out of Georgiana Slough during reverse flow conditions.
- There is remaining uncertainty regarding the relationships between Delta outflow, salinity, and subsequent Chinook salmon fry presence and abundance in the San Francisco Bay. Especially useful studies would assess fry abundance in the Bay at mid-range Delta outflows (between 32,000 and 50,000 cfs) and determine the relative fry contribution to the ocean fishery and escapement over multiple years. In addition, further studies are needed to define necessary fry dispersal in the Bay and determine to what extent flow pulses versus sustained outflow contribute to fry distribution.
- There is limited information on fry survival in the Delta. Current knowledge suggests that there is high mortality of fry throughout the Delta due to various pressures including, but not limited to, increased predation, water exports, reduced primary productivity, and contaminants. Additional studies, perhaps using PIT tag or coded wire tag releases, are needed to understand the effect of these stressors and document survival rates for this important life stage.
- There is limited information on where juvenile salmonids rear in the Delta. For instance, juvenile winter-run Chinook salmon are believed to rear downstream of Knights Landing for prolonged periods in some years in the early winter. It is not known how long winter-run-sized juveniles rear above or below the proposed north Delta intakes. Acoustic tracking of smaller-sized (perhaps wild) salmonids could give insight into how long and at what locations juvenile salmon are rearing. This information could also be used to evaluate the efficiency of the initial pulse protection and whether a later pulse protection in the spring may be more beneficial.
- Population responses of salmon to changes in Delta hydrology and operations is complicated by the many stages of their life cycle, the varying behaviors of different runs, and the several habitat types that comprise their overall habitat area. The continuation and completion of the

Chinook salmon life-cycle model, now in development by NMFS, as well as additional monitoring to address data gaps and model assumptions, is needed to improve the ability to assess the effects of BDCP actions and other operations and to provide guidance on research and monitoring needs.

Sturgeon

- Presently, our understanding of flow effects on annual sturgeon juvenile production is based on relating Year Class Indices (YCI) to flow conditions over several key months. Seasonal flow periods used as covariates with abundance include a range of months that cover several important and distinct life stages (i.e., adult migration, spawning, incubation, and larval transport). Additionally, there is strong auto-correlation between flows in the months within a water year (e.g., mean Jan-Mar flow is well-correlated to Feb flow). This confounds efforts to determine the mechanisms underlying the flow-abundance relationship and precisely identify optimal flow conditions at various times and locations. In order to optimize sturgeon production with minimal water yield cost, a number of research topics need to be addressed, including flow effects (e.g., pulses) on the timing and success of spawning migrations, the location of spawning, the annual abundance of adults on the spawning grounds, and reach-specific juvenile emigration survival rates.
- A detailed understanding of the relationship between annual juvenile sturgeon production and flow conditions is hindered by the limitations of current juvenile survey efforts. The best available juvenile abundance indices are derived from catches during IEP Bay Study otter trawl sampling, which occurs monthly and with limited sampling in the upper estuary. The low intensity of sampling does not provide the resolution to develop a robust flow-abundance relationship. Intensified otter trawl sampling during summer months in the upper estuary may provide the necessary information to better understand the environmental factors that are driving juvenile sturgeon production.
- A fundamental uncertainty relating to the Bay Study otter trawl index of the juvenile sturgeon indices is lack of understanding regarding the precise relationship between the size of the indices and actual juvenile abundance. This uncertainty affects interpretation of the flow-abundance relationship. The recommended improvements in otter trawl methods described above would reduce this uncertainty. However, additional investigations of Age-0 survival based on release and recapture of known numbers of Age-0 hatchery fish, and analysis focused on back-calculated abundance and mortality rates from older juvenile sturgeon is needed.
- Predicting long-term sturgeon population responses associated with BDCP flow criteria is complicated by the length of the sturgeon lifespan and the influence of harvest, both legal and illegal, over that lifespan. The development and use of sturgeon species life-cycle models are needed to improve BDCP effects prediction capability and distinguish BDCP effects from those of other factors. For green sturgeon in particular, better estimates of adult abundance are needed to populate models.
- The flow recommendations in USFWS (1995) need to be revisited and updated. The recommended flows rely substantially on recruitment strength characterizations derived from fish salvage data from the CVP/SWP intake facilities, which provide a very coarse and potentially biased measure of recruitment.

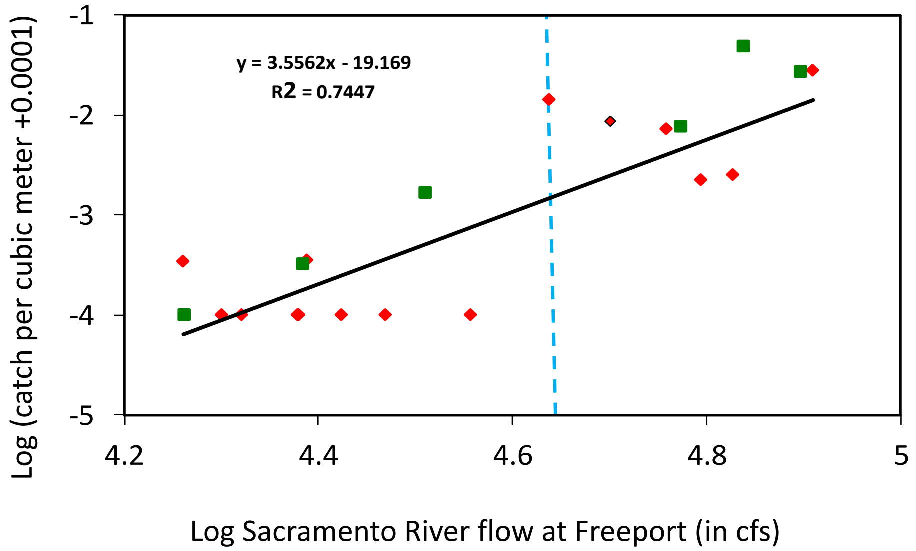

Figure 1. Mean log of catch per cubic meter+0.0001 of juvenile Chinook salmon in Jan-Mar at beach seine sites within San Francisco Bay versus log of mean flow at Freeport during February 1981-1986 (CDFW, green) and 1997-2011 (USFWS, red). Blue line indicates ~44,000 cfs. From Dekar *et al.* (2013).

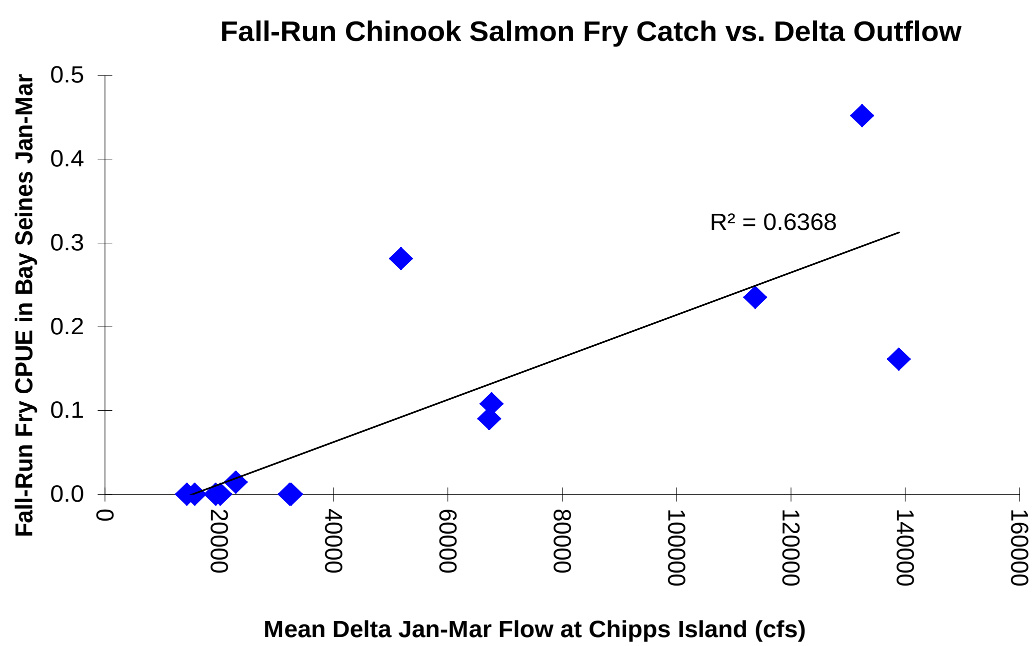

Figure 2. Correlation between CPUE of fall-run Chinook salmon fry in San Francisco Bay area beach seines and mean daily Delta outflow for Jan-Mar 1997-2009. From Redler *et al.* (2010).

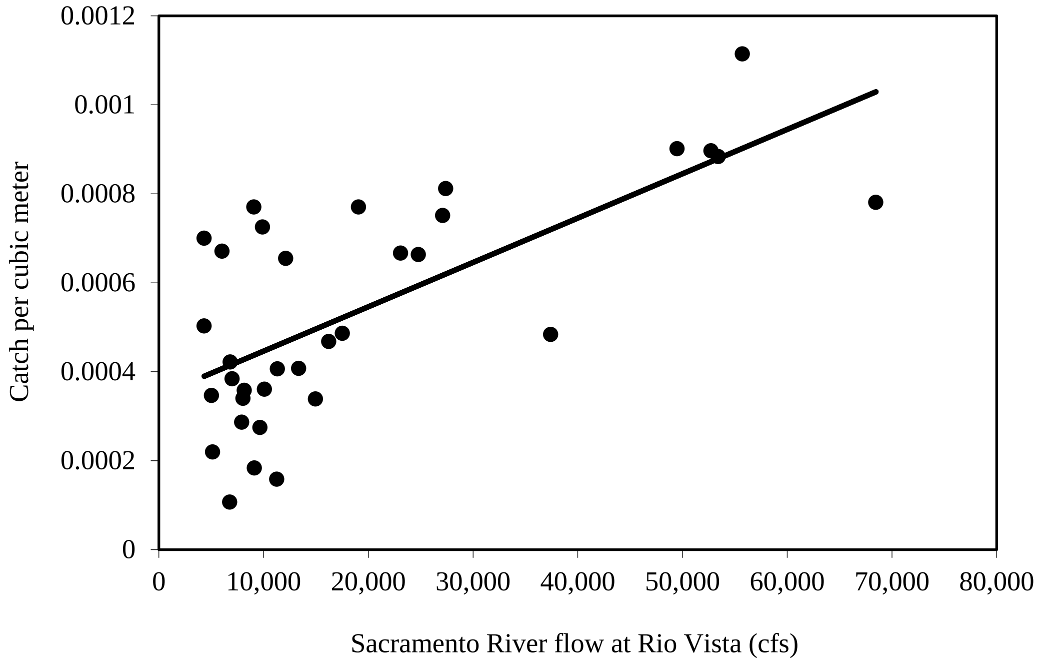

Figure 3. Mean catch per cubic meter of unmarked juvenile Chinook salmon in the midwater trawl at Chipps Island between April and June of 1978 to 2011 versus mean daily Sacramento River flow at Rio Vista between April and June in cfs. From Dekar *et al.* (2013).

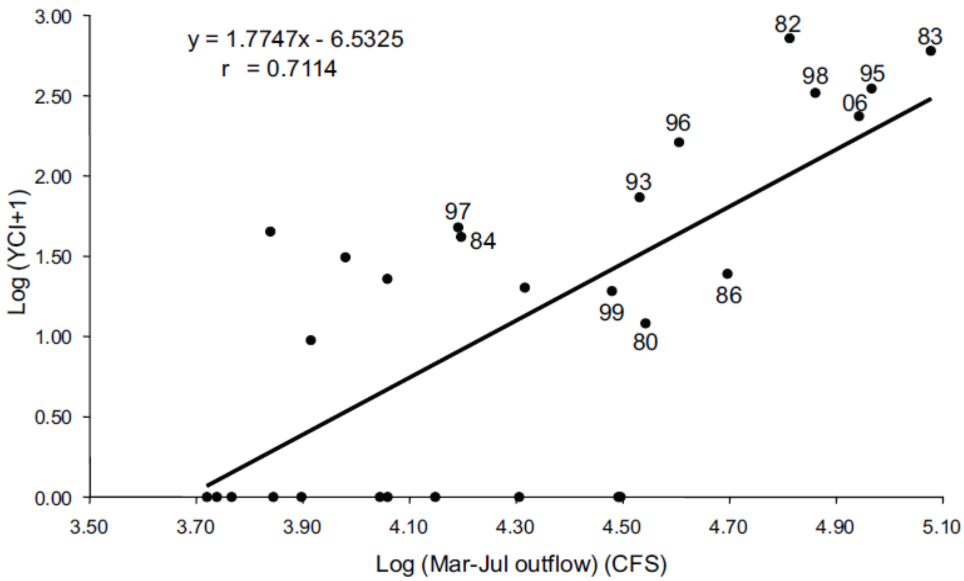

Figure 4. White sturgeon year-class index (YCI) from San Francisco Bay Study otter trawl catches versus mean daily Delta outflow for March through July. Numbers adjacent to points designate select year classes. From Fish (2010).

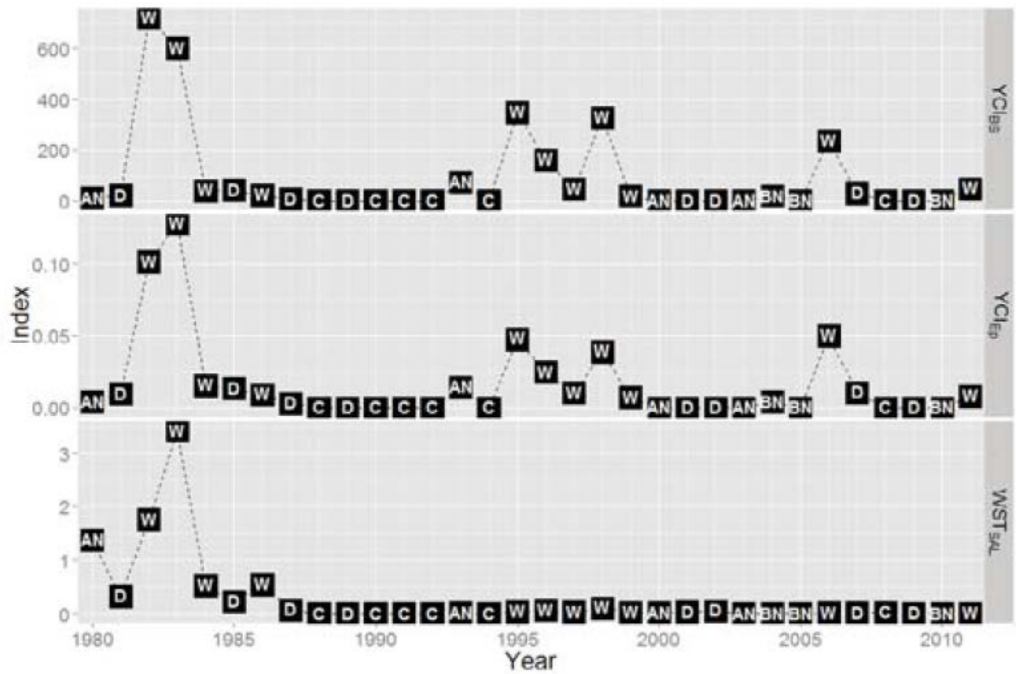

Figure 5. Time series from 1980 to 2011 of year-class strength indices for White Sturgeon from Bay Study (YCI_{BS} (top) and YCI_{Ep} (middle)) and White Sturgeon density at the SWP (WST_{SAL} (bottom)). Data points labeled with water-year type. From Gingras *et al.* (2013).

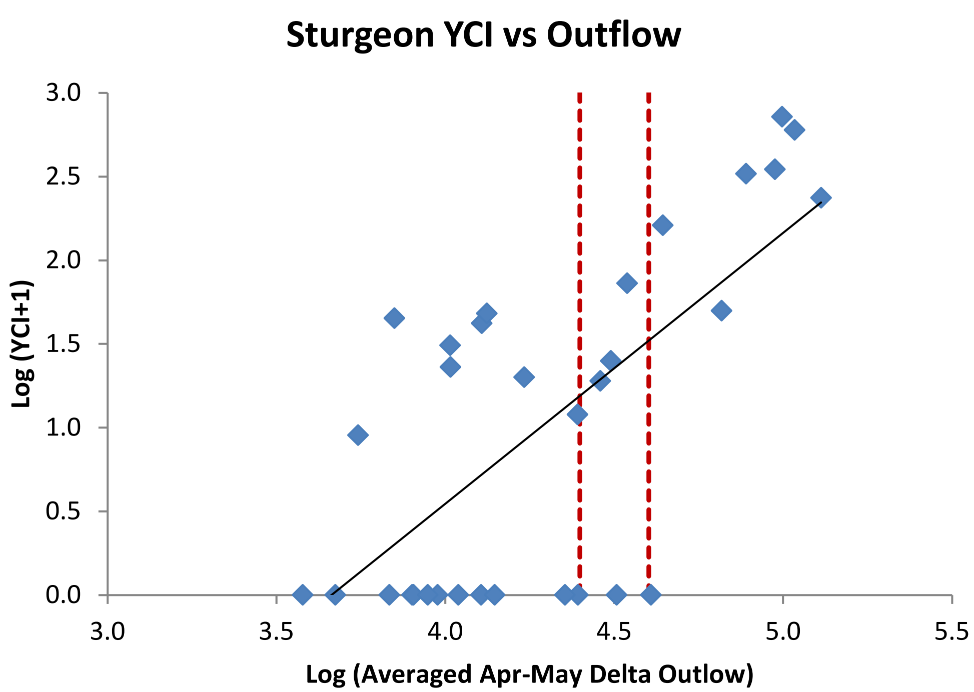

Figure 6. White sturgeon year-class index (YCI) from San Francisco Bay Study otter trawl catches versus mean Delta outflow for April and May. Red lines indicate ~25,000 cfs and ~40,000 cfs. Data from Gingras *et al.* (2013).

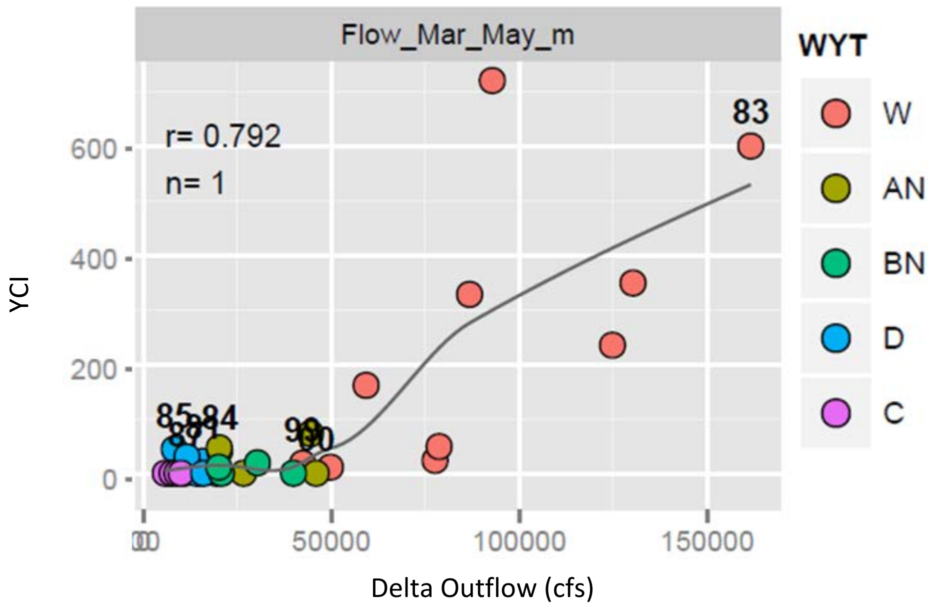

Figure 7. White sturgeon year-class index (YCI) versus mean Delta outflow for Mar-May. From Gingras, CDFW unpublished data.

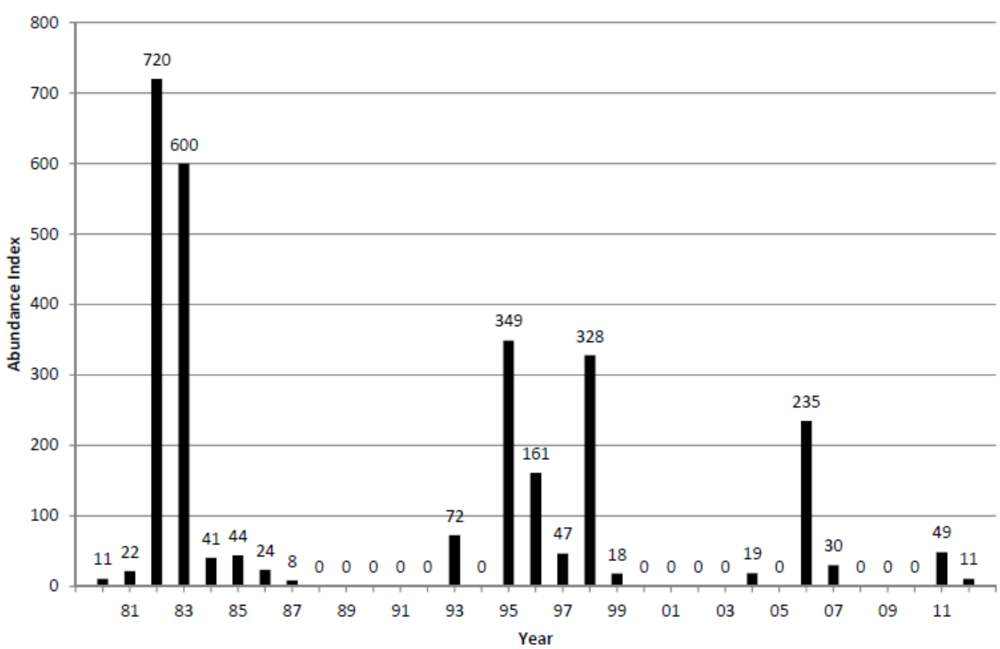

Figure 8. Index of Annual Age-0 White Sturgeon Abundance From Age-0 & Age-1 Fish Collected by Bay Study Otter Trawl, 1980-2012. Indices from 1980-1986 may be biased due to release of fish from hatcheries. For example, approximately 200,000 fingerling-sized fish were released into the Sacramento River by UC Davis in 1982.

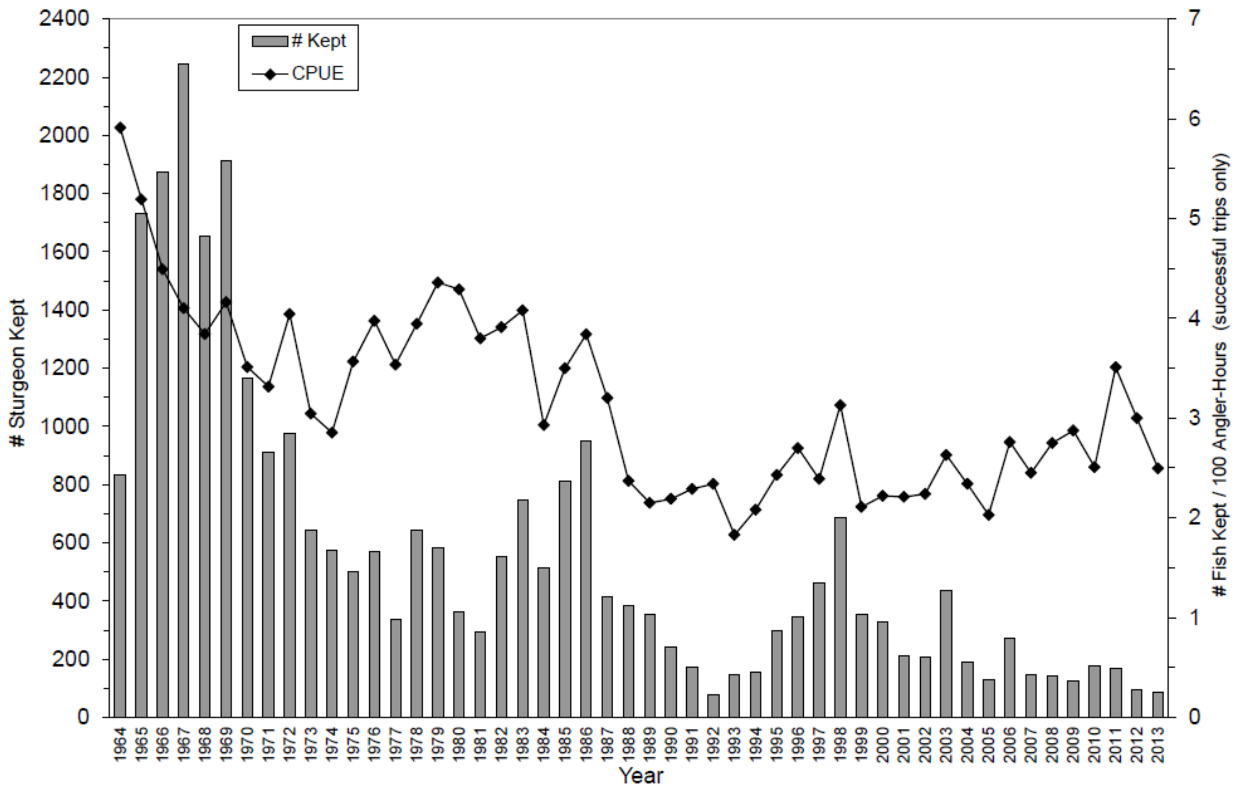

Figure 9. Harvest and CPUE for Sturgeon by Commercial Passenger Fishing Vessels in San Francisco Bay and Delta, 1964-2013.

<u>Flow Analysis Workgroup</u>

Krystal Acierto, California Department of Fish and Wildlife

Pat Brandes, U.S. Fish and Wildlife Service

Pat Coulston, California Department of Fish and Wildlife

Chad Dibble, California Department of Fish and Wildlife

Lee Harrison, NOAA Fisheries

Stephen Louie, California Department of Fish and Wildlife

Cathy Marcinkevage, NOAA Fisheries

Russ Perry, U.S. Geological Survey

Yvette Redler, NOAA Fisheries

David Swank, NOAA Fisheries

Michael Tucker, NOAA Fisheries

Carl Wilcox, California Department of Fish and Wildlife

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Preliminary late-fall Chinook salmon smolt outmigration analysis for SIT team, December 2016 meeting

Prepared by Cyril Michel, UCSC/NMFS-SWFSC Santa Cruz Lab

Amendments from previous June 2016 version

-Inclusion of USFWS-Red Bluff acoustic tagged late-fall Chinook salmon
-Inclusion of % water diverted in the delta from the DAYFLOW estimates in the survival model
-Summarizing of environmental conditions experienced is now using median travel times per release month and year, rather than median travel times per year as before
-Pearson correlation matrix is now included for environmental variables
-Goodness-of-fit test is now included, with AIC values corrected for overdispersion
-Several more minor changes

Introduction

At the request of the SIT team, I have attempted to revisit late-fall Chinook salmon acoustic tagging data from winter 2007 to 2011. The intention of this new analysis is to elaborate on results published in Michel et al., 2015 (Chinoook salmon outmigration survival in wet and dry years in California's Central Valley. CJAFS). These fish were tagged as part of CALFED funded grant to study survival dynamics of both late-fall Chinook and steelhead smolts in the Sacramento River.

Specifically, I would like to use mark-recapture modeling to investigate the potential influence of different environmental variables on Sacramento River region-specific survival of the smolts. I have done this through the RMark package in the R software program, which allows users to use Program Mark but through the interface of R. The following diagram shows the proposed environmental variables and their potential influence on different regions of the Sacramento River (fig.1).

These analyses are preliminary in nature, and have not been peer-reviewed. As such, they should be used with caution, and should only be used for discussion purposes and guiding future analyses/investigations.

Figure 1.

Diagram for Juvenile Outmigration Survival through the Upper and Lower Sacramento River

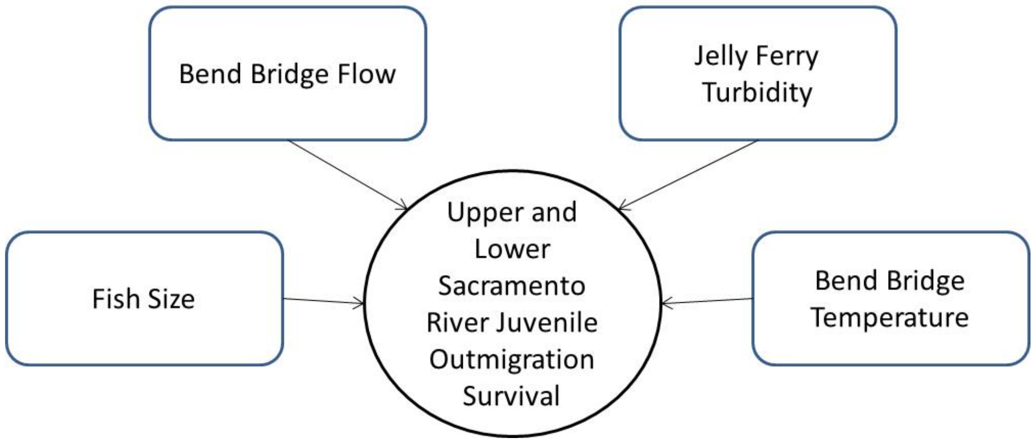
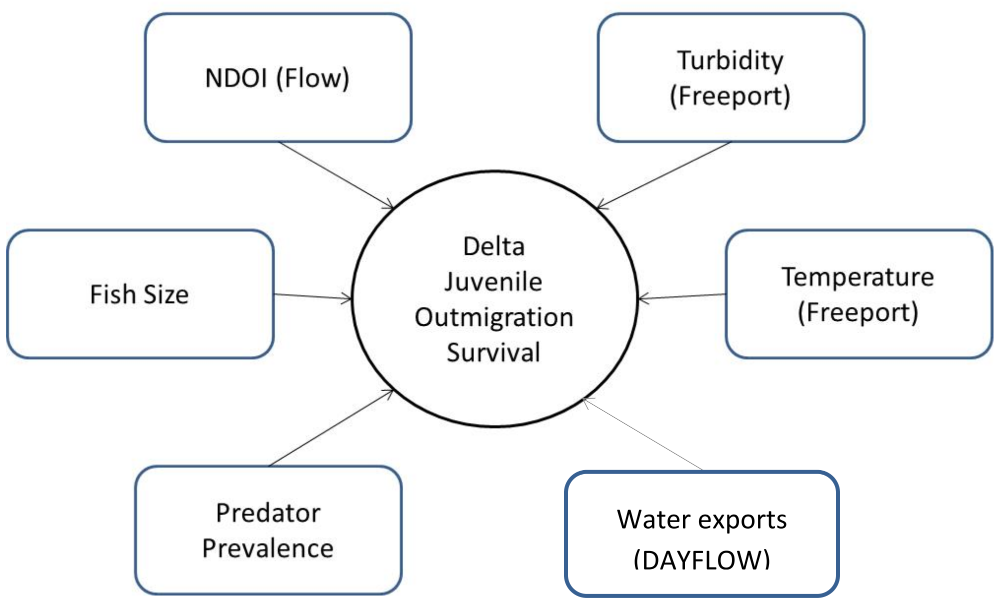


Diagram for Juvenile Outmigration Survival through the Delta



First steps/data massaging

For the analysis, I had to first collect all environmental variables, then bring them into R, then organize them in such a way to merge all the environmental variables into one large dataframe. This was done fairly easily, but took a fair bit of data massaging once everything was loaded into R.

I also loaded all detections and tagging metadata into R. The original detections loaded are for all years, and monitor sites, and for all releases. However, for this analysis, I decided to not include fish that were released mid-river, and only kept fish released at Jelly's ferry or upstream, near the source of all these fish (Coleman Hatchery). This comprised removing approximately half of all tagged late fall, but I believe that including these fish would not be appropriate since we are trying to look at correlations between environmental variables and survival on a river-wide basis.

I also removed all detections from receivers that are not needed for this analysis. This will make all data summarizing steps quicker, since there are ~2million detections to begin with. I only kept detections at Jelly's Ferry, Freeport, Chipps Island, Benicia, and the two lines at the Golden Gate Bridge. This effectively delineates the river, delta, Suisun bay, and SF bay, and the purpose of second Golden Gate line allows us to estimate survival to the first line, but the survival between the two lines is not meaningful.

In terms of study years, release strategies changed every year. In the first year, all fish were released in January of 2007, using a "trickle-out" method where ~13 fish were released per weekday for 4 consecutive weeks into Battle Creek. In the following 3 years, we released fish simultaneously from 3 different release sites (Jellys Ferry, Irvine Finch, Butte City) on one day in Dec and one day in Jan. Then in 2011, the last year, we released all fish from Jelly's, one release day in Dec and one day in Jan. In the latter two years, USFWS service also tagged and released late-fall into Battle Creek along with production late-fall releases for one day in Dec and one day in Jan for both years. Finally, for all fish that were released at Battle Creek, I removed all detections of fish that were never detected at Jelly's or further downstream since these fish likely died before passing Jelly's Ferry, and therefore shouldn't be included in the analysis.

Once all relevant detections had been subsetted, I used a crosstab analysis to summarize detections per location to a binary format, as used by program MARK. I then needed to find the environmental covariates experienced per fish per region (river and delta). The original analysis plan was find the means of the different river covariates over a 14 day period after release for the river section, and find the means of the different Delta covariates over a time window starting at (Release Date + Yearly median river transit time) and ending at [(Release Date + Yearly median river transit time) + Yearly median Delta transit time] for the Delta section. The 14 day window for the river was based off the median river transit time for all the tagged fish. However, river transit times did vary substantially per year, and therefore I decided it would make more sense to do the river covariate summarizing similarly to the Delta technique. In other words, I found the median river transit time per year and per release month, and then summarized the different covariates for the window starting at a fish's release date, and ending at the fish's (release date + Monthly median river transit time).

For this step, I first needed to estimate median transit time for the river and delta. For the river, this consisted of finding the median value of all travel times of all the fish that were detected at Freeport, the "end" of the river region in this analysis, per year (Table 1). For the Delta transit time, I found the median travel time of all fish that were detected both at Freeport (the "beginning" of the Delta region) to Chipps Island (the "end" of the Delta region; Table 1). Table 1 also includes the sample size for fish traveling through these regions for each release batch.

Table 1

Water year	Month	Median river travel time (days)	river travel N	Median delta travel time (days)	delta travel N
2007	1	11.3	7	6.7	3
2008	12	16.2	14	9.4	9
2008	1	9.5	11	5.1	3
2009	12	14.3	27	8.2	10
2009	1	17.0	9	5.2	4
2010	12	17.5	51	7.5	25
2010	1	10.2	13	6.5	8
2011	12	5.2	22	2.3	9
2011	1	11.5	57	4.9	32

A quick summary on each environmental variable:
-River_flow: flow (CMS) collected from Bend Bridge gauge, summarized as daily median
-River_temp: temperature (C) collected from Bend Bridge gauge, summarized as daily median
-River_turb: turbidity (NTU) collected from Jelly's Ferry gauge, summarized as daily median
-Delta_flow: NDOI flow (CMS) collected from dayflow estimates, the OUT variable, daily estimate
-Delta_divers: Percent delta exports (%) collected from dayflow estimates, the DIVER variable, daily estimate
-Delta_temp: temperature (C) collected from the Rio Vista gauge, summarized as daily median
-Delta_turb: an index consisting of the product of suspended sediment and flow at the Freeport gauge, daily estimates
-Delta_pred: predator prevalence (CPUE) from the IEP Mast report, yearly cumulative CPUE. This is the one variable that is summarized per year, rather than per day like all the others. I have included it at the request of the SIT team, but I don't believe it's entirely appropriate in this analysis.

Once mean environmental conditions experienced was calculated per fish, for the river and delta region separately, these were related to each fish's encounter history, and the individual covariate of length was also appended to this dataset. In the following table are the Pearson correlation coefficients between each variable used. Some relatively high correlation coefficients exist between the same variable in different regions (e.g. flow in river and flow in delta), however, in the following analysis, flow in river is only allowed to act on river survival, and flow in delta is only allowed to act on delta survival, and therefore we don't believe this to be problematic. More problematic, however, are the three coefficients highlighted in yellow because these are being applied to the same region. These are due to the fact that both the % diversion in delta ("diver_delta") variable and the delta turbidity index are calculated from the delta flow variable. Specifically, if flow in delta increases, and pumping stays relatively the same, the % diverted will get smaller. Similarly, since our turbidity index is a product of suspended sediment and flow, if flow in delta increases, turbidity will also increase. In future analyses, it may be an improvement to use actual water diverted ratio than a percentage, and it may also be wise to find a true measurement of turbidity.

	flow_river	flow_delta	turb_river	turb_index_delta	temp_river	temp_delta	diver_delta	pred_delta	fish_length
flow_river	1								
flow_delta	0.92	1							
turb_river	0.39	0.6	1						
turb_index_delta	0.59	0.79	0.33	1					
temp_river	0.66	0.52	-0.17	0.42	1				
temp_delta	0.52	0.53	0.06	0.49	0.78	1			
diver_delta	-0.63	-0.83	-0.66	-0.75	-0.28	-0.49	1		
pred_delta	0.59	0.41	-0.18	0.19	0.68	0.53	-0.17	1	
fish_length	0.14	0.13	0.22	0.06	-0.03	-0.02	-0.24	-0.19	1

CJS Modeling

For the modeling portion of this analysis, I used the Cormack-Jolly-Seber model for live recaptures, using Program Mark through the interface of RMark package in program R. CJS models estimate both survival and detection probability.

The first modeling exercise is to better understand how the survival and detection probabilities change through time and space. I created all possible combinations of space and time effects for survival and detection probability (Table 2). I also chose the best supported (and in this case, most complex) model and performed a bootstrap goodness-of-fit test with 500 simulations to estimate c-hat. For mark-recapture models, goodness-of-fit tests for violation of any of the following assumptions (Cooch E, White G (2016) Program MARK. "A gentle introduction". Colorado: Colorado State University):

1. every marked animal present in the population at time (i) has the same probability of recapture (pi)
2. every marked animal in the population immediately after time (i) has the same probability of surviving to time (i+1)
3. marks are not lost or missed.
4. all samples are instantaneous, relative to the interval between occasion (i) and (i+1), and each release is made immediately after the sample.

When testing for goodness-of-fit, we are essentially looking to quantify data overdispersion, as measured by the statistic c-hat in this case. When c-hat is equal to 1, the data fits all the model assumptions perfectly and is not overdispersed. Above 1, this indicates some degree of overdispersion, which can then be used to adjust AIC values accordingly.

We can estimate c-hat two ways: by dividing the original model deviance by the mean deviance of all the simulated models, or by dividing the original model c-hat by the mean c-hat of all the simulated models. In this case, the estimated c-hat for the two methods was 2.1 and 1.9, respectively. I chose the more conservative (higher) of the two, as recommended by Cooch and White (2016). Using this value, I adjusted AIC scores: the result is a QAIC (quasi-AIC) score.

The first step of this analysis will be to look for the spatio-temporal variability in survival and detection probability. For this initial step, I will not include any models that include environmental variables, instead I will create a suite of models that allow survival and detection probability to vary differently through space and time (Table 2).

Table 2. Each row of this table represents one model, with the parameter structure for survival in column 1, and for detection probability in column 2. "~1" means the model has just one parameter, i.e. survival of detection probability is not allowed to vary over time(year) or space (Region). In other words, the ~1 ~1 model at the bottom of the table represents the null hypothesis that survival and detection probability are not a function of time or space. These models are ranked by AIC support, with the best model on top.

Survival	**Detection Probability**	**Parameter Count**	**DeltaQAICc**	**Weight**
~Region + year	~Region + year	18	0.0	1.00
~Region + year	~Region * year	34	13.4	0.00
~Region * year	~Region + year	34	20.0	0.00
~Region + year	~Region	14	29.0	0.00
~Region	~Region + year	14	31.2	0.00
~Region * year	~Region * year	50	35.6	0.00
~Region	~Region * year	30	41.0	0.00
~Region * year	~Region	30	42.1	0.00
~1	~Region + year	10	58.3	0.00
~Region	~Region	10	61.4	0.00
~1	~Region * year	26	71.3	0.00
~1	~Region	6	81.8	0.00
~Region + year	~1	10	82.5	0.00
~Region * year	~1	26	96.6	0.00
~Region	~1	6	113.0	0.00
~1	~1	2	182.2	0.00

Table 2 indicates that there is strong support for region and year specific variation in both survival and detection probability. As a rule of thumb, a delta AIC of more than ~7 indicates substantially stronger support for the better model. Here, the (Region+Year) model for both survival and detection probability is substantially better supported than any other model. Since we are only interested in modeling the effect of environmental variables on survival, I will set the parameter structure of detection probability of all upcoming models to "Region + Year".

The survival estimates for the fully flexible model (Region * Year) are provided in Table 3 below. While the (Region * Year) survival model is not the best supported model, it allows for fully independent estimation of survival in each reach for each year, so while it is not informative mechanistically, it allows us to observe general trends in survival over space and time. In this case, we see similar patterns as seen in Michel et al, 2015: relatively low river and San Francisco Bay survival compared to other regions, with the exception of 2011 when a 2+ fold increase in survival was seen in the river region compared to previous years which results in the highest total outmigration survival rates of the five year study.

Table 3. Survival, standard error, lower and upper confidence interval estimates for the Survival (Region * Year) Detection (Region * Year) model.

year	region	Survival	SE	95% lower confidence level	95% upper confidence level
2007	river	0.17	0.06	0.09	0.32
2007	delta	0.64	0.22	0.22	0.92
2007	suisun	0.64	0.21	0.23	0.91
2007	SFBay	0.43	0.19	0.14	0.77
2008	river	0.39	0.07	0.26	0.53
2008	delta	0.49	0.1	0.3	0.69
2008	suisun	0.67	0.11	0.43	0.84
2008	SFBay	0.46	0.14	0.22	0.72
2009	river	0.36	0.05	0.27	0.46
2009	delta	0.43	0.09	0.27	0.6
2009	suisun	1	0	0	1
2009	SFBay	0.26	0.11	0.1	0.52
2010	river	0.37	0.05	0.27	0.47
2010	delta	0.58	0.09	0.4	0.75
2010	suisun	0.55	0.11	0.34	0.75
2010	SFBay	0.25	0.12	0.08	0.55
2011	river	0.7	0.09	0.49	0.84
2011	delta	0.66	0.09	0.47	0.82
2011	suisun	0.82	0.05	0.71	0.89
2011	SFBay	0.39	0.05	0.29	0.5

The next step of the analysis is to one-by-one incorporate different environmental covariates to a base model as you would an individual covariate, allowing us to compare the model support between each covariate model as an indication of support for that covariate. As a base model, I will use the "region" survival model. I have chosen this model and not the better supported "region + year" model because the purpose of this modeling exercise is partly to identify what covariates drive year to year differences in survival, and therefore we hope that the covariate parameter will explain the year to year fluctuations in lieu of the year parameters.

Table 4. Each row of this table represents one model, with all models sharing a detection probability parameter structure of (Region + Year). Most models contain one environmental variable, with the exception of the "Region" model, which will serve as our base model to which we will compare covariate models. Each environmental covariate is only allowed to act upon the region from which it was collected, e.g. for the Region + river_flow model, all reaches are allowed to have different survival estimates, and furthermore, the river region has a linear relationship with river_flow covariate. Finally, individual fish length is added as a covariate, both as an additive model and a multiplicative model. An additive model means fish length can have a linear relationship with region-specific survival, but this relationship doesn't change from region to region; a multiplicative model mean fish length can have a linear relationship with region-specific survival, and the slope of this relationship can change from region to region.

Survival	Parameter Count	DeltaQAICc	Weight	Beta Coefficient (95% LCI -> UCI)	Standardized Beta Coefficient (95% LCI -> UCI)
Region + river_flow	15	0	0.94	0.0092 (0.0051 -> 0.0134	1.51 (0.84 -> 2.19)
Region + delta_pred	15	6.5	0.04	20.49 (13.65 -> 27.33)	0.67 (0.45 -> 0.90)
Region + delta_flow	15	8.1	0.02	0.0013 (0.0007 -> 0.0018)	0.82 (0.45 -> 1.18)
Region + river_temp	15	9.7	0.0	0.554 (0.331 -> 0.776)	0.49 (0.29 -> 0.68)
Region + delta_diversion	15	16.1	0.0	-0.033 (-0.051 -> -0.015)	-0.48 (-0.74 -> -0.22)
Region + delta_temp	15	16.9	0.0	0.386 (0.162 -> 0.610)	0.44 (0.18 -> 0.69)
Region + delta_turb	15	17.7	0.0	0.00000036 (0.00000012 -> 0.00000059)	0.43 (0.15 -> 0.71)
Region	14	21.2	0.0		
Region + length	15	21.6	0.0		
Region + river_turb	15	23.2	0.0		
Region * length	19	26.7	0.0		

Table 4 indicates a strong relationship between flows in the river section and survival. The second best environmental model is the model allowing for predator CPUE to have a linear relationship with survival coming in next best. However, as mentioned before, this result is likely not meaningful because the predator CPUE are on a yearly time step while all the other variables are on a daily time step. Furthermore, looking at the beta parameter estimates of both the river_flow and delta_pred covariates, the river_flow beta parameter is positive, indicating that increases in flow are correlated with increases in survival. However, the delta_pred beta parameter is also positive, suggesting somewhat counterintuitively that an increase in predators in the delta correlate with increases in survival.

There is marginal support for the delta_flow and river_temp models over the Region (base) model off which they were constructed. All other models have similar or lower AIC values as the base model, and therefore are not well supported. In other words, this preliminary modeling exercise has not found strong support for % water diverted or turbidity being an important environmental variable, nor has it found support for a relationship between survival and fish length.

The next step of this analysis was to investigate if combining the influence of several variables may allow a model more support over the current set of models. For example, instead of river_flow and delta_flow being separate models, combine them so that one model allows river survival to vary in relationship with river_flows and delta survival to vary in relationship with delta_flows (see Table 5). For this exploratory analysis, I will run every possible combination of 8 of the 9 variables (I have not run the predation_index variable since it is not on the same time scale as the other variables). In all cases, the region factor will also be included as before in Table 4. This created 255 unique models, of which the top 10 models can found below in Table 5.

Table 5. Each row of this table represents one model, with all models sharing a detection probability parameter structure of (Region + Year). Here are presented only the top 10 models of the 255 model suite, as well as the base model (Region only). Models can contain 1 to as many as 8 different variables, with the exception of the "Region" model, which will serve as our base model on which we will add covariates. Each environmental covariate is only allowed to act upon the region from which it was collected, e.g. for the Region + river_flow model, all reaches are allowed to have different survival estimates.

Survival	Parameter Count	DeltaQAICc	Weight	Beta Coefficient (95% LCI -> UCI)	Standardized Beta Coefficient (95% LCI -> UCI)
Region + river_flow + river_turb	16	0.0	0.07	0.011 (0.006 -> 0.016); -0.039 (-0.069 -> -0.009	1.85 (1.01 -> 2.68); -0.29 (-0.52 -> -0.07)
Region + river_flow + river_temp	16	0.3	0.06	0.0087 (0.0046 -> 0.0129); 0.415 (0.081 -> 0.749)	1.43 (0.75 -> 2.11); 0.36 (0.07 -> 0.66)
Region + river_flow	15	1.1	0.04		
Region + river_flow + river_turb + river_temp	17	1.7	0.03		
Region + river_flow + river_turb + length	17	2.0	0.03		
Region + river_flow + river_turb + delta_temp	17	2.0	0.03		
Region + river_flow + river_turb + delta_diversion	17	2.0	0.03		
Region + river_flow + river_turb + delta_turb	17	2.0	0.03		
Region + river_flow + river_temp + length	17	2.3	0.02		
Region + river_flow + river_temp + delta_temp	17	2.3	0.02		
…	…	…	…		
Region	14	22.3	0.00		

Table 5 seems to reinforce the idea that river_flow is the most important variable in this analysis. Not only does it appear in all ten of the top ten models, but in the top two models, it's beta coefficient is much higher than for the other variable in those two models. Furthermore, the third best supported model is the one that only includes Region and river_flow. Other than river_flow, the next most frequent variables in the top ten models are river_turb and river_temp.

This next section is exploratory, and is a work in progress. The next logical step in this preliminary analysis is to better understand the relationship between river_flow and river survival, in particular the slope of the relationship. The current river_flow model allows for a simple linear relationship between river flow and river survival. But perhaps the relationship between river flow and river survival is better explained by a linear relationship including a squared term, which could better fit the relationship if it happens to be exponential, for example. Or perhaps the relationship is asymptotic, in which case a log function may better suit the relationship. Finally, perhaps the relationship is even more complex, and a quadratic relationship is required to capture it. I have created a basic model of these three in Table 6.

Table 6. These 4 different models attempted to discern the most supported relationship between river_flow and survival. For comparison, the region "base" model is included.

Survival	**npar**	**DeltaAICc**	**weight**
Region + river_flow + river_flow^2	16	0	0.33
Region + log(river_flow)	15	0.54	0.25
Region + river_flow^2	15	0.56	0.25
Region + river_flow	15	1.35	0.17
Region	14	22.63	0

Table 6 seems to indicate that the relationship between river_flow and survival may be better explained by a quadratic relationship, although only marginally better supported than the log and squared relationships.

We can then create a simulation plot showing the relationship of these river_flow models with survival. We do this by simulating multiple regularly spaced values ranging from the minimum to the maximum flow level experienced by these smolts. We then use the flow beta parameter estimate to predict what the survival estimate would be given each flow level. This allows us to visualize the relationship, potentially looking for "threshold" flow levels above which survival increases substantially (a stated objective of the SIT team). The four following figures show this relationship for all four of the river_flow survival models: (Region + river_flow + river_flow^2 ; fig. 2), (Region + log(river_flow); fig. 3), (Region + river_flow^2; fig.4) and (Region + river_flow; fig.5).

Figure 2. The simulated relationship between the flow and survival in the river section for the Region + river_flow + river_flow^2 survival model. For this plot, flow is plotted with CFS as the unit of measurement, while all previous analyses were done with CMS. The dotted lines represent 95% confidence intervals.

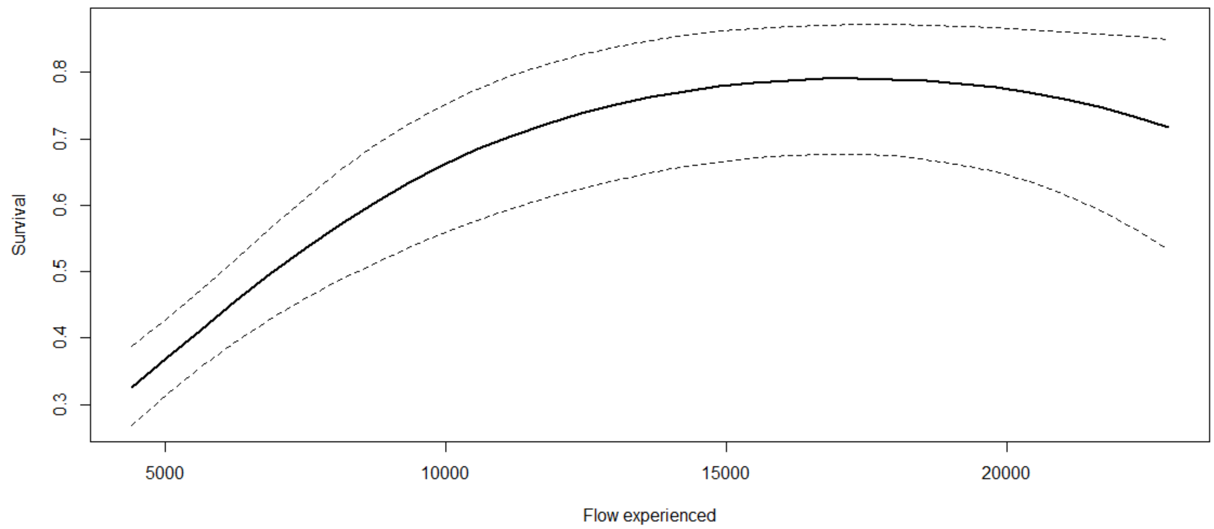


Figure 3. The simulated relationship between the flow and survival in the river section for the Region + log(river_flow) survival model. For this plot, flow is plotted with CFS as the unit of measurement, while all previous analyses were done with CMS. The dotted lines represent 95% confidence intervals.

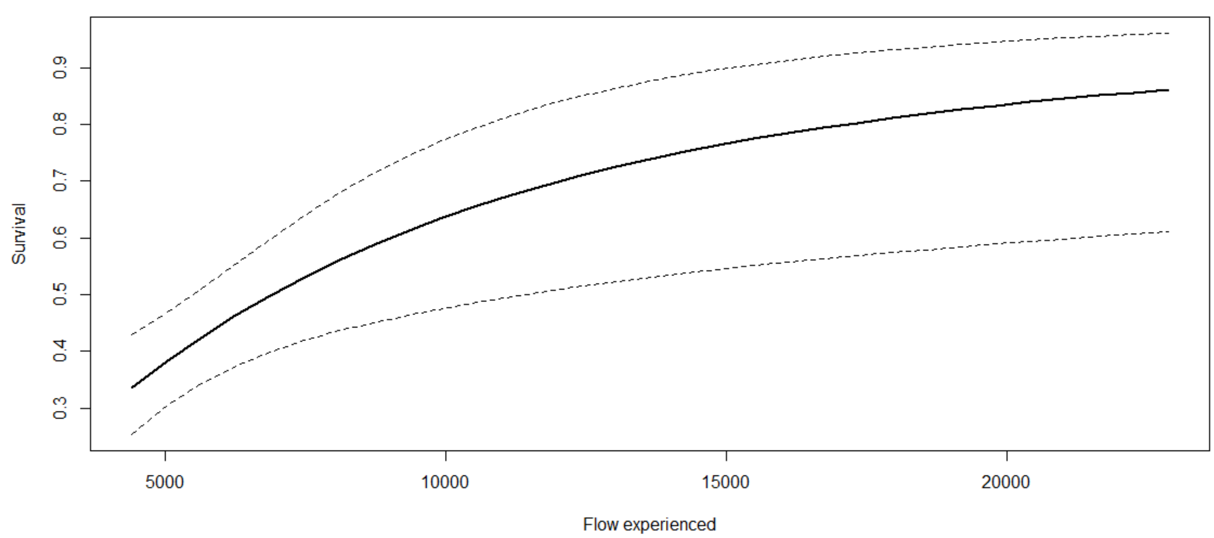


Figure 4. The simulated relationship between the flow and survival in the river section for the Region + river_flow^2 survival model. For this plot, flow is plotted with CFS as the unit of measurement, while all previous analyses were done with CMS. The dotted lines represent 95% confidence intervals.

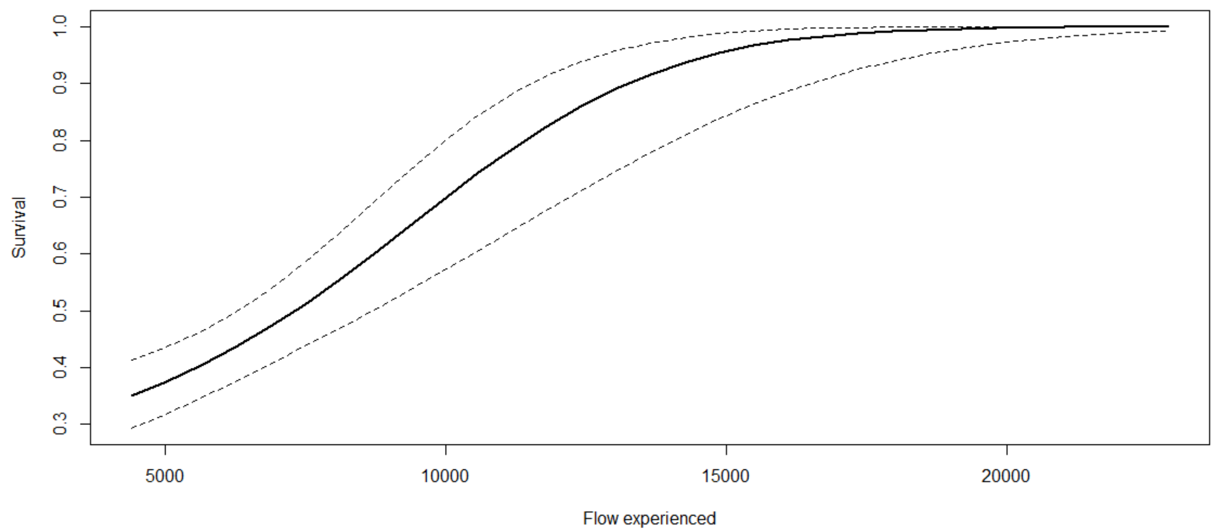
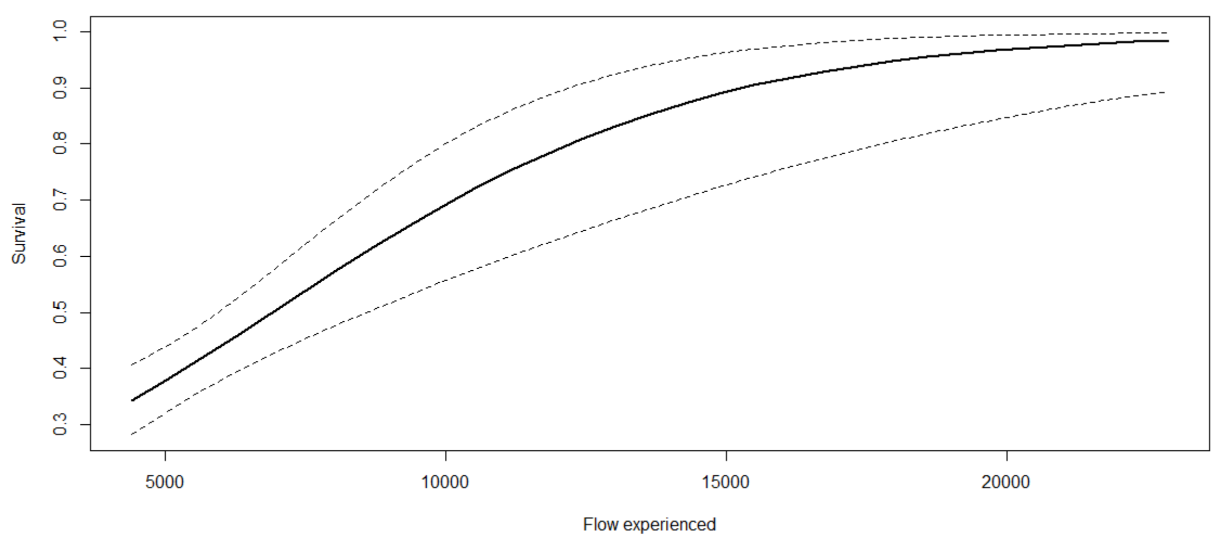


Figure 5. The simulated relationship between the flow and survival in the river section for the Region + river_flow survival model. For this plot, flow is plotted with CFS as the unit of measurement, while all previous analyses were done with CMS. The dotted lines represent 95% confidence intervals.



Figures 2 through 5 show a fairly strong relationship between flow and survival, where survival can hypothetically vary from 0.35 to almost 1 under varying flow conditions. We don't see a strong "threshold" or point of inflection signature, but it does seem from the figures that survival increases substantially up to approximately 13,000 cfs, after which there are diminishing returns in survival.

Future directions

This analysis is still very preliminary, but some promising future directions have presented themselves. They include:

-Adding the CALFED tagged fish that were released mid-river as part of this analysis. They might not be appropriate for inclusion into the river region analyses, but could be useful for Delta analyses.
-Adding additional environmental variables of interest
-Further testing hypothetical relationships between flow and survival
-Finding better variables for measuring predator prevalence, delta water diversion, and delta turbidity
-Make sure "OUT" from the DAYFLOW model is the best variable for measuring delta flow