Use of SALMOD in a Decision-Making Framework for Adaptation of Water Operations:

Answers to Questions Regarding OCAP RPA Actions

for the Salmonid Integrated Life-Cycle Models Workshop

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1. *How effectively can the model address the OCAP RPA Actions?*
   a. *How well does the model capture the effects of water operations and prescribed actions on specific salmonid life stages?* Can use water flow and temperature data for all freshwater life stages.
   b. *How well does the model capture the effects of water operations and prescribed actions on salmonid populations?* Calculates population-level abundance by time step, and by sub-reach (sub-population-level), year-round. The better the historical data available for calibration, the better the model performance (Garbage in, garbage out).
   c. *How well does the model capture the effects of water operations and prescribed actions on multiple stocks or individual stocks of salmonids populations?* SALMOD can handle up to 2 species; SALMOD II may handle 8.
   d. *Which RPA Actions are best addressed by the model?* (Refer to document "NMFS OCAP EFFECTS SUMMARY AND RPA ACTIONS":
      1) Shasta Reservoir - Models both lethal effects (temperature-related mortality) and sub-lethal effects (growth). Could be used to model spawning and rearing in the McCloud and/or Upper Sacramento Rivers.
      2) Clear Creek - Could modify Butte Creek model for Clear Creek, assuming that data are available or that same temp-mort relationships hold.
      3) Red Bluff Diversion Dam - Not good, doesn't handle upstream migration of adults.
      4) Lower Sacramento and upper Delta - Could do a single case study channel (assuming weighted usable area (WUA) data available), but doesn't handle multiple channels.
      5) Delta Cross Channel - No, doesn't handle multiple channels.
      6) Old and Middle River - No, doesn't handle multiple channels (can handle upstream swimming up juveniles, but only up the channel they originated from; semi-random dispersal).
      7) Delta pumps – Might be able to include entrapment in pumps as a freshet mortality relationship, as function of diversion flow.
      8) San Joaquin – SALMOD has relationship between flow and outmigration rate indirect effect of flow describes by **freshet movement** – flow affects density affects migration rate. Freshet Movement parameters include the distance moved, proportion moved, and associated mortality rate. These parameters are required for each juvenile life stage in the Anadromous model, and all life stages in the Resident model, by size class. Use specified freshet timing for historical data. Future freshet can be defined as function of 3-week running average.

9) American River - Would work fine for habitat below Nimbus, but can't include vertical temperature stratification of reservoir habitat unit (giant pool – okay if only need surface temperature).
10) Stanislaus River - May be able to model pulsed flow as a freshet. Would need WUA data for river cross section including high elevation areas that have no measured historical flood data, need fish use data (field studies; there may be field data for Stanislaus).
11) Nimbus Hatchery - Could treat hatchery vs. wild as 2 populations, if you know that the 2 groups have different temp-mort curves. But, SALMOD doesn't model predation directly; would have to include it as higher "natural" or "movement-related" mortality.

e. *How well does the model capture the effects of water operations and prescribed actions at the daily, monthly and annual time steps?* SALMOD works at weekly time step, results can be aggregated to annual time step.

2. *What are the strengths of the model?*
   a. Only need to enter input files
   b. Free download
3. *What are the limitations of the model?*
   a. Not open source – need to ask USGS to modify code
   b. Character limit on number of temperature and flow habitats (by habitat unit); also limit accuracy of temperature
   c. Deterministic calculation of mortality and other rates (rather than e.g., coin flip)
   d. Doesn't handle ocean population dynamics (survival, growth, run timing)
   e. Doesn't model temperature-based movement
   f. Models a linear stream segment, no branches or tributaries
4. *What are the data and input requirements for running the model?* Flow, water temperature, input number of spawners, WUA curves, relationships (e.g., temperature-mortality, temperature-growth, female size-fecundity, spawner sex ratio, movement-related mortality). Need historical flow, temperature, and fish data for calibration.
   a. *Is there a data set that, if available, would greatly improve the model?* For spring-run Chinook salmon, adult over-summer mortality and temperature data for other spring-run Chinook watersheds. WUA data for other watersheds.
   b. *Does the model use data and inputs that are identified as triggers for RPA actions by implementing agencies or NMFS?* Yes, for actions involving standards for flow, temperature, rearing habitat.
   c. *Can data and inputs be easily varied to evaluate how changing their value could influence daily, monthly, annual, and decadal responses of populations?* Yes, for monthly and annual responses. Doesn't model daily responses. At decadal scale need to make assumptions regarding input spawner numbers each year, and ocean survival.
   d. *How much uncertainty is associated with the intrinsic parameters of the model?* We couldn't find anything in the documentation referring to internal parameter values at all. This isn't very surprising given how many parameters are provided as user inputs. Most of the uncertainty comes from the internal assumptions and external parameters rather than internal parameters.

e. *To what inputs/parameters is the model most sensitive?* Parameters and inputs relating to water temperature (growth, mortality, [spawning temp for spring- and winter-run]); affecting density (WUA, average redd area, density-movement/mortality); affecting timing (migration, spawning).

5. *What are the key uncertainties associated with the model outputs?* Adult summer is driven by temperature-related mortality, but mortality is probably a function of both temperature and disease dynamics. Disease-related mortality is probably a function of immediate temperature, flow, fish density, and cumulative temperature stress. Also, model does not include temperature-related movement between habitat units (only density-related movement).
   a. *How should these model uncertainties be addressed?* Currently model fit is adequate; temperature-mortality relationship fit has $r^2 = 0.93$ using historical temperature data for 8 years, but adding a temperature-disease-mortality function may improve future fit as more years of calibration data become available. Adding temperature related movement function would improve realism at high temperatures, especially for lower reaches where fish densities are typically too low to provoke movement.
6. *What assumptions are embedded in the model regarding how the fish respond to RPA actions and/or habitat?* Fish respond mainly to temperature, flow, habitat availability, and fish density. Model does not include disease, food availability, predation.
   a. *Are data and inputs currently monitored adequately to reduce uncertainty in assumptions (increase precision and accuracy)?* Monitoring was adequate for Butte Creek. More upstream temperature data would have helped us to model further upstream and increase the number of water management options. Not sure how much temperature data and summer mortality exists for other streams.
   b. *Can assumptions be easily varied to evaluate how changing their value may influence daily, monthly, annual, and decadal responses of populations?* Can easily vary assumptions regarding modeled factors using input files. Cannot easily add factors not already included in the model (e.g., predation near Delta pumps).
7. *What methods have been used to validate the model?* We calibrated the model to 8 years of observed temperature and adult summer mortality data. We also calibrated another version of the model to total outmigrant smolt numbers (using a back-calculation of spawner coded wired tag observations related to the number of outmigrating smolts tagged in rotary screw traps n Butte Creek). From Campbell et al. (2010), p. 8: "SALMOD, the fall Chinook salmon fish production component of SIAM, remains "unverified" because, to date, sufficient data have not been collected to provide an independent data set to compare against another data set and perform a traditional model calibration/verification procedure. USGS held a workshop with Klamath Basin resource managers, stakeholders, and Tribal participants in October, 2006, to parameterize the SALMOD model, using a collective best evidence approach. A sensitivity analysis for the model was performed to determine those factors most sensitive to change. The results were reported in Bartholow and Henriksen (2006) and have been incorporated into the current version of SIAM. In general, predictions of fall Chinook salmon production are considered valid where flow and/or temperature are varied because any changes in population estimates can be attributed to those driving factors. USGS also specifies that differences between simulation predictions must exceed ±10%, an estimate of the model confidence interval."

8. *What is the present model development stage? (e.g,. completed, still validating, documented, the model has been used to address specific questions in the Delta or other systems, is subject to documentation for Biological Assessment, is subject of publication as peer reviewed article etc.).* Complete, but still waiting for validation. Has been subject of multiple peer-reviewed papers. Our work currently in peer-review (in *Climate Change*).
9. *For what water management programs and/or ecosystems and for what hypotheses has the model been applied for adaptive management?* Butte Creek spring-run Chinook salmon survival related to climate change (2010-2099) and water management adaptations; Klamath River fall Chinook production related to flow and temperature, reservoir operations (Campbell et al. 2010, p. 6; Note: in Klamath River the flow and temperature data were generated by MODSIM and HEQ-5Q, using SIAM integrated interface.); Trinity River; Sacramento River (Shasta Dam releases); Atlantic salmon.
    a. *Are the results of the model provided at appropriate time step for use is daily, annual or decadal water operation and other prescribed action implementation?* Yes, for monthly and annual responses. Doesn't model daily responses. At decadal scale need to make assumptions regarding input spawner numbers each year, and ocean survival.
10. *Is the model available in the public domain?* Yes.
11. *Is the model user-friendly for stakeholder and agency engagement?* Yes.
12. *What are the technical and financial barriers to implementation of the model by the agencies?* Would need to fund alteration of model, probably by USGS, or provide trained staff and funding for reverse engineering of model to open source code (to avoid reliance on USGS for code revisions).

SALMOD References

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