

Memorandum

To: CVPIA Core Team
From: Science Integration Team (SIT) Structured Decision Making Mentor
Date: 3 March 2017
Subject: CVPIA Science Integration Team: FY18 Decision Support Model activities and FY17 priorities

Background

Members of the Science Integration Team (SIT) met during a series of 8 in-person workshops and 23 conference calls from April 2016 to February 2017 to complete a number of tasks including: identifying restoration scenarios and refining the fall Chinook Salmon (*Oncorhynchus tshawytscha*) Decision Support Model (DSM) as detailed in the 2017 SIT technical memorandum; identifying and refining objectives for winter and spring Chinook Salmon; collaborating with the Steelhead (*O. mykiss*) and Sturgeon (*Acipenser sp.*) Project Work Teams (PWTs) in developing objectives, scenarios, and priorities for the corresponding taxon; and the identification of FY18 priorities. The purpose of the FY18 SIT activities were to: (1) improve the existing DSM and use it to identify priorities and (2) use the information to initiate the integration of priorities for all the focal taxa that were identified by the Core Team in the initial SDM efforts (Peterson et al. 2014). To incorporate the FY17 prioritization suggestions provided by the Core Team, the SIT: was as specific as possible on priority recommendations; incorporated CVPIA generated fall Chinook monitoring data; attempted to differentiate between physical conditions and biological outcomes; and coordinated with NMFS life cycle monitoring efforts. Notes from meetings and conference calls can be found on the data portal at:

<https://connect.doi.gov/fws/Portal/cvpiasitfp/FY18%20Priorization%20meeting%20materials/Forms/AllItems.aspx>

FY18 Prioritization Process Overview

SIT attempted to implement the same process for all focal taxa identified by the Core team. The first step in the process included the identification of key population attributes (objectives) that were quantifiable (measurable) and could be used to track progress toward the fundamental objective of achieving strong, self-sustaining populations of anadromous fishes. For the three Chinook Salmon runs, SIT previously identified fall Chinook Salmon objectives and identified objectives for winter and spring runs. For the remaining taxa, SIT members volunteered to reach out to the Sturgeon and Steelhead PWTs to request assistance and engage in the process. There were no SIT members that volunteered to outreach to the winter and spring Chinook Salmon PWTs and given the lack of a Science Coordinator and tight time lines, the SIT decided to use the FY17 process to elicit those priorities.

The second step in the prioritization process was to identify restoration scenarios that could lead to achieving the fundamental objective of achieving strong, self-sustaining populations of

anadromous fishes. Members of the SIT and the PWT volunteers were asked to think about the primary factors affecting or hypothesized to affect their taxa of interest and use these to identify specific actions that would lead toward achieving their fundamental objectives.

The third step in the process was to evaluate the effectiveness of each scenario to change the population attributes (objectives) using simple scoring criteria: (+) strongly positive, (-) strongly negative, (0) minor or no effect, and (?) unknown/unsure as implemented in a consequence table (Conroy and Peterson 2013). For fall Chinook Salmon, SIT members reviewed model simulation output (described below) and scored each scenario based on their interpretation of the model. A similar, but not identical, process was followed for Steelhead and Sturgeon species, with volunteers from the SIT and PWTs scoring each scenario based completely on expert judgment. The taxon-specific scores were summarized and provided to the SIT. The large number of fall Chinook Salmon scenarios provided by the simulation modeling efforts necessitated an additional step. The summary scores were used to identify a top subset of management scenarios for further consideration. These scenarios were then scored by SIT members jointly during an in-person meeting and following the meeting, on their own using an analytic hierarchy process (Conroy and Peterson 2013).

The fourth step in the process was the identification of taxon-specific priorities based on the summary of fall Chinook Salmon, Steelhead, and Sturgeon PWT and SIT scores and reviews of the priorities identified by the winter Chinook Salmon PWT and spring Chinook Salmon interagency group. The SIT was provided with summaries of scores and the ranking documents via email and on the data portal. During the February 2017 meeting, SIT then discussed the scenarios and characterized the priorities using the following criteria: (1) the score associated with the scenario/ priority, with larger score or higher rank interpreted as higher priority; (2) the specificity of the management scenario (per the Core team request), with greater specificity¹ interpreted as receiving greater consideration; (3) the differentiation between physical conditions and biological outcomes, with greater detail interpreted as the scenario/priority receiving greater consideration (per the Core team request); and (4) the degree of uncertainty (or confidence) in the biological outcome after implementation as reflected in the variability of ranking (where applicable) or confidence in the DSM predictions, with scenarios with lower uncertainty (greater confidence) receiving greater consideration. Scenarios with relatively strong potential to help achieve fundamental objectives, but high uncertainty were considered as candidates for adaptive resource management. Priorities for each taxon were discussed individually without regard to other taxa. SIT members used model output (fall Chinook Salmon), summary scores and rankings, personal knowledge/expertise, and other materials provided by the PWTs and spring Chinook salmon interagency group (i.e., Chinook Winter-run SAIL Potential Management Actions and Hypothesized Responses). Priorities were identified by consensus of the participants attending the meeting (in person or electronically).

¹ To avoid the perception of conflict of interest, SIT attempted to avoid the identification of specific projects for priorities as instructed by the Core team during FY17 prioritization.

The fifth step in the process was across taxon integration of priorities. Here, SIT members scored each taxon-specific priority based on 4 attributes with a consequence table using the simple scoring criteria described above. The attributes included the following: progress toward numeric (doubling) goal; multi-taxa (> 2) benefits; benefits to threatened or endangered species; and contributes to model/information gaps. Scores were assigned by consensus of the participants attending the meeting (in person or electronically).

Focal taxon objectives

Chinook Salmon

The SIT identified 5 valley-wide and 4 tributary-scale objective categories that corresponded with viable salmon population metrics: spatial structure (valley wide only), abundance, natural productivity, life-history diversity, genetic diversity (Table 1). Within these categories, SIT identified 11 valley-wide and 8 tributary-scale quantifiable attributes that they used to score the scenarios and identify priorities.

Sturgeon

Volunteers from the Sturgeon PWT and select members of the SIT (total 8 participants) identified a set of measureable/quantifiable attributes that could be used to track progress toward a strong self-sustaining population(s) of Green Sturgeon (*Acipenser medirostris*) and White Sturgeon (*Acipenser transmontanus*). The group was not asked to identify threshold or target values for these attributes. Rather, they were asked to identify those measureable factors that would indicate progress toward the fundamental objective. The group identified 9 of these attributes for Green and White Sturgeon (Table 2). The two species shared 8 of these measurable attributes in common, differing on only two: growing of population of oversized fish (White Sturgeon) and annual spawner abundance (Green Sturgeon).

Steelhead

Volunteers from the Steelhead PWT and select members of the SIT (total 12 participants) identified a set of measureable/quantifiable attributes that could be used to track progress toward a strong self-sustaining population(s) of Steelhead (*O. mykiss*, anadromous life history). As above, the volunteer group was not asked to identify threshold or target values for these attributes. Rather, they were asked to identify those measureable factors that would indicate progress toward the fundamental objective. The group identified 7 of these attributes for Steelhead that included: spatial diversity, natural productivity, and genetic fitness/integrity metrics (Table 3).

Scenarios identified for FY18

Fall Chinook Salmon

The SIT identified 9 scenarios to be evaluated with the fall Chinook Salmon DSM that included reduced diversion during April and May on San Joaquin Tributaries; eliminating predator contact points

in Sacramento and San Joaquin tributaries and mainstem; increasing seasonally inundated habitats (two alternatives 2 year & 1 year inundation frequency); increasing perennially inundated habitats; reducing the number of hatchery origin fish spawning in tributaries; pulse flow from Shasta only to 17,500 cfs, giving 1 week to prompt juvenile fall Chinook migration; and contrasting strategies that focus multiple improvements on single tributary with single improvements in multiple tributaries (Table 4). For each scenario except the last two listed above, SIT identified three levels of change (i.e., low, medium, and high). The juvenile habitat changes were scaled relative to previous estimates of habitat needed to support the doubling goals (i.e., Emigrating Salmonid Habitat Estimation, or ESHE, values described below). For consistency, pseudo-ESHE values were calculated for spawning habitat assuming redd size of 12.5 m² and assuming 50/50 sex ratios (described below).

Sturgeon

For each Sturgeon species, the volunteer group identified management scenarios that they believed to have the greatest potential to improve Sturgeon populations in the Central Valley. As part of the process, participants were asked to think of these actions using the following: Sturgeon in the Central Valley (or tributary X) would be doing much better if only we would/could do “this”, with participants supplying the “this.” Using this process, the group identified 10 scenarios for each species that included the use of pulse flows during specific months to facilitate reproduction and recruitment, improving passage, and reducing legal and illegal harvest (Table 5). Members of the group believed that spawning pulse flows during the spring and summer in the Yuba and Feather Rivers would facilitate spawning but were unable to identify specific flow values.

Steelhead

The Steelhead volunteer group also identified management actions (scenarios, manipulations) that they believed would have the greatest potential to improve *O. mykiss* anadromous life history expression in the Central Valley. As described above, participants were asked to think of these actions using the following: Steelhead in the Central Valley (or tributary X) would be doing much better if only we could/would do “this”, with participants supplying the “this.” Using this process, the group identified 10 scenarios and candidate locations for the actions that included actions that encouraged or facilitated anadromy, pulsed flows during specific months, and improving spawning and rearing habitat (Table 6). However, the group was unable to provide greater specificity for many of the scenarios because they believed that factors influencing *O. mykiss* anadromous life history were too complex and highly uncertain.

Fall Chinook Salmon Decision Support Model

The refinement of the fall Chinook Salmon DSM was guided by the FY18 scenarios identified by the SIT, the results of the FY17 prioritization, and the feedback received from the Core Team. The SIT developed new conceptual models of adults salmon survival and straying, juvenile survival and growth, egg incubation, juvenile survival and movement, adult and juvenile migration routes that include Yolo and Sutter bypasses (Figure 1), and empirical estimates of habitat availability for the north Delta. In addition, the fall Chinook models were calibrated using monitoring estimates of adult returns in each tributary, Chipps Island juvenile abundance, and the abundance from the CAMP rotary screw trap

platform. The model components, sources of data, and processes are described in the sections below and the various versions of the fall Chinook Salmon conceptual models can be found on the data portal at:

<https://connect.doi.gov/fws/Portal/cvpiasitfp/Fall%20Chinook%20Model%20Versions/CONCEPTUAL%20FALL%20CHINOOK%20MODELS%20TO%20DATE%20August%202016.pdf>.

Model Inputs

The Coarse Resolution Fall Chinook Salmon DSM includes the following inputs:

1. Daily water temperature, summaries (e.g., average daily).
2. Instream juvenile habitat and spawning habitat, by climate scenario.
3. Juvenile floodplain habitat availability by climate scenario and month.
4. Total water diverted and proportion of water diverted from each location, e.g., tributary, Sacramento River section, north and central south Delta (Figure 1).
5. Delta juvenile rearing habitat.
6. Monthly discharge, by climate scenario and month.
7. Number of contacts points by location.
8. Number days per month cross channel gate is open.
9. Redd scouring and dewatering frequencies.
10. The number of hatchery smolts introduced each year.
11. Hatchery returning adults stray rate.
12. Angler (instream) and ocean harvest rates.
13. Predator prevalence.

Of the inputs listed above, only the last was based on expert opinion. Similar to the FY17 evaluation, estimates of floodplain inundation and proportion of streamflow diverted were monthly and based on two climate periods, dry period: 1924–1944 and wet 1971–1991. The modifications to the input data described below were made by FlowWest, working in coordination with Mark Gard from the U.S. Fish and Wildlife Service and the SIT, and National Marine Fisheries Service (NMFS) personnel working on the winter Chinook Salmon life-cycle model. The largest change in the model inputs was the use of CalLite rather than CASLIM to facilitate climate change evaluations (not included in the scenarios). Instream juvenile and spawning habitat and floodplain habitat model input files were developed using the same basic approach as in the previous iteration of the model. All input databases are maintained by FlowWest.

Hydrology

To develop basic hydrology for this iteration of the salmon DSM, FlowWest used a baseline run of the CalLite operations model to simulate flows across the Central Valley by simulating operations of water facilities in California over a common hydrologic period. CalLite is an interactive model developed by DWR and USBR staff to quickly simulate system operations in the Central Valley. An overview of the CalLite model is available on the DWR website at:

<http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalLite/index.cfm>. Previous versions of the salmon population model used CASLIM output, which is similar to CalLite, but does not have accepted climate change runs. CalLite was the platform used to develop Bureau of Reclamation (USBR) climate

change assessments. USBR ran a baseline CalLite simulation that approximated current regulatory conditions and water use for all of the CVPIA watersheds except the Mokelumne, which is run as a separate module. For the prior model FY17 run, East Bay Municipal Utility District (EBMUD) provided Mokelumne flows from a slightly different operations model - CALSIM. Flows and diversions for the Mokelumne were provided based on the previous model run.

Water Diversions

CalLite output (and CALSIM output for the Mokelumne) included monthly discharge for each of the CVPIA streams. These discharges were used to evaluate floodplain habitat as noted in the description of floodplain habitat. CalLite monthly output also provided diversion information for the watersheds. Based on the model's schematic depiction of nodes (which estimate deliveries to agricultural and municipal water users), the limit of anadromy was estimated for each watershed. Given initial flows and subsequent diversions within each watershed, an estimate of percent diversion within each reach was calculated. In some cases, due to accretions and return flows, the total diversion within a month can be greater than the initial upstream flow. For these instances, a maximum percentage diversion effect was limited to 100 percent.

Water temperature data

CalLite output also provided inputs for the HEC-5Q model, which was used to estimate daily mean, minimum and maximum temperature. These values were summarized to monthly values for use in the DSM.

Contact points

Contact points were derived from the Passage Assessment Database (PAD) (<https://nrm.dfg.ca.gov/PAD/view/query.aspx>) maintained by California Department of Fish and Wildlife. Each location considered in the model (e.g., tributary, Sacramento reach, and delta subdivisions) was assessed for all structures identified in the PAD.

Cross-channel gate operations

For the purposes of the salmon DSM, Delta Cross Channel (DCC) gate operations are assumed to follow the recommendations of the NMFS winter-run Chinook Salmon Biological Opinion (<https://www.usbr.gov/mp/mpr-news/docs/factsheets/delta-cross-channel-canal.pdf>). According to the Biological Opinion, DCC gates are closed October 1 through January 31, which covers the migration period in the salmon DSM.

Instream Juvenile Habitat and Spawning Habitat

Instream habitat values were calculated for the median flow from the CalLite model monthly flow data (described above) using the Instream Flow Incremental Methodology (IFIM) flow:area curves, where available, and using the average proportion of habitat area to total inundated area where IFIM studies were not available. Input values for the scenarios evaluating increases in instream habitat as proportions of the total habitat required to satisfy the CVPIA Doubling Goal (as determined by the ESHE model) were determined by taking the total habitat need for each watershed from Appendix H of the Central Valley Flood Protection Plan (http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf), subtracting the existing instream and floodplain rearing habitat input areas, and then multiplying the

difference by the proportions of the Doubling Goal (25%, 50%, and 75%). Pseudo ESHE spawning habitat amounts were estimated as the product of the tributary Doubling Goal, 0.5 (50/50 sex ratio) and the average size of Chinook Salmon redd (12.5 m²) used in the DSM (Appendix A).

Floodplain habitat

Floodplain habitat model input values were determined on a monthly time step. If the monthly average flow from CalLite exceeded the 2-yr, 14-day threshold flow for a given watershed, the model input was the area of suitable floodplain habitat associated with the 2-yr, 14-day flow. If the monthly average flow did not exceed this threshold, the model input was zero. Input values for the scenarios evaluating increases in frequency of inundation were developed by reducing the flow threshold to the 1-yr, 14-day flow (in most cases, a significantly lower flow). Input values for scenarios evaluating increases in floodplain area as proportions of the total habitat required to satisfy the CVPIA Doubling Goal (as determined by the ESHE model) were determined by taking the total habitat need for each watershed from Appendix H of the Central Valley Flood Protection Plan (http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf), subtracting the existing instream and floodplain rearing habitat input areas, and then multiplying the difference by the proportions of the Doubling Goal (25%, 50%, and 75%). This iteration of model input also included floodplain areas for the Sutter Bypass and the Yolo Bypass. Yolo Bypass area was calculated using the flow:area curve developed by the California Department of Water Resources in support of the Central Valley Project Biological Opinion evaluations of Yolo Bypass assuming existing conditions at Fremont Weir. Yolo Bypass area was scaled to flow over Fremont Weir and not limited by the 2-yr, 14-day criteria for other floodplain areas. Yolo Bypass areas were also not scaled for suitability. Sutter Bypass area was taken as the existing conditions value from the Central Valley Flood Protection Plan (http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf) assuming 27% suitability.

Juvenile delta habitat

Juvenile Chinook Salmon habitat models in the north Delta section (Figure 1) were provided by NMFS (contact: Correigh Greene) was calculated for the median flow from CalLite using flow:area relationships. Central South Delta juvenile habitat was taken as the existing conditions value from the Central Valley Flood Protection Plan (http://www.water.ca.gov/conservationstrategy/docs/app_h.pdf) assuming 27% suitability.

Hatchery Origin Adults

Hatchery origin adults were assigned to watersheds based on the average hatchery proportion from 2011–2013 coded wire tag (CWT) data used in the Constant Fractional Marking Program (unpublished). If CWT data were not available for a watershed, the assumed Anadromous Fisheries Restoration Program (AFRP) hatchery proportion was used during the evaluation.

Changes to Model Structure and Relationships

The meta-structure of the fall Chinook DSM remained largely unchanged from the FY17 prioritization (Figure 2) with most of the modifications focused on the transitions between model components, termed submodels. Changes to the DSM submodels included the addition of an adult en route and prespawning survival submodels, adult straying submodel, an egg viability submodel, and a

juvenile movement submodel. In addition, the following existing submodels were reparametrized using a combination of published studies, analyses of empirical data, and model calibration: juvenile instream and Delta rearing survival, and juvenile outmigration survival. The only submodel unmodified from the original version reported in Peterson et al. (2014) was the incubation success submodel. Revisions to the submodules are summarized below and the final DSM parameters and sources are in Appendix A.

- Adult en route survival was modeled as a function of stranding in the Sacramento River bypasses, average 7-day daily maximum temperature and sportfishing harvest. Parameter estimates from the calibration, published sources, and expert opinion. Harvest rate was assigned to tributaries based on average proportion from 2010–2012 coded wire tag (CWT) data used in the Constant Fractional Marking Program.
- Adult prespawn mortality was modeled as a function of thermal exposure and was parameterized using estimates from a published study.
- Adult straying was a function of origin (naturally produced or hatchery), proportion of streamflow from natal tributary, number days cross channel gate were open (San Joaquin tributaries), and how hatchery fish were transported and released. Parameter estimates were from analysis of data in published reports and memorandum.
- Egg viability was modeled as a function of temperature accumulation and was parameterized using unpublished models.
- Juvenile rearing survival (river, delta, and bypass) were modeled as functions of body size, water temperature, stranding, predator prevalence, predator contact points, water diversion, and habitat use. Parameter estimates were from a combination of calibrated and published values.
- Juvenile movement was modeled as a function of habitat availability, body size, and the timing and magnitude of high flow events. Fish movement rules in relation to habitat availability and body were unchanged from FY17 version of the model. However, parameters relating the effect of flows on movement were from unpublished model fit using CAMP rotary screw trap data from 7 tributaries from 2007–2015.
- Juvenile outmigrant survival for San Joaquin River mainstem were unchanged from the FY17 version of the model. However, outmigrant survival in the Sacramento River mainstem and through the Delta were parameterized using a combination of calibrated values, published parameters, and unpublished parameter estimates from models fit by NMFS collaborators to experimental releases of late fall juvenile Chinook Salmon. Based on model selection criterion, two and three survival models for outmigrants through the Sacramento River and Delta, respectively were considered plausible. Estimates from these alternative models were weighted equally and averaged during model runs.

Model calibration

The DSM was calibrated using empirical escapement estimates, screw trap, and Chipps Island Trawl data from 2007–2015 adjusted for capture efficiency. Model parameters were estimated using a combination of genetic algorithm (R package *rgenoud*; Sekhon and Mebane 1998) and particle swarm optimization (R package *hydroPSO*; Zambrano-Bigiarini Rojas 2014) and minimizing the sum of squared differences between predicted and observed juvenile abundance and known and predicted adult

escapement. During an initial calibration effort, the following intercept parameters were fit during the calibration: adult en route survival, juvenile rearing survival in tributaries and the Delta, juvenile out migrant survival, and ocean entry survival.

Visual inspection of observed vs. predicted escapement estimates and juvenile abundance at Chipps Island for the calibrated intercepts suggested very poor model fit (e.g., negative to no correlation between observed and predicted). The very poor calibration results suggested that other parameters that were used in the model were not appropriate for approximating the factors affecting fall Chinook Salmon dynamics. A combination of simulation and exhaustive search indicated that four parameters used to estimate juvenile survival were the primary source of the problem. These included: the effect of contact points on juvenile survival; the effect of proportion water diverted on juvenile tributary survival; the effect of total amount of water diverted on juvenile tributary survival; and the effect of total amount of water diverted on juvenile Delta survival. Therefore, these four parameters were estimated in addition to the four intercepts listed above. The calibration results indicated a reasonable fit to the monitoring data with the greatest differences between observed and predicted values at the extremes (Figures 3 and 4). The change in the value of the four aberrant juvenile survival parameters can be found in Table 7.

Model Simulation and Evaluation

To identify fall Chinook priorities, SIT requested a series of model runs using the calibrated version of the DSM and inputs described above. Each model run began with adults arriving in the spawning tributary. Initial escapement of naturally produced adults in years 1–3 was assigned as the average of estimated adults from 2010–2015 from the GrandTab database. If initial escapement estimates were unavailable for a watershed, 100 adults were assigned to a watershed. Naturally produced fish were assigned to their natal watersheds. Hatchery origin adults were assigned to watersheds based on average proportion from 2010–2012 from the coded wire tag data used in the Constant Fractional Marking Program (unpublished). If CWT data were not available for a watershed, the assumed AFRP hatchery proportion was used during the evaluation. The growth and survival of juvenile salmon were modeled on a monthly time step beginning January and ending in August using the submodels described earlier (Appendix A). Naturally produced adults were randomly assigned to specific yearly returns and survived as a function of ocean harvest (Peterson et al 2014). At the end of each year, the model output the subset of four valley-wide and four tributary-scale attributes defined above.

The models were run under current conditions and for each of the fall Chinook scenarios identified by SIT (Table 1) over two climatic periods defined as the dry period: 1924–1944 and the wet period 1971–1991. For each climate period, estimates of the number of diversions, discharge, and floodplain habitat availability varied by year and month as described above. Floodplain inundation was assumed to last two weeks per month. In-channel juvenile rearing habitat availability also differed between dry and wet climate periods, but water temperature metrics and probability of redd scour and stranding did not. For each climate scenario, DSM v2 was run for 20 years the 11 valley-wide and 8 tributary-scale attributes were output at year 5 and 20. The results of all model runs were summarized for all scenarios and a subset of scenarios that excluded contact points and 1 year floodplain per the request of SIT members. Model run results and summaries were provided to SIT members for review

and were posted on the data portal at:

<https://connect.doi.gov/fws/Portal/cvpiasitfp/Fall%20Chinook%20FY18%20Prioritization%20Materials/Forms/AllItems.aspx>

Sensitivity analyses

One-way sensitivity analysis was used to identify the SDM components that had the greatest effect on the expected value of the decision. During the one-way sensitivity analysis, values for model parameters (e.g., survival) were varied +/- 50% of the model values (Appendix A) and the estimated response was recorded for the top scenario. Here the response focused on two SIT metrics at the valley-wide and tributary scales, under two climates (wet and dry), and at two points in time 5 and 20 years: change in natural productivity (number naturally-produced adults) and number of juveniles per spawning adult. The results of the one-way sensitivity analysis are graphically displayed in a tornado diagram. The sensitivity to each model component was represented by a horizontal bar that corresponded to the range of estimated change in the SIT metric observed during the sensitivity analysis. The model components are sorted from the most influential component (i.e., widest bar) at the top to the least influential (i.e., narrowest bar), which then resembles a funnel or tornado. One-way sensitivity analysis revealed similar patterns between climates (wet, dry), years (5 vs 20), and valley-wide and tributary attributes with the survival model parameters being among the most influential components as demonstrated in Figures 5 and 6. In addition, factors affecting reproduction-- fecundity, redd size, and sex ratio, also were among the most influential factors affecting the estimated SIT metrics.

One-way response profile sensitivity analysis also was used to evaluate the sensitivity of decisions to the model components. Similar to one-way sensitivity analysis, one component was varied at a time to evaluate the change in the estimated SIT metrics. Unlike one-way sensitivity analysis, the estimated value for each decision, not just the optimal (highest) decision, is recorded. These values then were plotted to examine how optimal decisions change over the range of values for the model component. Because of the large number of plots (model components) and scenarios, the results are summarized and counts of the number of changes in the membership of the top 20 scenarios (i.e., the scenarios with the largest estimates of number of naturally produced adults and number of naturally produced juveniles per spawner). Model components for which decisions changed several times across a range of plausible values as indicated by large changes in the membership of the top 20 scenarios were considered influential components. Similar to the one-way sensitivity analysis, the response profile analysis results were similar between years and across scales. Examples of the relative rankings of influence are shown in Figures 7 and 8. In general, juvenile survival parameters tended to be among the most influential parameters as well as factors affecting reproduction. In addition, juvenile growth and territory size also were somewhat influential in the ordering of the top 20 scenarios.

To identify the key uncertainties, the top 10 most influential components for each climate, year and SIT metric combination were compiled at each scale. Components that were included in the top 10 list for 6 of the 8 combinations (e.g., wet climate, year 5, naturally produced adults) were considered key uncertainties that were high priority for improvement or further study. Of the 84 components evaluated (Appendix A), only 8 were key uncertainties that largely controlled the estimated SIT metrics and relative

rankings among scenarios (Table 8). That only a few model parameters are influential is typical for most DSM (Conroy and Peterson 2013) and speaks to the need for greater parsimony in the modeling approach. The key uncertainties were virtually identical for the valley-wide and tributary metrics with five juvenile survival components and sex ratio in common between the two sets of key uncertainties. SIT members were provided with the results of the sensitivity analyses prior to scoring the scenarios in the second round, as described below.

SIT model assessment

Similar to FY17, the SIT qualitatively assessed the fall Chinook Salmon DSM inputs and model components. In general, the SIT graded model components that had greater empirical support and submodels that were published or parameterized with empirical data higher. The assessments can be found in Appendices B and C.

FY18 prioritization and results

The sections below briefly describe the general tenor of the SIT discussions regarding the priorities that were identified during the process described above. Discussions regarding other scenarios and proposed priorities are omitted for brevity. However, notes from all meetings can be accessed through the data portal linked above,

Chinook Salmon

Fall run

During the first round of scenario evaluation, 8 members of SIT reviewed the Chinook Salmon DSM output and scored the scenarios using the output as a guide. Summaries of the scoring suggested that participants believed that multiple actions would be most beneficial in seven locations that included (not in order): the American, Feather, upper and lower-mid Sacramento, Stanislaus, and Yuba rivers and Big Chico Creek (Figure 9). There also was some support for a reduced number of actions in Battle Creek and the Mokelumne, Tuolumne, and lower Sacramento rivers. One of the January meeting objectives was to reduce the set of scenarios/locations to a smaller candidate set for greater scrutiny and there was consensus that these locations (listed earlier) were a reasonable place to start. After substantial discussion regarding the inclusion of additional locations or exclusion of those on the list based on their potential to achieve/improve the SIT Chinook Salmon attributes (Table 1), the SIT agreed to a list of 10 locations to evaluate as potential priorities (Table 9). The group then proceeded to weight each of the locations according to their importance in contributing to the increase or enhancement of four SIT attributes: genetic integrity/ adaptation, life history diversity, natural production, and spatial diversity using an analytic hierarchy process. This resulted in three initial tiers of 10 candidate locations identified for further scrutiny.

Following the January meeting, SIT members then participated in the analytic hierarchy process by individually scoring each scenario for each of the 10 locations based on the scenario's ability to increase or enhance the four sit attributes listed above. These scores then were averaged across SIT members and weighted using two methods. The first method was to use the SIT weights for the

attributes created during the January meeting (Table 9) to facilitate comparisons across scenarios and locations. The second method was to average the scores across attributes for each scenario and location. This average score would allow for the identification of the best scenario within a location. These scores were combined in a table with estimates of change from current conditions for two valley-wide metrics, naturally produced adults and natural juvenile per spawner and provided to SIT one week prior to the February SIT meeting.

Twelve SIT members completed scoring of the candidate scenarios with 9 scoring all combinations. Summaries of the top 10 scenarios based on SIT weighted scores and the top action in all candidate locations revealed similar patterns. Improving juvenile habitat (perennially and seasonally inundated) in the mainstem Sacramento below Bend Bridge were in the top ten and also ranked in the top 5 based on naturally produced adults and natural juvenile per spawner from the DSM results (Table 10). Increasing spawning and floodplain habitat in the Yuba River also were in the top 10 based on weighed score and the ranked DSM results, with increasing spawning habitat as higher ranked based on both the DSM ranks and weighted scores. Increasing floodplain habitat in the Stanislaus River also was in the top 10 based on SIT weighted scores and the DSM results. For remaining top 10 based on the weighted scores, the ranks of the DSM estimates were relatively poor (high) and suggested that there no clearly superior scenario remaining in that list. However, the list of the top scenarios for each of the candidate locations (Table 10, bottom) indicated that increasing floodplain habitat in the America River was ranked in the top 10 for naturally produced adults and natural juvenile per spawner based on the DSM estimates. The American River also was within the top tiers of the candidate locations. Therefore, these four scenarios were adopted by consensus of the SIT.

The SIT then discussed, at length, the DSM estimates and the fact that reducing contact points was among the top scenarios based on some of the SIT attributes. In general, SIT members agreed that the effect of predation and manmade contact points is very uncertain, as is the potential effectiveness of actions to reduce the influence of manmade contact points. During the discussion, it was clear that SIT members had beliefs that ranged from the belief that predation was the key factor and could be reduced, to the belief that predation may be a factor but there is little that can be done about it Valley and Delta-wide. There was general agreement that it would be beneficial **if** predation could be reduced, but little agreement on whether it could be done effectively and efficiently. This uncertainty and substantial scientific disagreement can be resolved through an adaptive management process that includes: 1) a well thought out design including explicit quantifiable hypotheses; 2) implementing management actions under conditions that can be transferable to other areas on the Central Valley (i.e., no special cases); and 3) monitoring design (SIT identified Before After Control Impact design) that can clearly demonstrate whether the actions were successful or not. SIT was emphatic that this was **not** to be an experiment but should be the implementation of actual management actions intended to reduce the effect of contact points on juvenile survival. Note that the SIT specifically desired the identification and treatment of contact points, not a manipulation of predator abundance or distribution. Therefore, this adaptive management scenario was adopted by consensus.

Winter run

SIT was provided with the priority rankings and supplementary material by the winter Chinook PWT (Appendix D & E). SIT discussed the rankings at length and were concerned that many of the priority stressors in the rankings were too vague to interpret as specific recommendations per the Core Team request following FY17. They also consulted the supplementary materials provided by the PWT, which included greater specificity that could be readily interpreted into specific priorities. Both the supplementary material and rankings referred to the great importance of increasing egg-to-fry survival in the upper Sacramento River and the need to improve conditions. The SIT discussed these factors and, in particular, the need to ensure that there was sufficient high quality spawning habitat in areas that could support successful winter Chinook reproduction. Based on these discussions and the SIT judgement, there was consensus that spawning habitat should be improved in the Sacramento above the temperature control points to increase egg-to-fry survival (the #1PWT priority). SIT also discussed two interpretable stressors that were in the top two rankings on the PWT list-- reducing predation. They agreed that the fall run priority for adaptively managing predator contact points would also likely benefit winter run Chinook provided any learning could be targeted at key winter run contact points. Another interpretable stressor identified in the top two PWT rankings included rearing habitat limitations. Discussions among the SIT personnel from the upper Sacramento basin and those familiar with juvenile winter run Chinook rearing focused on the need for rearing habitat below Red Bluff because these areas were believed to rear a significant number of juvenile winter Chinook Salmon. In addition, recent evidence collected by NMFS suggested that a significant proportion of juvenile Chinook salmon that return as adults, rear in tributaries of the Sacramento River. Based on these discussions, there was consensus that creating juvenile habitat in the mainstem below Red Bluff and creating or increasing juvenile rearing habitat (seasonally or perennially inundated) in Sacramento tributaries were winter run priorities.

Spring run

SIT was provided with a list of ranked projects by a group of biologists representing NMFS and CDFW, but did not include members from other CVPIA collaborating agencies (Appendix F). The list consisted of a number of specific projects that the SIT members familiar with the systems did not agree with and those with which they agreed based on their best scientific judgment. Of those in the agency group list, SIT concurred by consensus that improving fish passage and improving and increasing juvenile habitat (perennially and seasonally inundated) in Mill and Deer Creeks were high priorities. Discussion then focused on improving juvenile habitat on the Yuba River, which was one of the priorities in the agency list. SIT believed that establishing a strong spring run on the Yuba River was important for increasing spatial diversity, an important SIT Chinook Salmon attribute. However, SIT members were generally concerned that inbreeding between fall and spring run Chinook in the Yuba River could worsen if habitat improvements were made such a place or manner that it facilitated interaction of adult spring and fall run. Therefore, the SIT recommended by consensus that improvement of juvenile rearing habitat in the Yuba River be a high priority, but that consideration should be given for improving segregation of the adults runs to minimize inbreeding.

Sturgeon

Eight sturgeon PWT and SIT volunteers participated on a WebEx call on February 7, 2017 to score sturgeon scenarios using a contingency table and simple scoring criteria described earlier. The results of the scoring were sent to the participants who were asked to revise any of the scores with which they disagreed. Two participants returned revised contingency tables prior to the SIT meeting. These were summarized and provided to the SIT. An additional revised sheet was received after the SIT meeting. The values (in the additional revised sheet) were in general agreement with the original assessment (WebEx exercise) and the two revised sheets submitted by the volunteers. In the interest of transparency, values in this score sheet are included in Tables 11 and 12. In general, the SIT was disappointed with the lack of participation in the revision among sturgeon volunteers (relative to the Steelhead group, see below) and they were unable to interpret this as a lack of interest or a reflection of the uncertainty expressed by participants in the conference calls. Four SIT members participated in the two conference calls with sturgeon PWT (one was a member of the PWT) and their input during the discussions was essential to help the SIT understand the issues regarding sturgeon conservation in the Central Valley.

Green Sturgeon

During the conference calls, the sturgeon PWT and SIT volunteers expressed a large degree of uncertainty regarding the factors affecting Green Sturgeon populations. One exception to this uncertainty was reducing illegal harvest of Green Sturgeon. There was general agreement among the PWT and SIT volunteers that it would improve four of the population attributes (Table 11). Therefore, reducing illegal harvest of Green Sturgeon was identified as a SIT priority by consensus. There also was general agreement that pulsed flows in spring and early summer in the Yuba and Feather Rivers would promote reproduction, but specific flow values were unknown. In addition, there was uncertainty as to whether those pulsed flows would lead to increased recruitment, which was believed to be essential for recovery of the species. In fact, much of the sturgeon discussions eventually led to the questions regarding the effects of the scenarios on recruitment. The large degree of uncertainty expressed by the sturgeon PWT volunteers and SIT members regarding the factors affecting green sturgeon recruitment and importantly, what management actions could be implemented to improve recruitment led the SIT to recommend as a priority the development and implementation of an adaptive management strategy for increasing juvenile Green Sturgeon recruitment. The strategy should include the development of a conceptual model of Green Sturgeon dynamics, detailed descriptions of the locations and management actions, explicit predictions of the expected changes in recruitment due to management actions, implementation of actions, and the BACI monitoring design that will provide evidence of the changes following implementation.

White Sturgeon

Discussions of the conservation needs and uncertainty regarding White Sturgeon populations were similar to the Green Sturgeon. There was general agreement that reducing harvest, particularly illegal harvest, was most likely to benefit White sturgeon populations (Table 12). Hence, the SIT recommended reducing illegal harvest of White Sturgeon by consensus. The success of the remaining potential White Sturgeon management scenarios was considered uncertain by SIT. As with Green

Sturgeon, the SIT recommends by consensus the development of a White Sturgeon adaptive management project as a priority. The SIT believed that White Sturgeon populations could be improved and uncertainty reduced in an adaptive management framework. However, SIT emphasized that the focus of the adaptive management should be on improving juvenile White Sturgeon recruitment and that uncertainty reduction should focus on improving sturgeon management. The framework should include the development of a conceptual model of White Sturgeon dynamics, detailed descriptions of the locations and management actions, explicit predictions of the expected changes in recruitment due to management actions, implementation of actions, and the BACI monitoring design that will provide evidence of the changes following implementation.

Steelhead

Seven PWT and SIT volunteers filled out the contingency scoring sheets and submitted them for the SIT evaluation. Discussions among the Steelhead PWT and SIT volunteers during conference calls emphasized the lack of information and high degree of uncertainty about how to enhance or encourage anadromous life history in *O. mykiss*. The respondents scores reflect this high degree of uncertainty. For instance, three of the scenarios for encouraging anatomy: manipulating water temperatures, outplanting above rim dams, and Feb–April pulse flows contained a relatively even mix of negative, positive and large number of unknown scores (Table 13). One slight exception was the removal of barriers (improve passage) on Battle Creek, which tended to have a large number of positives, no negatives, and was believed by SIT members familiar with the systems to be high priority. Thus, removal of barriers (improve passage) on Battle Creek was identified as a priority by a consensus of the SIT. The SIT discussed the substantial uncertainty surrounding Steelhead recovery in the valley and the importance of understanding the factors that affect the expression of the anadromous *O. mykiss* life history and the management actions that can be taken to increase the frequency of anadromy. Therefore, the SIT believed that this uncertainty can be resolved through an adaptive management as described above. The SIT requested that process include: 1) a well thought out design including explicit quantifiable hypotheses; 2) implementing management actions under conditions that can be transferable to other areas of the Central Valley; and 3) monitoring design (SIT identified BACI design) that can clearly demonstrate whether the actions were successful or not. SIT was clear that this was *not* to be an experiment but should be the implementation of actual management actions intended to increase the frequency of anadromy. Therefore, this adaptive management scenario was adopted by consensus.

FY18 recommendations to the Core Team

The final FY18 recommendations to the Core team are detailed in Table 14. SIT also attempted across taxa integration using a contingency table and simple scoring criteria as described earlier.

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Table 1. Chinook Salmon objectives and measureable attributes.

Category	Fundamental objective attribute^d
Valley Wide	
Spatial structure	Total no. of viable spawning populations per diversity group (NMFS def. of independent population)
Abundance ^a	Total no. of spawning natural origin adults (across watersheds)
	Naturally-spawned juvenile abundance at Chipps
	Naturally produced fish in the ocean
Natural productivity ^b	Total number of natural origin spawning adults per natural origin escapement
	Nat. returning adult/natural spawner (cohort replacement)
	No. natural juveniles at Chipps /Natural origin spawning adults
Life history diversity	Timing of outmigration by juvenile stage (duration detected per size group and distribution shape) (at Chipps)
	Variation (CV) of timing of peak outmigration among screwtraps
	Outmigrating proportion juvenile stages (4 size classes) size/developmental stage at Chipps
Genetic Diversity ^c	Prop of hatchery fish that are strays
Watershed-specific	
Abundance	No. of returning natural origin adults
	Naturally-spawned juvenile abundance
Natural Productivity	Nat. origin returning adult/natural origin spawner previous cohort
	Total number of natural origin spawning adults per natural origin escapement
	Total number of natural origin spawning adults per natural origin escapement
Life history diversity	Timing of outmigration by juvenile size (number of weeks detected per size group and distribution shape) per watershed
	Outmigrating proportion juvenile sizes (small, medium, large, very large) size/developmental stage at location
Genetic diversity	Prop of natural spawners vs hatchery

a- When rebuilding winter and spring run, follow introgression phase for counting natural.

b- When rebuilding same as above for natural def.

c- When reintroduction or rebuilding winter and spring run, SIT define natural based of introgression criteria (NMFS) treat like fall run.

d- Currently winter run includes Upper Sacramento populations only, future incorporate other watersheds

Table 2. White and Green Sturgeon measureable attributes.

<u>Naturally reproducing self-sustaining populations</u>	<u>Green Sturgeon</u>	<u>White Sturgeon</u>
Population growth, Lambda > 1 over multiple generations	X	X
Recruitment, Abundance ages 0-1-2	X	X
Growing of pop of oversized fish (152 cm) fork length		X
Annual spawner abundance	X	
Multiple cohorts in the population	X	X
Presence of repeat spawners	X	X
Increasing maximum length of adults	X	X
Number of rivers where spawning occurs	X	X
Increasing catch of mature FL	X	X
Number of spawning aggregations	X	X

Table 3. Steelhead measureable attributes

<u>Attribute</u>
Increase freq. anadromous life history
Increase number spawning anadromous <i>O. mykiss</i>
Increase in fitness/ genetic diversity <i>O. mykiss</i>
Natural productivity anadromous <i>O. mykiss</i>
Spatial diversity spawning anadromous <i>O. mykiss</i>
Increase population growth rate (λ) <i>O. mykiss</i>
Increase recruitment age 0, 1, 2 <i>O. mykiss</i>

Table 4. Fall Chinook Salmon FY18 scenarios

<u>Scenario</u>	<u>Changes*</u>
Reduce diversion in April and May (one month at a time) San Joaquin watersheds (individually) % of tributary Q	0.05
	0.10
	0.35
Eliminate predator contact points each watershed (individually)	0.05
	0.1
	0.5
Increase seasonally inundated juvenile habitat each watershed individually (2 yr. freq.) % ESHE value	0.25
	0.5
	0.75
Increase seasonally inundated juvenile habitat each watershed individually (1 yr. freq.) % ESHE value	0.25
	0.5
	0.75
Increase perennially inundated juvenile habitat each watershed individually % ESHE value	0.25
	0.5
	0.75
Increase spawning habitat each watershed individually % pseudo ESHE value	0.25
	0.5
	0.75
Reduce the % hatchery origin spawners	0.05
	0.15
	0.3
Pulse flows: Shasta only to 17500 cfs, 1 week (during month) prompt juvenile fall chinook migration	Jan
	Feb
	March
	April
Change multiple factors in single watershed vs. multiple factors single watershed 1) decrease diversion 50%; eliminate contact points 50%; increase FP habitat 50% ESHE; increase spawning habitat 50% ESHE	Upper Sacramento
	Stanislaus
	Mokelumne
	Feather
	American

* % refer to percent increases relative to current values unless otherwise demoted as ESHE

Table 5. Sturgeon FY18 scenarios.

<u>Green Sturgeon</u>	<u>White Sturgeon</u>
High in-channel flows every year in Sacramento River during April–mid June 17500 cfs Bend	High in channel flows every year in Sacramento River during March–May
Attraction flow pulses in Yuba River, Feb–April (>5000 cfs)	High in channel flows every year in San Joaquin River during March–May (>3000cfs at Patterson)
Spawning flow pulses in Yuba River, March–July (cfs TBD) ¹	Increase flow in Bear River (March–Apr) to approx. 3000 cfs at Wheatland
Attraction flow pulses in Feather River, Feb–April (>5000 cfs)	Improve spawning habitat (substrate) in Sacramento and San Joaquin Rivers
Spawning flow pulses in Feather River, March–June (cfs TBD) ¹	Attraction flow pulses in Feather River, Feb–April (> 5000 cfs)
Reduce stranding in flood bypasses	Reduce stranding in flood bypasses
Increase temperatures to levels that are near optimal for growth and survival of multiple species (including Green Sturgeon) (approx. 15–19 C)	Increase age 0+ carrying capacity during the summer by restoring habitats in areas with lower salinity water with better DO and temps
Reduce illegal harvest (poaching) of adults	Increase summer (June–Sept) outflows to increase age 0+ carrying capacity during the summer (by increasing areas with lower salinity water with better DO and temps)
Improve passage on the Yuba River	Reduce legal harvest of adults
Improve passage on the Feather River	Reduce illegal harvest (poaching) of adults

1 To be determined, potentially through adaptive management.

Table 6. Steelhead FY18 scenarios

<u>Scenarios</u>
Increase summer water temperatures to encourage anadromy
Increase winter flows
Increase outmigrant survival
Increase summer rearing habitat tributaries
Reducing/excluding hatchery spawners
Improve spawning habitat
Outplanting adults above rim dams (Yuba, Upper SJ)
Remove barriers (Battle Creek)
Winter / spring pulse flows Feb–April
Avoid redd dewatering (maintain flows over redds during incubation)

Table 7. Changes in four aberrant juvenile survival estimates with original values at the top and calibrated values at the bottom, also expressed as odds ratios for interpretation.

<u>Parameter estimate</u>	<u>Scaled odds ratio</u>	<u>Interpretation</u>
<u>Effect of contact points on juvenile survival</u>		
-0.9478	2.5800	times less likely to survive with each contact point, original
-0.0068	1.0068	times less likely to survive with each contact point, calibrated
<u>Effect of proportion water diverted on juvenile tributary survival</u>		
-3.5100	1.4205	times less likely to survive with each 0.1 increase in proportion diverted, original
-0.1755	1.0177	times less likely to survive with each 0.1 increase in proportion diverted, calibrated
<u>Effect of total amount of water diverted on juvenile tributary survival</u>		
-0.0021	1.0002	times less likely to survive with each 1 cms increase in total diverted, original
-0.0005	1.0001	times less likely to survive with each 1 cms increase in total diverted, calibrated
<u>Effect of total amount of water diverted on juvenile delta survival</u>		
-0.0021	1.0002	times less likely to survive with each 1 cms increase in total diverted, original
-0.0011	1.0001	times less likely to survive with each 1 cms increase in total diverted, calibrated

Table 8. Key uncertainties in the fall Chinook Salmon SDM based on tributary and valley-wide estimates of number of naturally produced adults and number of naturally produced juveniles per spawner.

<u>Model component</u>	<u>Tributary</u>	<u>Valley wide</u>
Juvenile delta outmigrant survival: Delta flow model weight	X	X
Juvenile delta rearing survival: Intercept	X	X
Juvenile growth: In-channel habitats	X	X
Juvenile ocean entry survival: Intercept	X	X
Juvenile Sacramento outmigrant survival: Intercept	X	X
Reproduction: Sex ratio	X	X
Reproduction: Fecundity	X	
Reproduction: Redd size		X

Table 9. Results if initial analytic hierarchy process used to weight locations based on their importance to four valley-wide SIT attributes. Three initial tiers were developed based on ranking of the importance of attributes to attaining the fundamental objective for fall Chinook Salmon.

<u>Location</u>	<u>SIT attribute</u>				<u>Weighted Score</u>	<u>Initial SIT Tier</u>
	<u>Genetic integrity/adaptation</u>	<u>Life history diversity</u>	<u>Natural production</u>	<u>Spatial diversity</u>		
Sacramento mainstem (below Bend bridge)	0.02	0.27	0.22	0.08	37.2	1
San Joaquin River	0.02	0.23	0.09	0.26	29.9	1
Yuba River	0.26	0.16	0.15	0.07	27.1	1
American River	0.07	0.06	0.09	0.02	13.0	2
Upper Sacramento River	0.07	0.02	0.15	0.03	12.7	2
Stanislaus River	0.12	0.07	0.07	0.18	11.5	2
Mokelumne River	0.07	0.06	0.07	0.04	11.2	2
Tuolumne River	0.28	0.07	0.05	0.18	9.9	2
Feather River	0.03	0.03	0.08	0.02	8.9	3
Merced River	0.05	0.04	0.03	0.12	6.0	3

<u>SIT attribute</u>	<u>Rank</u>	<u>Scaled value</u>
Life history diversity	1	100
Natural productivity	2	100
Maintain local genetic adaption	3	40
Spatial diversity	4	1

Table 10. Top 10 scenario and location based on the SIT scores weighted by the SIT attribute (top) and the top scenario in each of the candidate locations identified by the SIT (bottom). Ranks (1=best) of estimated change in natural produced adults and natural number juveniles/spawner.

<u>Top 10 based on SIT weighted scores</u>					
<u>Location</u>	<u>Scenario</u>	<u>SIT weighted score</u>	<u>Natural adult</u>	<u>Nat juvenile/spawner</u>	
Tuolumne River	Increase floodplain habitat	43	17	15	
Yuba River	Increase spawning habitat	42	3	1	
Sacramento mainstem	Increase floodplain habitat	41	2	2	
Sacramento mainstem	Increase in channel habitat	40	1	3	
Yuba River	Increase floodplain habitat	40	7	48	
Stanislaus River	Increase floodplain habitat	34	13	10	
Tuolumne River	Increase in channel habitat	34	32.5	31.5	
Yuba River	Increase in channel habitat	32	48	53	
San Joaquin River	Increase floodplain habitat	30	20	17	
Tuolumne River	Reduce hatchery origin spawners	30	41	37	
<u>Top scenario for each location based on average rank</u>					
<u>Location</u>	<u>Scenario</u>	<u>Ave. score</u>	<u>Natural adult</u>	<u>Nat juvenile/spawner</u>	<u>Initial SIT Tier</u>
Sacramento mainstem	Increase in channel habitat	74	1	3	1
San Joaquin River	Increase in channel habitat	49	32.5	31.5	1
Yuba River	Increase spawning habitat	65	3	1	1
American River	Increase floodplain habitat	67	8	6	2
Upper Sacramento River	Increase in channel habitat	65	11	49	2
Stanislaus River	Increase floodplain habitat	78	13	10	2
Mokelumne River	Increase floodplain habitat	73	19	14	2
Tuolumne River	Increase floodplain habitat	76	17	15	2
Feather River	Increase in channel habitat	57	39	11	3
Merced River	Increase floodplain habitat	77	15	13	3

Table 11. Scoring summary for White Sturgeon scenarios with numbers of negative (-), positive (+), neutral (0), and unknown (?) responses by PWT and SIT volunteers.

Attribute	High in channel flows every year in Sacramento River during April–mid June 17500 cfs Bend	Attraction flow pulses in Yuba River, Feb–April (>5000 cfs)	Spawning flow pulses in Yuba River, March–July (cfs TBD) ²	Attraction flow pulses in Feather River, Feb–April (>5000 cfs)	Spawning flow pulses in Feather River, March–June (cfs TBD) ²	Reduce stranding in flood bypasses	Best location/population
	Overall effect	Overall effect	Overall effect	Overall effect	Overall effect	Overall effect	
	?,+,0	?,+,0	?,+,0	?,+,0	?,+,0	?,+,0	
Annual spawner abundance	1,3,0	0,3,1	2,2,0	0,3,1	0,4,0	0,4,0	
Catch of mature fish (based on FL)	2,2,0	4,0,0	4,0,0	4,0,0	4,0,0	3,1,0	Fremont Weir, Sacramento River up to Battle Creek
Maximum length of adults	0,0,4	0,0,4	0,0,4	0,0,4	0,0,4	0,0,4	
Multiple cohorts in the population	2,2,0	4,0,0	3,1,0	3,1,0	2,2,0	4,0,0	
Number of rivers where spawning occurs	3,0,1	0,4,0	0,4,0	0,4,0	0,4,0	0,0,4	
Number of spawning aggregations	1,1,2	1,3,0	0,4,0	1,3,0	0,4,0	2,1,1	
Population growth >1 over multiple generations	0,4,0	4,0,0	3,1,0	1,3,0	0,4,0	0,4,0	
Presence of repeat spawners	0,2,2	1,3,0	0,4,0	1,3,0	0,4,0	1,3,0	
Recruitment, abundance ages 0-1-2	0,4,0	3,0,1	4,0,0	2,1,1	1,3,0	1,3,0	
Summary of scores across each scenario	? + 0 9 18 9	? + 0 17 13 6	? + 0 16 16 4	? + 0 12 18 6	? + 0 7 25 4	? + 0 11 16 9	

Table 11 (cont.)

Attribute	Increase temperatures to levels that are near optimal for growth and survival of multiple species (including Green Sturgeon) (approx. 15-19 °C)		Reduce illegal harvest (poaching) of adults		Improve passage on the Yuba River	Improve passage on the Feather River
	Overall effect	Best location/ population	Overall effect	Best location/ population	Overall effect	Overall effect
	?,+,0		?,+,0		?,+,0	?,+,0
Annual spawner abundance	2,1,1		0,4,0		0,3,1	0,3,1
Catch of mature fish (based on FL)	4,0,0		0,4,0		0,1,3	0,1,3
Maximum length of adults	3,0,1		1,2,1	Feather River, All tributaries	0,0,4	0,0,4
Multiple cohorts in the population	3,1,0	All tributaries	3,0,1		4,0,0	3,1,0
Number of rivers where spawning occurs	0,4,0		2,1,1		0,4,0	0,4,0
Number of spawning aggregations	0,4,0		1,3,0		0,4,0	0,4,0
Population growth >1 over multiple generations	3,1,0		0,4,0		4,0,0	1,3,0
Presence of repeat spawners	2,0,2		0,4,0		1,3,0	1,3,0
Recruitment, abundance ages 0-1-2	2,2,0		4,0,0		4,0,0	3,1,0
Summary of scores across each scenario	? + 0 19 13 4		? + 0 11 22 3		? + 0 13 15 8	? + 0 8 20 8

Table 12. Scoring summary for White Sturgeon scenarios with numbers of negative (-), positive (+), neutral (0), and unknown (?) responses by PWT and SIT volunteers.

Attribute	High in channel flows every year in Sacramento River during March-May	High in channel flows every year in San Joaquin River during March–May (>3000cfs at Patterson)	Increase flow in Bear River (March–Apr) to approx. 3000 cfs at Wheatland	Improve spawning habitat (substrate) in Sacramento and San Joaquin Rivers	Attraction flow pulses in Feather River, Feb–April (> 5000 cfs)	Reduce stranding in flood bypasses	Best location/population
	Overall effect ¹	Overall effect	Overall effect	Overall effect	Overall effect	Overall effect	Best location/population
Catch of mature fish (based on FL)	-,?,+,0	?,+,0	?,+,0	?,+,0	+,0,?	?,+,0	
Maximum length of adults	0,1,2,0	1,3,0	2,2,0	0,1,3	1,1,2	2,2,0	
Multiple cohorts in the population	0,0,0,3	0,0,4	1,0,3	0,0,4	0,2,2	1,0,3	Fremont weir,
Number of oversized fish (152 cm FL)	0,1,2,0	0,4,0	2,2,0	3,1,0	2,1,1	2,1,1	Sacramento River up to Colusa,
Number of rivers where spawning occurs	0,1,0,2	0,0,4	1,0,3	0,0,4	0,3,1	1,2,1	Tisdale weir
Number of spawning aggregations	1,1,0,1	0,4,0	1,3,0	1,3,0	3,0,1	1,1,2	
Population growth >1 over multiple generations	1,1,0,1	3,1,0	1,3,0	0,4,0	2,0,2	2,1,1	
Presence of repeat spawners	0,0,3,0	0,4,0	2,2,0	3,1,0	2,0,2	0,4,0	
Recruitment, abundance ages 0-1-2	0,1,2,0	2,2,0	1,3,0	3,1,0	2,0,2	1,3,0	
Recruitment, abundance ages 0-1-2	0,0,3,0	0,4,0	2,2,0	1,3,0	2,0,2	1,2,1	
Summary of scores across each scenario	- ? + 0	? + 0	? + 0	? + 0	+ 0 ?	? + 0	
	2 6 12 7	6 22 8	13 17 6	11 14 11	14 7 15	11 16 9	

Table 12 (cont.)

Attribute	Increase age 0+ carrying capacity during the summer by restoring habitats in areas with lower salinity water with better DO and temps		Increase summer (June–Sept) outflows to increase age 0+ carrying capacity during the summer (by increasing areas with lower salinity water with better DO and temps)		Reduce legal harvest of adults		Reduce illegal harvest (poaching) of adults	
	Overall effect	Best location/population	Overall effect	Best location/population	Overall effect	Best location/population	Overall effect	Best location/population
	+,0,?		+,0,?		?,+,0		?,+,0	
Catch of mature fish (based on FL)	1,1,1		1,1,1		0,4,0		0,4,0	
Maximum length of adults	0,2,1		0,2,1		3,1,0		1,2,1	
Multiple cohorts in the population	2,0,1		1,0,2		2,2,0		2,2,0	
Number of oversized fish (152 cm FL)	1,1,1		1,1,1		1,3,0	All tributaries	1,3,0	Bear River, All tributaries
Number of rivers where spawning occurs	0,2,1	Delta	0,2,1		2,1,1		3,1,0	
Number of spawning aggregations	1,1,1		1,1,1		2,2,0		2,1,1	
Population growth >1 over multiple generations	1,0,2		1,0,2		0,4,0		0,4,0	
Presence of repeat spawners	1,1,1		1,1,1		1,3,0		0,4,0	
Recruitment, abundance ages 0-1-2	2,0,1		1,0,2		3,1,0		3,1,0	
Summary of scores across each scenario	+ 0 ?		+ 0 ?		? + 0		? + 0	
	9 8 10		7 8 12		14 21 1		12 22 2	

Table 13. Scoring summary for Steelhead scenarios with numbers of negative (-), positive (+), neutral (0), and unknown (?) responses by PWT and SIT volunteers.

Attributes	Manipulate water temperatures to encourage anadromy	Improve winter flows	Increase outmigrant survival	Increase summer rearing habitat tributaries	Reducing/excluding hatchery spawners	Improve spawning habitat	Outplanting adults above rim dams (Yuba, Upper SJ)	Remove barriers (Battle Creek)	Winter or spring pulse flows Feb-April	Avoid redd dewatering (maintain flows over redds during incubation)
	-,?,+,0	?,+,0	?,+,0	-,?,+,0	-,?,+,0	?,+,0	?,+,0,-	+,0,?	+,0,?	+,?,0
Increase freq. anadromous life history	0,1,4,0	1,3,1	2,2,1	1,3,1,0	1,2,0,2	3,0,2	4,0,1,1	2,1,3	6,0,0	1,2,3
Increase in fitness/genetic diversity <i>O. mykiss</i>	0,4,1,0	1,2,2	0,3,2	0,1,2,2	0,0,5,0	2,0,3	2,4,0,0	1,3,2	2,2,2	4,2,0
Increase number spawning anadromous <i>O. mykiss</i>	0,2,2,1	1,4,0	1,4,0	0,3,1,1	2,2,0,1	1,4,0	3,2,1,0	2,0,4	3,1,2	4,1,1
Increase population growth rate (l) <i>O. mykiss</i>	0,2,2,1	2,1,2	2,3,0	0,2,3,0	2,3,0,0	1,4,0	3,2,1,0	4,0,2	4,0,2	5,1,0
Increase recruitment age 0,1, 2 <i>O. mykiss</i>	1,2,1,1	3,1,1	3,2,0	0,2,3,0	0,2,1,2	1,3,1	2,2,2,0	3,1,2	4,0,2	5,0,1
Natural productivity anadromous <i>O. mykiss</i>	0,2,2,1	0,4,1	0,4,1	0,2,2,1	1,1,3,0	1,4,0	3,2,1,0	6,0,0	5,1,0	6,0,0
Spatial diversity spawning anadromous <i>O. mykiss</i>	0,3,0,2	1,2,2	1,2,2	0,1,2,2	0,2,1,2	0,5,0	0,6,0,0	6,0,0	3,3,0	1,2,3
Summary of scores across each scenario	- ? + 0	? + 0	? + 0	- ? + 0	- ? + 0	? + 0	? + 0 -	+ 0 ?	+ 0 ?	+ ? 0
	1 16 12 6	9 17 9	9 20 6	1 14 14 6	6 12 10 7	9 20 6	17 18 6 1	24 5 13	27 7 8	26 8 8

Table 14. SIT FY18 Priorities by taxon and simple scoring across taxa based on SIT multi-taxa attributes.

Taxon	Scenario	Description	Progress toward numeric goal	Multi-taxa benefits > 2	Benefit TE species	Contributes to model/information gaps
Fall Chinook	Sacramento Mainstem below Bend Bridge, Improve/increase juvenile Chinook rearing habitat	SIT believes that increasing juvenile Chinook Salmon habitat in the Sacramento River below Bend Bridge, both perennially inundated and seasonally inundated habitats, are priority based on interpretation of modeling results.	+	+	+	0
Fall Chinook	Yuba River, Improve/increase spawning and juvenile rearing habitat	SIT believes that improving spawning and juvenile Chinook Salmon habitat in the Yuba River are priority based on interpretation of modeling results.	+	+	+	+
Fall Chinook	Stanislaus River, Improve/increase juvenile rearing habitat (floodplain)	SIT believes that increasing juvenile Chinook Salmon habitat in the Stanislaus River, with an emphasis on seasonally inundated (floodplain) habitats, are priority based on interpretation of modeling results.	+	0	+	0
Fall Chinook	Adaptively manage reduction/improvement predator contact points	Based on discussions of published studies and modeling results, SIT believes that elimination or improvement of predator contact points could benefit to juvenile Chinook Salmon survival; however much uncertainty remains. SIT members think that identifying and implementing effective management strategies for increasing survival of juveniles is essential for achieving the doubling goal. Toward that end, SIT believes that the development and implementation of a management strategy for eliminating or improving predator contact points (to increase juvenile survival) should be a priority. The SIT emphasizes that this should be conducted in an adaptive management framework that should include detailed descriptions of the locations and management actions, explicit predictions of the expected changes in juvenile survival due to management actions, implementation of the management action(s), and the BACI monitoring design that will provide evidence of the changes in survival following implementation.	0	+	+	+

Table 14 (cont.)

<u>Taxon</u>	<u>Scenario</u>	<u>Description</u>	Progress toward numeric goal	Multi-taxa benefits > 2	Benefit TE species	Contributes to model/information gaps
Fall Chinook	American River, Improve/increase juvenile rearing habitat (floodplain)	SIT believes that increasing juvenile Chinook Salmon habitat in the American River, with an emphasis on seasonally inundated (floodplain) habitats, are priority based on interpretation of modeling results.	+	+	+	0
Winter Chinook	Upper Sacramento River above temperature control points, increase spawning habitat	SIT believes that increasing winter Chinook Salmon spawning habitat in the Upper Sacramento River above the expected temperature control points (greater use closer to Keswick) are priority based on interpretation and discussion of priorities identified by the winter Chinook PWT.	+	+	+	0
Winter Chinook	Sacramento River below Red Bluff, increase juvenile rearing habitat	SIT believes that increasing juvenile Chinook Salmon habitat in the Sacramento River below Red Bluff, both perennially inundated and seasonally inundated habitats, are priority based on interpretation and discussion of priorities identified by the winter Chinook PWT.	+	+	+	+
Winter Chinook	Create/improve juvenile rearing habitat in non-natal tributaries	SIT believes that increasing juvenile Chinook Salmon habitat, both perennially inundated and seasonally inundated habitats, (accessible to winter run juveniles or can be made accessible) in tributaries of the Sacramento River (i.e., non-natal tributaries) are priority based on SIT interpretation and discussion of priorities identified by the winter Chinook PWT.	0	+	+	+
Spring Chinook	Mill Creek, improve fish passage	SIT believes that improving adult Chinook Salmon passage in Mill Creek are high priorities based on interpretation and discussion of priorities identified by program cooperators.	+	0	+	0
Spring Chinook	Deer Creek, improve fish passage	SIT believes that improving adult Chinook Salmon passage in Deer Creek are high priorities based on SIT interpretation and discussion of priorities identified by program cooperators.	+	0	+	0

Table 14 (cont.)

<u>Taxon</u>	<u>Scenario</u>	<u>Description</u>	Progress toward numeric goal	Multi-taxa benefits > 2	Benefit TE species	Contributes to model/information gaps
Spring Chinook	Mill Creek, improve/increase juvenile rearing habitat	SIT believes that improving juvenile rearing habitat in Mill Creek are high priorities based on SIT interpretation and discussion of priorities identified by program cooperators.	0	+	+	0
Spring Chinook	Deer Creek, improve/increase juvenile rearing habitat	SIT believes that improving juvenile rearing habitat in Deer Creek are high priorities based on SIT interpretation and discussion of priorities identified by program cooperators.	0	+	+	0
Spring Chinook	Yuba River, Increase juvenile rearing habitat	SIT concurs that increasing juvenile Chinook Salmon habitat in the Yuba River, both perennially inundated and seasonally inundated habitats, are a priority. This determination was based on SIT interpretation and discussion of priorities identified by program cooperators. In addition, SIT emphasizes that consideration should be given for improving the segregation of fall and spring run adults.	0	+	+	0
Steelhead	Adaptively manage tributary flows, habitat, and/or temperatures to increase the frequency of anadromy	Members of the SIT and Steelhead PWT had lengthy discussions of management actions could benefit the maintenance and increase of <i>O. mykiss</i> anadromous life history; however there is substantial uncertainty regarding effectiveness of potential management actions. SIT members believe that identifying and implementing effective management strategies for promoting anadromy are essential for achieving the doubling goal. Therefore, SIT believes that the development and implementation of a management strategy for increasing the frequency of anadromy in populations should be a priority. The SIT also emphasizes that this should be conducted in an adaptive management framework that should include the development of a conceptual model of <i>O. mykiss</i> dynamics, detailed descriptions of the locations and management actions, explicit predictions of the expected changes in the frequency of anadromy due to management actions, implementation of the actions, and a BACI monitoring design that will provide evidence of the changes following implementation.	0	0	+	+

Table 14 (cont.)

<u>Taxon</u>	<u>Scenario</u>	<u>Description</u>	Progress toward numeric goal	Multi-taxa benefits > 2	Benefit TE species	Contributes to model/information gaps
Steelhead	Remove barriers to passage on Battle Creek	SIT concurs that improving passage in Battle Creek is a high priority based on SIT interpretation and discussion of priorities identified by Steelhead PWT.	0	+	+	0
Green Sturgeon	Adaptively manage flows, habitats, and/or temperature to increase juvenile recruitment	In discussions among the SIT and with members of the Sturgeon PWT, there was general agreement that juvenile Green Sturgeon recruitment is essential for recovery of the species but there is substantial uncertainty regarding the effectiveness of potential management actions. SIT believes that the development and implementation of a management strategy for increasing juvenile Green Sturgeon (GS) recruitment should be a priority but should be conducted in an adaptive management framework. It should include the development of a conceptual model of GS dynamics, detailed descriptions of the locations and management actions, explicit predictions of the expected changes in recruitment due to management actions, implementation of actions, and the BACI monitoring design that will provide evidence of the changes following implementation.	0	0	+	+
Green Sturgeon	Reduce illegal harvest (poaching) of adults	SIT concurs that reducing poaching, perhaps through increased enforcement, is a priority based on SIT interpretation and discussion of priorities identified by Sturgeon PWT.	+	0	+	0
White Sturgeon	Adaptively manage flows, habitats, and/or temperature to increase juvenile recruitment	Discussions of White Sturgeon (WS) priorities among the SIT and with members of the Sturgeon PWT were similar to GS. The success of the potential WS management scenarios considered was uncertain. As with the GS, the SIT believes that WS populations could be improved and uncertainty reduced in an adaptive management framework. However, SIT emphasizes that focus of the adaptive management should be on improving juvenile recruitment and that uncertainty reduction should focus on improving management. It should include the development of a conceptual model of WS dynamics, detailed descriptions of the locations and management actions, explicit predictions of the expected changes in recruitment due to management actions, implementation of actions, and the BACI monitoring design that will provide evidence of the changes following implementation.	0	0	0	+
White Sturgeon	Reduce illegal harvest (poaching) of adults	SIT concurs that reducing poaching, perhaps through increased enforcement, is a priority based on SIT interpretation and discussion of priorities identified by Sturgeon PWT.	+	0	+	0

Movement and Rearing Watershed Groups

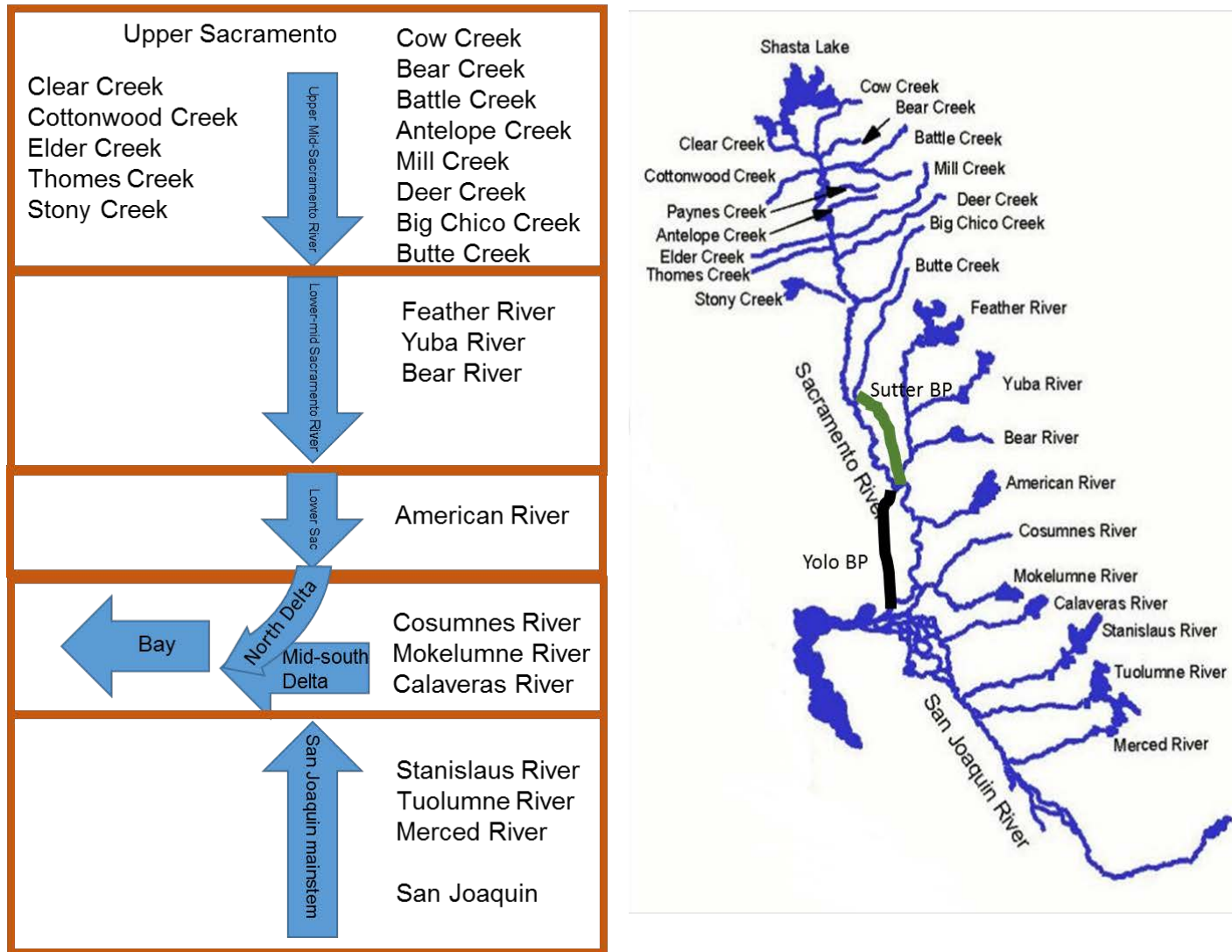


Figure 1. The relative location of the 26 CVPIA watersheds and routing of Chinook Salmon that were included in the coarse resolution evaluation and prioritization. The watershed groups (in boxes) are listed from top to bottom as: upper Sacramento, lower Sacramento, Delta, and San Joaquin.

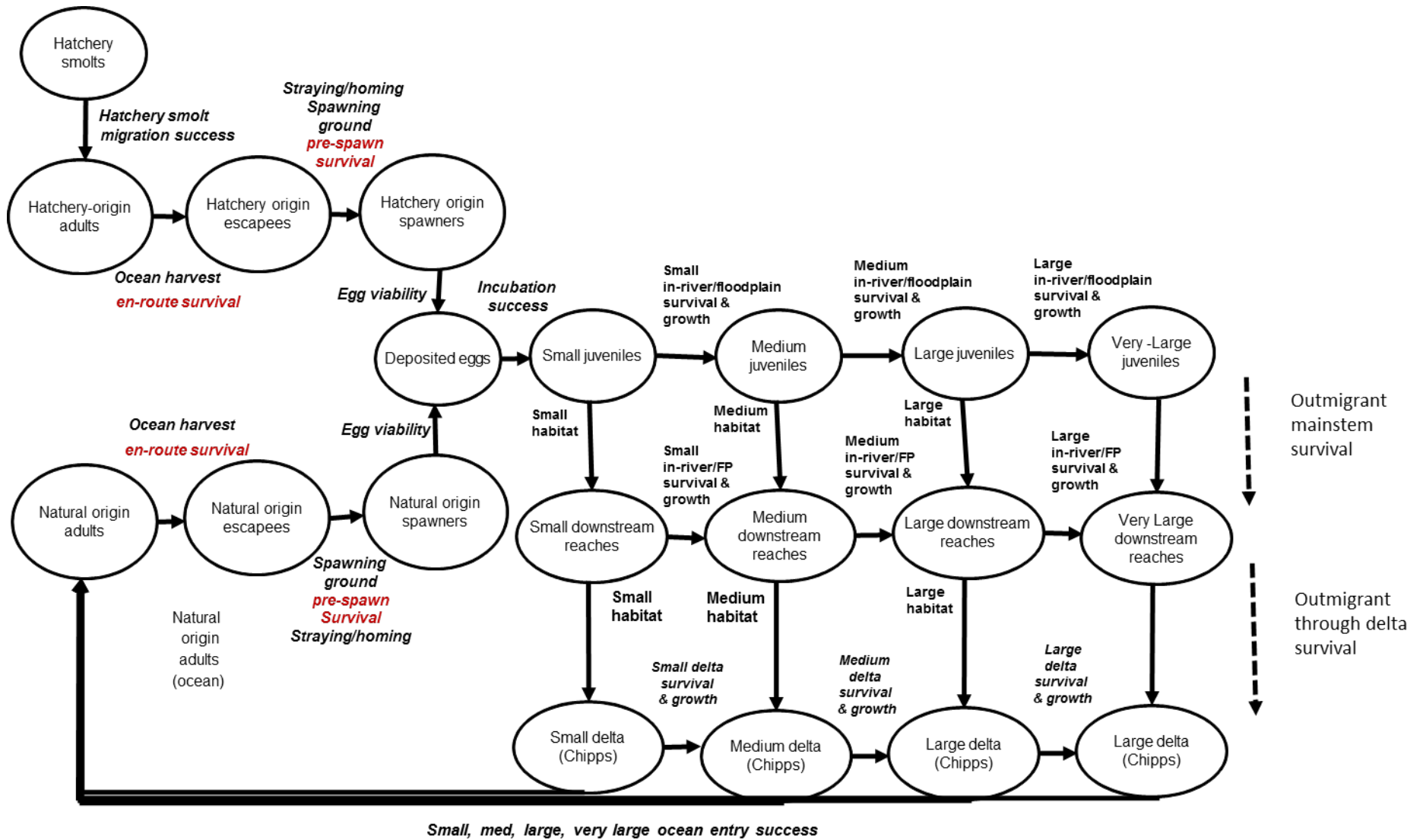


Figure 2. Graphical example of DSM v2 baseline Chinook Salmon population dynamics model used to identify fall Chinook Salmon priorities. Labeled arcs indicate model components that were used to model state transitions.

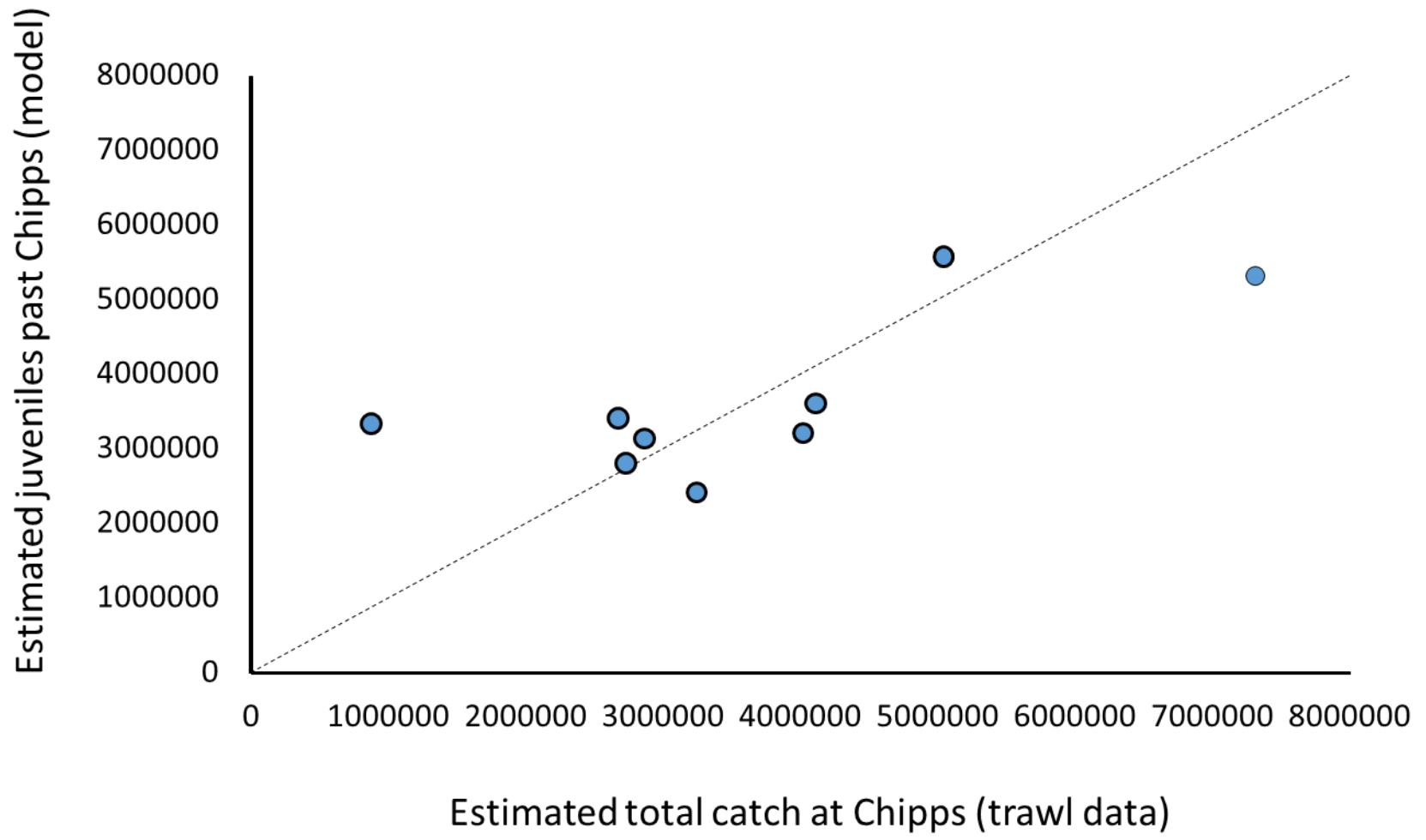


Figure 3. Plot of estimated juvenile abundance based on trawl data (2007–2015) and the calibrated fall Chinook DSM. Broken line represents one-to-one relationship.

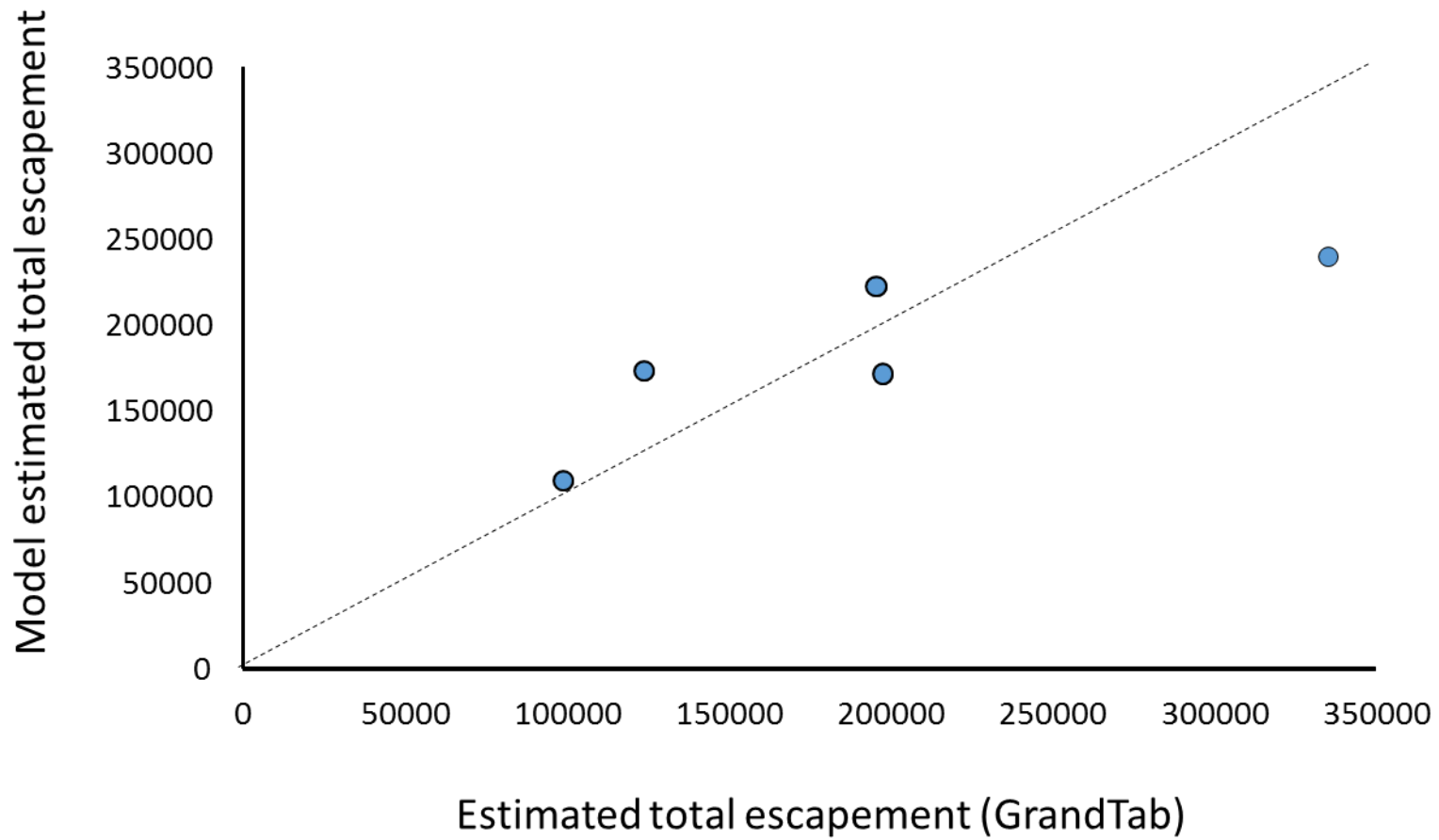


Figure 4. Plot of estimated total adult escapement from GrandTab (2011–2015) and the calibrated fall Chinook DSM. Broken line represents one-to-one relationship.



Figure 5. Tornado diagram from one-way sensitivity analyses of fall run Chinook Salmon SDM components for number of naturally produced adults under dry climate at year 20. All components, except alternative models, were evaluated using the composite model and varying each component +/- 50% of mean values.



Change in juvenile per spawner year 20

Figure 6. Tornado diagram from one-way sensitivity analyses of fall run Chinook Salmon SDM components for number of naturally produced juveniles per spawner under dry climate at year 20. All components, except alternative models, were evaluated using the composite model and varying each component +/- 50% of mean values.

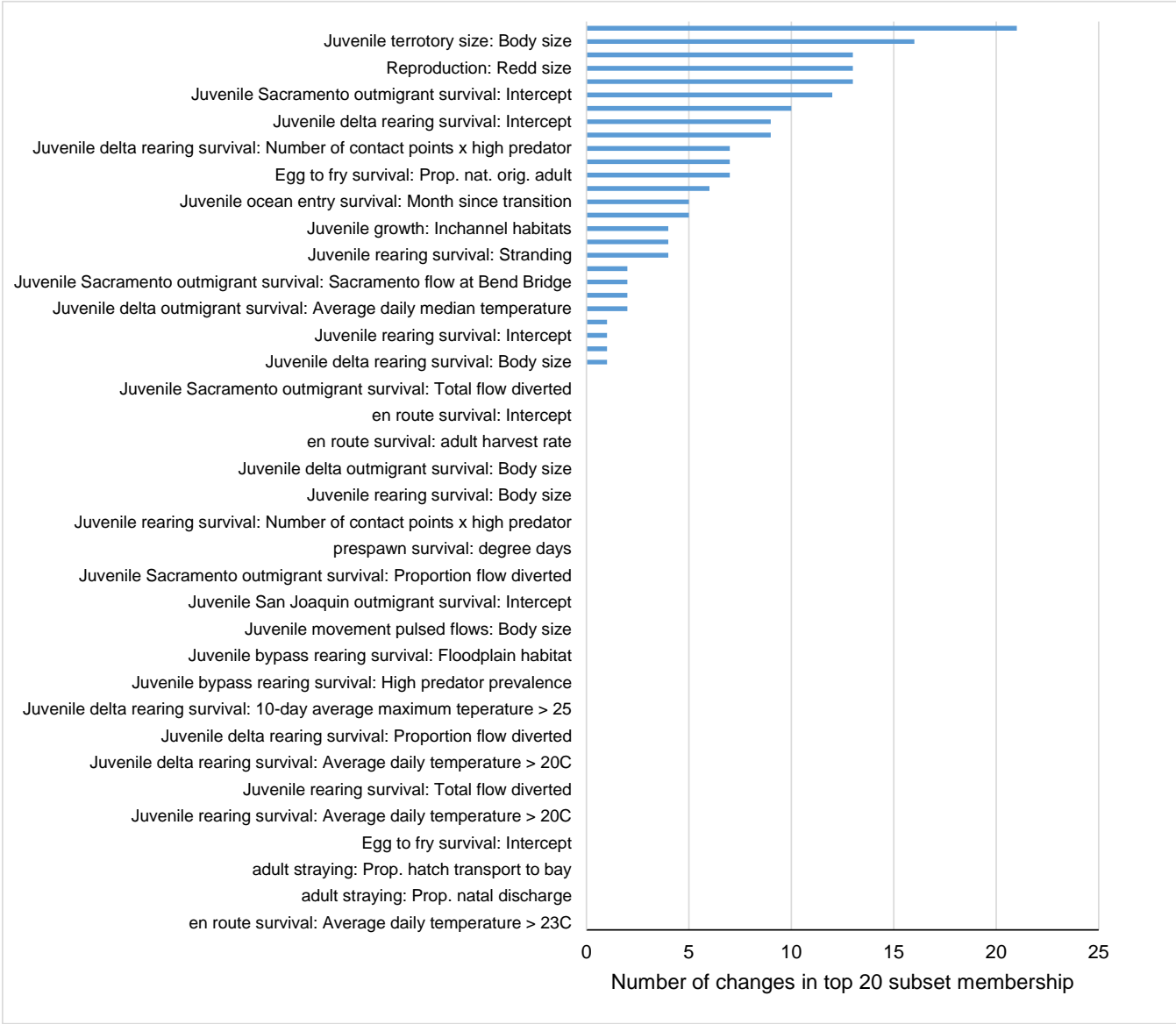


Figure 7. Summary of number of changes in membership of the top 20 scenarios based on one-way response profile sensitivity analyses of fall run Chinook Salmon SDM components for n number of naturally produced adults under dry climate at year 20. All components, except alternative models, were evaluated using the composite model and varying each component +/- 50% of mean values.

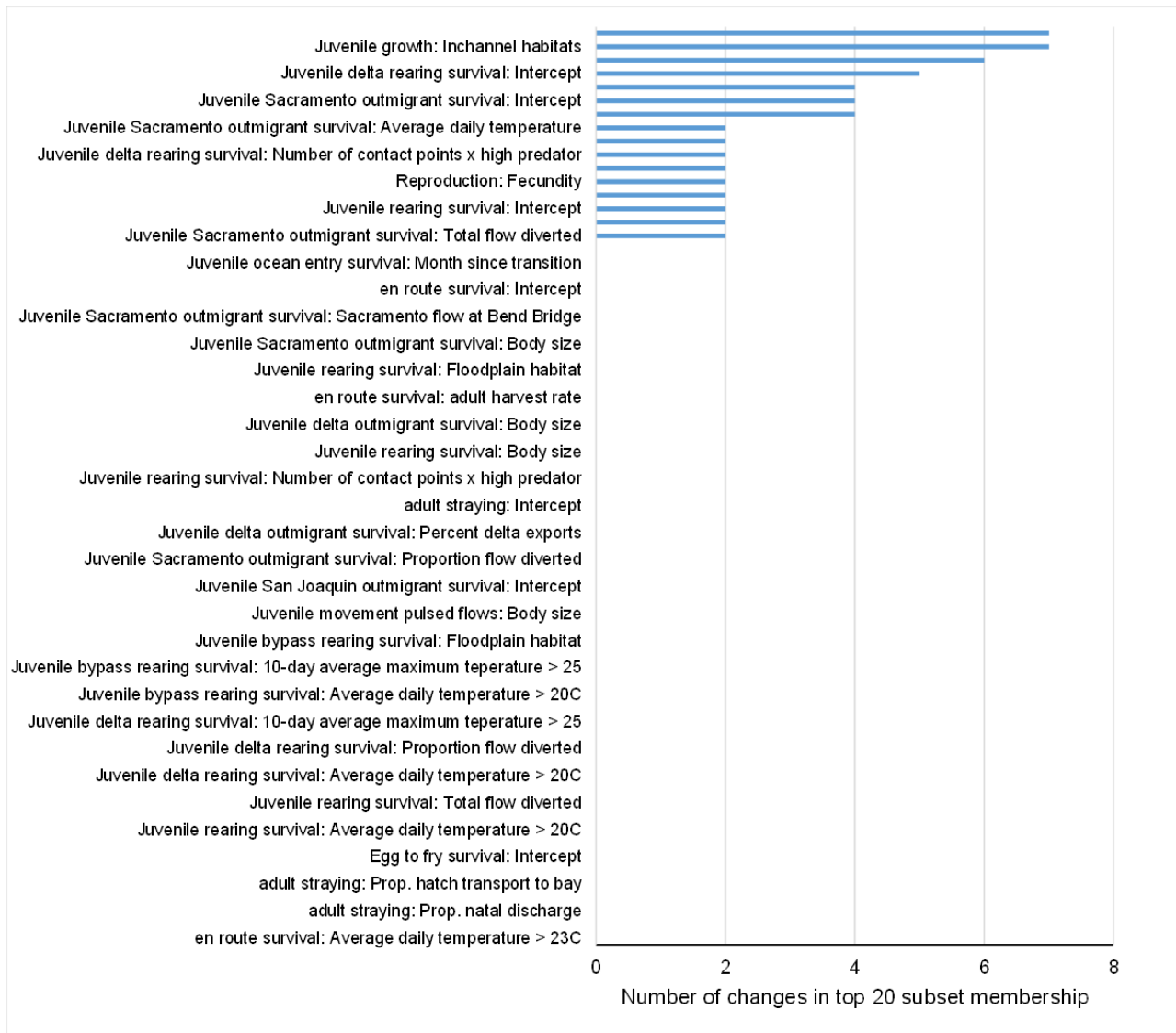


Figure 8. Summary of number of changes in membership of the top 20 scenarios based on one-way response profile sensitivity analyses of fall run Chinook Salmon SDM components for number of naturally produced juveniles per spawner under dry climate at year 20. All components, except alternative models, were evaluated using the composite model and varying each component +/- 50% of mean values.

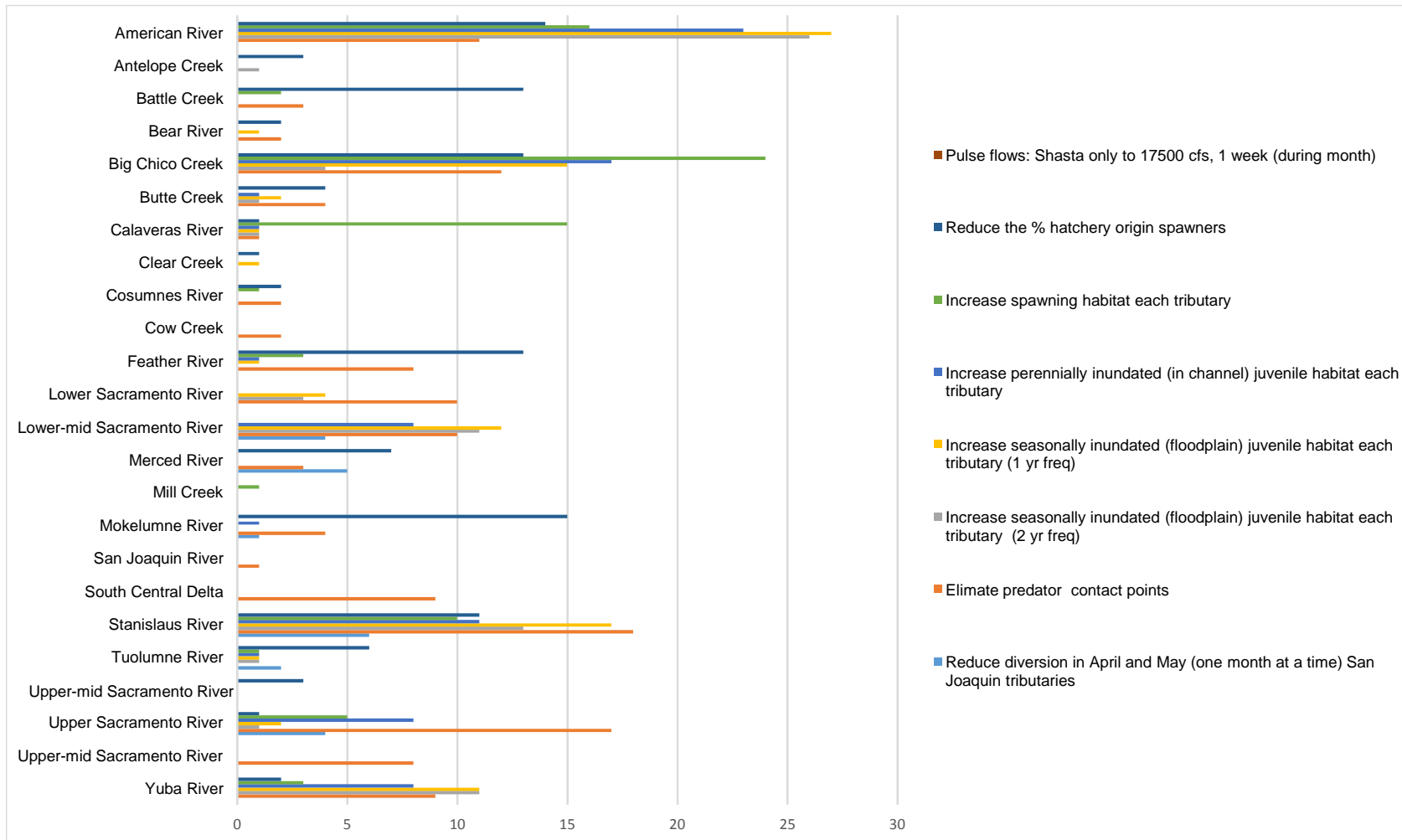


Figure 9. Total number of positive (+) scores for each fall Chinook Salmon scenario summer across SIT attributes and participants in the scoring process.

Appendix A. Parameter estimates from FY18 fall Chinook Salmon SDM

Parameter	Estimate	Source
<u>En route survival</u>		
Intercept	2.9870	Calibration estimate
Average daily temperature > 23°C	-0.2600	Schreck et al. (1994)
Bypass overtopped (stranding)	-0.0190	Expert opinion by Ted Somer, estimates 3K year (tributaries above bypasses only)
adult harvest rate	Tributary specific	average CWT estimates 2010-2102
<u>Prespawn survival</u>		
Intercept	3.1007	Calibration estimate
degree days	-0.0007	Colvin et al. (in review)
<u>Adult straying</u>		
Intercept	2.9010	Empirical model estimate 2008-2011 data provided by EBMUD.
Natural origin adult	-5.5003	Estimated with CTW data 2010-2012
Prop. natal discharge	-1.9900	Empirical model estimate 2008-2011 data provided by EBMUD.
Cross channel days open	-0.1740	Empirical model estimate 2008-2011 data provided by EBMUD.
Prop. hatch transport to bay	2.0900	Estimated with CTW data 2010-2012
Prop. hatch transport to delta	2.8900	Estimated with CTW data 2010-2012
<u>Reproduction</u>		
Sex ratio	0.5000	Expert opinion
Redd size	12.4000	Healey (1991)
Fecundity	5522.0000	Moyle (2002)
<u>Egg-to-fry survival</u>		
Intercept	0.0410	
Prop. nat. orig. adult	0.5330	Model in Peterson et al. (2014)
Scour event	-0.6550	
Egg viability	Tributary specific	Empirical estimate varies with water year developed by C. Hammersmark (unpublished)

Juvenile river rearing survival

Intercept	-0.7500	Calibration estimate
Average daily temperature > 20 °C	-0.7170	Marine and Chech (2004)
Number of contact points x high predator	-0.0068	Calibration estimate
High predator prevalence	-0.1220	Cavallo et al. (2012)
Proportion flow diverted	-0.1755	Calibration estimate
Total flow diverted	-0.0005	Calibration estimate
Stranding	-1.9390	Model in Peterson et al. (2014)
10-day average maximum temperature > 25 °C		Acute lethal; Brett (1952)
Medium body size	0.1480	Connor et al. (2004)
Large body size	2.2230	Connor et al. (2004)
Floodplain habitat	0.4700	Sommer et al. (2001)

Juvenile delta rearing survival

Intercept	4.9000	Calibration estimate
Average daily temperature > 20 °C	-0.7170	Marine and Chech (2004)
Number of contact points x high predator	-0.0068	Calibration estimate
High predator prevalence	-0.1220	Cavallo et al. (2012)
Proportion flow diverted	-3.5100	Newman and Brandes (2010)
Total flow diverted	-0.0011	Newman and Brandes (2010)
10-day average maximum temperature > 25 °C		Acute lethal; Brett (1952)
Medium body size	0.1480	Connor et al. (2004)
Large body size	2.2230	Connor et al. (2004)

Juvenile bypass rearing survival

Intercept	-0.7500	Sommer et al. (2001)
Average daily temperature > 20C	-0.7170	Marine and Chech (2004)
High predator prevalence	-0.1220	Cavallo et al. (2012)
10-day average maximum temperature > 25 °C		Acute lethal; Brett (1952)
Medium body size	0.1480	Connor et al. (2004)
Large body size	2.2230	Connor et al. (2004)
Floodplain habitat	0.4700	Sommer et al. (2001)

Juvenile movement with flows		
Intercept	-7.7074	
Pulse proportion of base flow	0.2658	
Medium body size	1.6685	Empirical model fit to CAMP screwtrap platform data from American River, Stanislaus River, Feather River, Mokelumne River, Sacramento River, Tuolumne River, Clear Creek 2008-2015 (unpublished)
Large body size	0.5706	
Very large body size	-4.3050	
Medium body size x pulse	-0.2548	
Large body size x pulse	-0.4478	
Very large body size x pulse	0.3290	
Juvenile San Joaquin outmigrant survival		
Intercept	-2.1300	Assumed to average 2.4%, size parameters reflect same relative differences among sizes as Sacramento out-migrant model.
Medium body size	0.4800	
Large body size	1.2230	
Juvenile Sacramento outmigrant survival		
Intercept	-7.3500	Calibration estimate
Average daily temperature	0.5540	Empirical model fit by Cyril Michaels (NMFS) to Late-fall chinook release data per request of SIT (unpublished)
Sacramento flow at Bend Bridge	0.0092	
Proportion flow diverted	-0.1755	
Total flow diverted	-0.0005	
Medium body size	0.4800	Newman (2003); Perry (2010)
Large body size	1.2230	Newman (2003); Perry (2010)
Sacramento flow model weight	0.5000	Assumed equal weight between competing models
Juvenile delta outmigrant survival		
Intercept	-3.1500	Calibration estimate
Average daily median temperature	0.3860	Empirical model fit by Cyril Michaels (NMFS) to Late-fall chinook release data per request of SIT (unpublished)
Delta flow	0.0013	
Percent delta exports	-0.0330	
Medium body size	0.4800	Newman (2003); Perry (2010)
Large body size	1.2230	Newman (2003); Perry (2010)
Delta flow model weight	0.3330	three model weights 1/3 each

Juvenile ocean entry survival

Intercept	-2.4729	Calibration estimate
Month since transition	0.3500	
Small body size	-0.0897	
Medium body size	-0.0710	Satterthwaite et al. 2014
Large body size	-0.0209	
Very large body size	0.0733	

Juvenile growth

In channel habitats	0.5000	Sommer et al. (2001)
Floodplain habitats	1.0600	

Juvenile territory size

Small body size	0.0542	
Medium body size	0.1454	Grant and Kramer (1990)
Large body size	0.4847	

Appendix B

Summary of coarse resolution model inputs and the relative confidence of SIT in the model inputs. Future action indicates that SIT members were continuing modifications of the inputs.

<u>Model input</u>	<u>Relative confidence^a</u>	<u>Improvement</u>	<u>Future action</u>
Spawning habitat	Moderate	No	
Juvenile in channel rearing habitat	Low	No	
Juvenile floodplain rearing habitat	Low	No	
Juvenile delta rearing habitat	Low	Yes	
Water temperature statistics	Low	No	
Streamflow statistics	Moderate	No	
Total water diverted	Low	Yes	
Proportion water diverted	Low	Yes	
No. days cross channel gates closed/open	High	Yes	
Hatchery origin adults returning	Low	No	Under development
Predator prevalence	Low	No	Under development
Contact point data	Low	Yes	Under development

^aRelative confidence definitions

Low - little or no empirical support, primarily based on expert opinion or based on limited empirical data available for less than 50% of watersheds

Moderate - some empirical support, based on existing data or surrogate data (e.g., remote sensed or out of basin data), but data are incomplete.

High - strong empirical support, data available for large majority of watersheds but improvement is possible

Low - little or no empirical support, primarily based on expert opinion or based on limited empirical data available for less than 50% of watersheds

Moderate - some empirical support, based on existing data or surrogate data (e.g., remote sensed or out of basin data), but data are incomplete.

High - strong empirical support, data available for large majority of watersheds but improvement is possible

Appendix C

Summary of fall Chinook DSM parameters and the relative confidence of SIT. Future action indicates that SIT members were continuing modifications of the parameters.

<u>Parameter</u>	<u>Relative confidence^a</u>	<u>Improvement</u>	<u>Future action</u>
Adult en route survival	Moderate	Yes	
Adult pre spawn survival	Moderate	Yes	
Adult straying dynamics	Low	Yes	
Hatchery origin influence reproduction	Low	No	Under development
Egg to fry Survival (viability)	Moderate	Yes	
Behavioral dynamics in watershed (rearing)	Low	No	Under development
Juvenile Tributary Survival (rearing)	Low	Yes	
Juvenile River Growth (rearing)	Moderate	No	
Juvenile Mainstem Survival (rearing)	Moderate	Yes	
Juvenile movement rate vs. flow model	Moderate	Yes	
Juvenile routing rules	Low	No	
San Joaquin to Delta juvenile survival (migrating)	Moderate	No	
Behavioral dynamics in delta (rearing)	Low	Yes	
Juvenile Delta Growth (rearing)	Low	No	
Juvenile Delta Survival (rearing)	Low	Yes	
Through delta survival juvenile	Moderate	Yes	
Ocean entry survival	High	No	

^aRelative confidence definitions

Low - little or no empirical support, primarily based on expert opinion or based on limited empirical data available for less than 50% of watersheds

Moderate - some empirical support, based on existing data or surrogate data (e.g., remote sensed or out of basin data), but data are incomplete.

High - strong empirical support, data available for large majority of watersheds but improvement is possible

Appendix D. Priority rankings provided by the winter Chinook Salmon PWT.

FY 2017 Priority and stressors (please rank priorities only)	2016 Priority Ranking (PWT)	2017 Priority Ranking (NMFS)	2017 Priority Ranking Collins	2017 Priority Brandes	2017 Priority Ammann	2017 Priority Pisciotto	2017 Priority Lacy	2017 Priority Killam	2017 Priority Kratville	2017 Priority Smith	2017 Priority Berry	2017 Priority Israel	2017 Priority average PWT Team Ranking AVG	Rounded Priority
Low egg to fry (<50mm) survival in the upper Sacramento River (Keswick Dam to Red Bluff)	1	3	3	1	2	1	2	1	1	1	1	1	1.5	1.0
a. High water temperatures during egg incubation and rearing in critically dry water years														
b. High prevalence of pathogens with low flows and high temperatures in critically dry water years														
c. Altered natural hydrology/flow regime														
d. Flow alterations that result in redd dewatering and juvenile stranding														
e. Limited rearing habitat (including flood plain and side channel habitat) due to urban and agricultural development, levee construction and channelization for flood management, and water delivery operations.														
f. High predation rates with low and clear flows														
Low juvenile survival in the Sacramento River (Red Bluff to the Delta)	2	4	4	5	3	2	4	2	2	2	2	2	2.8	2.0
a. Limited rearing habitat (including flood plain, side channel and low velocity edge habitat) due to urban and agricultural development, levee construction and channelization for flood management, and water delivery operations.														

b. Altered natural hydrology/flow regime															
c. Water quality degradation															
d. Predation and competition															
e. Delayed migration in low and clear flows															
f. High prevalence of pathogens with low flows and high temperatures															
Limited spatial and genetic diversity	5	1	1	2	1	3	1	5	6	4	5	5	3.3	3.0	
a. Single spawning population															
b. Blockage of historical habitat by Shasta and Keswick dams															
c. Loss of habitat due to hydroelectric development on Battle Creek															
d. Loss of genetic integrity due to increased artificial propagation in critically dry water years (2014 and 2015)															
e. Lack of suitable adult spawning habitat															
High adult pre-spawn mortality	4	2	2	3	6	5	3	4	5	5	4	3	3.8	4.0	
a. False attraction into the Colusa-Basin Drain resulting in loss to the spawning population															
b. Upstream migration delays in the Yolo Bypass due to agricultural barriers and weirs															
Low juvenile survival in the Sacramento River/San Joaquin Delta	3	5	5	6	5	4	5	3	4	3	3	4	4.2	5.0	
a. Limited rearing habitat (including flood plain habitat) due to urban and agricultural development, levee construction and channelization for flood management, and water delivery operations.															

b. Altered natural hydrology/flow regime															
c. Water exports and diversions into the Interior , Central, and South Delta															
d. Water quality degradation															
e. Predation and competition															
f. Entrainment in unscreened or poorly screened water diversions															
g. Delayed outmigration timing															
Lack of knowledge monitoring/research based priorities.	6	6	6	4	4	6	6	6	3	6	6	6	5.4	6.0	
a. Understanding the covariates that influence egg to fry survival															
b. Being able to estimate fry survival to the Delta.															
c. Understanding the covariates that influence fry survival from RBDD to the Delta															
d. Understanding the diversity in the population by using Parental based tagging to assess number of spawners successfully producing fry at RBDD.															
e. Annual variation in ocean conditions effect on return and the potential development of an annual index of ocean conditions.															

Appendix E. Supplementary material provided by the winter Chinook Salmon PWT.

Chinook Winter-run SAIL: Conceptual Models and Manuscript Table 1

1. Egg to Emerging Fry
2. Rearing to Migrating Juvenile in Upper Sacramento River
3. Rearing and migrating juvenile in Middle Sacramento River
4. Rearing to Migrating Juvenile in Bay-Delta
5. Ocean Juvenile to Ocean Adult
6. Adult Migration from Ocean to Upper Sacramento River
7. Adult Holding Upper River

Table S1. Example tool-box for applying the conceptual models to Sacramento River winter-run Chinook Salmon management by life stage and geographic regions. Note: The potential management actions outlined here are the actions denoted by stars in the individual submodels (Figures 1-7).

Life stage Conceptual Model (CM)	Potential Management Actions	Hypothesized Responses	Management authorities
Upper River			
Eggs CM1	Reduce in-river fishery	Reduces trampling impacts to redds (H ₁)	CDFW fishing regulations ⁵
Eggs CM1	Prescribe Keswick releases [temperature and flow]	Provides non-lethal temperatures (H ₇), high DO (H ₅), reduces risks of dewatering/ stranding (H ₄), and mobilizes fine sediments (H ₈)	Annual Temperature Management Plan, State Water Resource Control Board Water Rights Order 90-51; NMFS Biological Opinion 2009 ⁶
Eggs CM1	Implement multi-year reservoir management	Provides reliable quantity of cold water (H ₇)	End of September storage, NMFS Biological Opinion 2009 ³
Eggs CM1	Augment gravel	Increases the quality of redds through optimal gravel sizes facilitating interstitial flows (H ₅)	Central Valley Project Improvement Act (CVPIA) 1992 (b)(13)
Juveniles CM2	Maintain/reduce contaminant loading	Reduces chemical exposure [Iron Mountain] and associated impacts to fish physiology, growth and behavior (H ₁)	US EPA Clean Water Act, Section 404; Superfund ⁷
Juveniles CM2	Optimal hatchery release densities and timing	Minimizes impacts of intra-specific competition with natural origin fish and predator assemblage (H ₂). Minimizes likelihood of prey-switching behavior in predators to prevent increased predation rates.	Hatchery Genetic Management Plan; NMFS Biological Opinion 2009 ³
Juveniles CM2	Prescribe Keswick releases [temperature and flow]	Increases availability of shallow water riparian refuge habitat (H ₃), decreases predation risk and competition (H ₂)	NA

Juveniles CM2	Screen irrigation diversions and provide adequate riverine flows	Reduces entrainment risk and minimizes impacts of water withdrawals [ACID] on survival rates (H ₉)	Anadromous Fish Screen Program, CVPIA 1992
Adults CM7	Reduce in-river fishery	Reduces pre-spawn mortality from catch-release handling (H ₃)	CDFW fishing regulations ²
Adults CM7	Mate only natural-origin genetic SRWRC	Maintains locally adapted traits within ESU, reduces inbreeding, maximizes genetic diversity, and reduces domestication selection (H ₂)	Hatchery Genetic Management Plan, NMFS
	with most unrelated individuals in hatchery		Biological Opinion 2009 ³
Adults CM7	Produce and release an optimal number of	Prevents extinction if natural mortality is high, minimizes genetic (introgression/ domestication	Hatchery Genetic Management Plan, NMFS
Adults CM7	Augmentation gravel	Increases the amount of spawning habitat and placement can influences the spatial distribution	Central Valley Project Improvement Act
Adults CM7	Prescribe Keswick releases [temperature	Influence the location and timing of spawning (H ₆), vulnerability of eggs to dewatering/	Annual Temperature Management Plan, State
Middle River			
Juveniles CM3	Maintain/reduce contaminant loading	Reduces chemical exposure and associated impacts to fish physiology, growth and behavior (H ₁)	US EPA Clean Water Act, Section 404
Juveniles CM3	Release an optimal number of hatchery juveniles over time	Minimizes impacts of intra-specific competition with natural origin fish (H ₂). Minimizes likelihood of prey-switching behavior in predators to prevent increased predation rates.	Hatchery Genetic Management Plan, NMFS Biological Opinion 2009 ³
Juveniles CM3	Prescribe Keswick releases and tributary flows to achieve floodplain	Increases availability of shallow water refuge habitat [Sutter Bypass] (H ₃), prey quantity and quality and retention (H ₄), decreases predation risk and competition (H ₂)	NA
Juveniles CM3	Screen irrigation diversions and provide adequate	Reduces entrainment risk and minimizes impacts of water withdrawals on survival rates (H ₉).	Anadromous Fish Screen Program, CVPIA 1992
Tidal Estuary			
Juveniles CM4	Maintain/reduce contaminant loading	Reduces chemical exposure and associated impacts to fish physiology, growth and behavior (H ₁)	US EPA Clean Water Act
Juveniles CM4	Release an optimal number of hatchery juveniles over time	Minimizes impacts of intra-specific competition with natural origin fish (H ₂). Minimizes likelihood of prey-switching behavior in predators to prevent increased predation rates.	Hatchery Genetic Management Plan, NMFS Biological Opinion 2009 ³
Juveniles CM4	Prescribe Keswick releases and tributary flows to achieve floodplain	Increases availability of shallow water refuge habitat [Yolo Bypass] (H ₃), prey quantity and quality and retention (H ₄), decreases predation risk and competition (H ₂)	NMFS Biological Opinion ³
Juveniles CM4	Restore shallow water habitat	Increases amount of juvenile rearing habitat providing prey quantity and quality (H ₄), structural complexity for refuge (H ₃) from predation (H ₂)	NMFS Biological Opinion ³ ; EcoRestore, California's Natural Resources Agency ⁸
Juveniles CM4	Screen irrigation diversions and provide adequate riverine flows	Reduces entrainment risk, provides adequate outmigration cues (H ₅) and minimizes impacts of water withdrawals on survival rates (H ₉)	Anadromous Fish Screen Program, CVPIA 1992

Juveniles CM4	Reduce the number of non-native predators in key locations	Modifies fish assemblages and reduces predation on juveniles	NMFS Biological Opinion3
Migratory adults CM6	Modify passage barriers in flood bypasses	Allows volitional passage between bypasses and river, reduces migration delay, and stranding risk (H3)	NMFS Biological Opinion3
Migratory adults CM6	Enforce fishing regulations	Reduces poaching and pre-spawn mortality from catch-release handling (H2)	NMFS Biological Opinion3
Migratory adults CM6	Provide adequate mainstem flows during adult migration	Reduces false attraction flows through the bypasses	NMFS Biological Opinion3
Ocean			
Adults CM5	Sustainable harvest allocation	Minimizes bycatch of winter run in mixed stock fishery	NMFS Biological Opinion ³
Adults CM5	Optimal hatchery release densities and timing	Minimizes impacts of intra-specific competition with natural origin fish (H ₂)	Hatchery Genetic Management Plan, NMFS Biological Opinion 2009 ³
Adults CM5	Provide adequate mainstem flows during migration	Provides adequate attraction flows and cues to spawning grounds (H ₄)	NMFS Biological Opinion ³

Appendix F. Supplementary material provided by the spring Chinook Salmon interagency group.

1	Feather River	Sunset Pumps Weir Fish Passage Improvement	NMFS Recovery Plan (FER-2.13); CDFW Region 2 Fisheries	Still needs funding, 21 mil. This is a top priority as it would benefit spring-run Steelhead and Sturgeon. Last year's charter wasn't funded. We are planning to update and resubmit this charter by breaking into phases.	<p>1. Salmon: Rock dam impacts adult spring and fall run upstream passage, particularly at low flows. Rock dam disorients juvenile spring and fall-run cascading over the falls making them prone to predation and diversion screen doesn't meet current screening or sweeping velocity criteria leading to risk of entrainment/impingement.</p> <p>2. Steelhead: Rock dam disorients juveniles cascading over the falls making them prone to predation and diversion screen doesn't meet current screening or sweeping velocity criteria leading to risk of entrainment/impingement.</p> <p>3. Sturgeon: Rock dam blocks upstream passage for adult Green and White Sturgeon across most flows ($\leq 6K$ CFS).</p>
2	Sutter Bypass	Tisdale Fish Passage Improvement	NMFS Recovery Plan (SAR-1.12); CDFW Region 2 Fisheries; NCWA list	Charter submitted but not funded. this is a winter/spring/Steelhead/Sturgeon top priority. We are planning to try to update the charter. Based on Sturgeon mortality observations at the Oxbow in the Yolo bypass I'd like to link Tisdale fish passage in with adjacent low lying areas on north and south side Tisdale bypass.	<p>1. Salmon: Weir over tops yearly or more frequently typically during salmonid immigration and emigration windows. Weir wall and bypass side apron block and hold adult winter, spring, and fall-runs on declining limb of hydrograph trapping and stranding them, where they die unless rescued. Weir wall and bypass side apron disorient and trap juvenile winter, spring, and fall runs cascading over the wall on declining limb of hydrograph making them prone to predation and stranding them where they die unless rescued.</p> <p>2. Steelhead: Weir wall and bypass side apron block and hold adult Steelhead on declining limb of hydrograph trapping and stranding them. Weir wall and bypass side apron disorient and trap juvenile Steelhead cascading over the wall on declining limb of hydrograph making them prone to predation and stranding them.</p> <p>3. Sturgeon: Weir wall and bypass side apron block and hold adult Green and White Sturgeon on declining limb of hydrograph trapping and stranding them.</p>
3	Mill Creek	Upper Dam Fish Passage Improvement	NMFS Recovery Plan (MIC-1.1), CDFW Region 1 Fisheries	Still needs funding, 2.5 mil	1. Salmon/Steelhead: The existing fish ladder does not meet criteria for adult passage. The fish screen is very far down the canal and juvenile fish are susceptible to increased predation and stranding.
4	Deer Creek	Deer Creek Irrigation District Fish Passage Improvement	NMFS Recovery Plan (DEC-1.2), CDFW Region 1 Fisheries	Funded through CVPIA already?	1. Salmon/Steelhead: The existing facilities do not have a fish ladder, which impedes upstream migration of adults.
5	Deer Creek	Stanford Vina Ranch Irrigation Company Fish Passage	NMFS Recovery Plan (DEC-1.2), CDFW Region 1 Fisheries	Design, permitting, and alternatives analysis funded through Prop 1 and AFRP	1. Salmon/Steelhead: The existing fish ladder does not meet criteria for adult passage. The fish screen does not meet criteria and is in very bad shape which allows juveniles to be entrained into the diversion ditch. There has been documented fish kills of adult spring run due to insufficient passage conditions
6	Butte Creek	Weir 1 Fish Passage Improvement	CDFW Region 2 Fisheries and NMFS OLE documentation of adult stranding and	Funded but no RFP was sent out.	<p>1. Salmon: Outdated adult fish passage structure blocks adult spring migrating to holding/spawning reaches during medium to low flows. Typically occurs after April when agricultural diversion in the Sutter Bypass and Upper Butte Basin begin or when debris buildup is isn't cleared.</p> <p>2. Steelhead: Unknown if it also blocks adult Steelhead up or downstream passage.</p>

			mortality; NCWA list		
7	Mill Creek	Increase spring, early summer and fall instream flows for adult and juvenile fish passage through water acquisition, conjunctive use wells and storage, and water use efficiency plans and improvements. Flows targets should be based on CDFW Flows studies related to the CA Water Action Plan and SWRCB Phase 4 of Bay-Delta Plan update	NMFS Recovery Plan (MIC-1.2), CDFW Region 1 Fisheries; NCWA list	Actively pursuing through various programs	1. Salmon/Steelhead: enhancing flows will increase juvenile survival and allow adults to successfully reach their spawning grounds throughout their natural migration period.

8	Deer Creek	<p>Increase spring, early summer and fall instream flows for adult and juvenile fish passage through water acquisition, conjunctive use wells and storage, and water use efficiency plans and improvements. Flows targets should be based on CDFW Flows studies related to the CA Water Action Plan and SWRCB Phase 4 of Bay-Delta Plan update</p>	<p>NMFS Recovery Plan (DEC-1.1), CDFW Region 1 Fisheries, NCWA list</p>	<p>Actively pursuing through various programs</p>	<p>1. Salmon/Steelhead: enhancing flows will increase juvenile survival and allow adults to successfully reach their spawning grounds throughout their natural migration period.</p>
9	Yuba River	<p>Rearing habitat restoration within the proximity of the Yuba Goldfields</p>	<p>Numerous but most recently the Garamendi group; NMFS Recovery Plan (YUR-2.2)</p>	<p>R2 input needed. This is still important but there are other Yuba actions that may be higher priority. Under prop 1 planning, design engineering, and permitting was funded for the south diversion fish screen. Construction would probably be the highest priority/near term action.</p>	<p>1. Salmon: Multiple projects affecting juvenile and adult spring and fall runs. Lack of floodplain and suitable rearing habitat is thought to be the limiting factor for spring and fall run populations on the Lower Yuba River. Outdated and obsolete rock gabion is currently used for blocking juvenile spring and fall runs at the Brophy/South Yuba Irrigation District diversion. Juvenile salmon are entrained into the rock gabion or washed over the gabion during high flows and trapped. Daguerre Point Dam fish ladders block upstream passage for adult salmon during high flows ($\geq 25K$ CFS) and function poorly to attract and pass adults during low flows. 2. Steelhead: Outdated and obsolete rock gabion is currently used for blocking juvenile Steelhead at the Brophy/South Yuba Irrigation District diversion. Juvenile salmon are entrained into the rock gabion or washed over the gabion during high flows and trapped. Daguerre Point Dam fish ladders block upstream passage for adult Steelhead during high flows ($\geq 25K$ CFS) and function poorly to attract and pass adults during low flows. 3. Sturgeon: Daguerre Point Dam fish ladders block upstream passage for adult Green and White Sturgeon.</p>

10	Battle Creek	Natural Barrier Fish Passage Improvement	CDFW Region 1 Fisheries, NMFS Recovery Plan (BAC-1.12)	Still needs funding	Adult salmon and Steelhead: Improved upstream migration
11	Butte Creek	Increase water availability for April-June pulse flows for juvenile emigration survival	CDFW Region 2 Fisheries; NMFS Recovery Plan (BUC-1.1)	Actively pursuing through various programs	Juvenile salmon and Steelhead: Improved growth and survival
12	Clear Creek	Increase water availability for April-June pulse flows for juvenile emigration survival	Bratcher; NMFS Recovery Plan (CLC-1.3)		Juvenile salmon and Steelhead: Improved growth and survival
13	Upper-mid Sacramento River	Continued screening of unscreened diversions	CDFW Region 2 Fisheries; NMFS Central Valley Office		1. Salmon: Juvenile salmon entrainment and predation associated with diversion structure. 2. Steelhead: Juvenile Steelhead entrainment and predation associated with diversion structure.
14	Lower-mid Sacramento River	Continued screening of unscreened diversions	CDFW Region 2 Fisheries; NMFS Recovery Plan (SAR-1.3)		1. Salmon: Juvenile salmon entrainment and predation associated with diversion structure. 2. Steelhead: Juvenile Steelhead entrainment and predation associated with diversion structure.