

March 10, 2015

TO: Robin Schrock, Exec. Dir., TRRP; Ernie Clarke, Sci. Coord., TRRP

FROM: Joe Polos, Fishery Biol. USFWS-Arcata

SUBJECT: Update on the TRRP Juvenile Salmonid Production Model for the March 2015 TMC meeting (information provided by R. Perry, J. Plumb, N. Som, and T. Hardy).

Below is an update on the development of the juvenile salmonid fish production model (stream salmonid simulator or S3) for the TRRP. Attached at the end of the update is a document developed by the modelers that addressed the capabilities of S3 in addressing a variety of management scenarios or questions what were developed by TRRP partners (Attachment 1).

Overall Progress

The timeline for completion of the Trinity S3 model for the restoration reach (Lewiston to the North Fork Trinity River confluence) is dependent on the timeline for completion of the SRH2D model. The S3 modeling team feels that once three key components are in place — 1) water temperature model, 2) flow data compilation, and 3) flow-habitat relationships — construction of the Trinity S3 model will proceed at a rapid pace. Further refinements will follow, such as including tributary production aspects of the model, but having the underlying habitat, flow, and temperature template is essential. Under the assumption that the we will have the final outputs of the completed SRH2D model this spring, the team feels that we could have a version of S3 together and running by early to mid-summer 2015, and then would likely have a calibrated or in-calibration model by early November, 2015. Based on current progress, the water temperature model is on track to be completed by late April 2015. Below are specific updates for each of the tasks listed in the proposal.

Task 1: Meso-Habitat Typing the Trinity River: building Mesohabitats.csv

Task 2: Constructing Weighted Usable Area Curves: WUA.csv

As stated above, Tasks 1 and 2 will be among the first tasks to be completed upon availability of the SRH2D model.

Task 3: River Discharge Data for Trinity River

As part of the Trinity River water temperature modeling project, a historical reconstruction of tributary inflows has been completed by Lorrie and Alan Flint (USGS, California Water Science Center). This historical reconstruction consists of daily discharge for 17 tributaries of the Trinity River spanning 1960 – 2014. Along with historical flows from Lewiston Dam, tributary inflows will be used to construct Trinity River discharge at 17 control points for the period 1960-2014. This flow data set will be used as the basis for the Trinity S3 model, providing a rich set of environmental conditions for simulating salmon population dynamics.

Task 4: Daily Temperature Data for Trinity River: Temperature.csv

The water temperature model is on schedule to be finished by late April, 2015. The river geometry inputs for the temperature model have been completed using the HEC-RAS model for the restoration reach of the Trinity River, and the geometry inputs from the RMA 2-11 model for the Lower Trinity River. Meteorological input data (daily min. and max. air temperature and cloud cover) has been reconstructed for the period 1960-2103 by Lorrie and Alan Flint. Statistical models for relating tributary water temperature to air temperature are currently in progress, and then model calibration can begin.

Task 5: Compile Juvenile Chinook Salmon Production Data for Trinity River Tributaries: Tributary Juveniles.csv

At the last Trinity S3 workshop held in July, 2014, we identified that many of the tributaries likely have little to no empirical data (mean emigration date or mean size at emigration) to inform production estimates of juveniles. The team plans to update the spawner-emigrant analysis developed to predict productivity and capacity of Klamath/Trinity tributaries. Goals of this analysis will be to 1) develop relationships between watershed area and mean date of emigration, and 2) update the productivity estimates with recent data, and 3) develop tributary production relationships for Trinity tributaries lacking empirical data. Since few large tributaries are located within the restoration reach, this analysis will be completed after initial construction and calibration of the Trinity S3 model for the restoration reach.

Task 6: Compile Adult Chinook Salmon Data: Spawners.csv

This task has not yet been completed because the input data set depends on the mesohabitat data. Owing to spatially explicit redd counts for the Trinity River, we will be able to assign spawners to specific habitat units once the mesohabitat input data set has been constructed.

Task7: Model Development

Model development of the S3 framework has progressed considerably towards specific needs of the Trinity version of the S3 model. Model development identified under this task included:

- **Link Trinity and Klamath SSS models** – This will not occur until the lower Trinity model is constructed, likely after initial construction and calibration of the restoration reach.
- **Track source populations** – S3 has been modified to track a user-specified number of source populations. For each source population, dynamics will depend on the size and life stage of each source population. Specifically, for the Trinity version of the S3 model, tracking source populations was a critical advancement to allow simultaneous modeling spring and fall Chinook juveniles (as well as Klamath River and Trinity River juveniles in the extended model).
- **Predation mortality function** – Predation is thought to be an important factor in the Trinity River. With this in mind, we have completed incorporation of a predation sub-model into S3.

- **Trinity-specific disease sub-model** – Disease-related mortality of Trinity River juveniles in the lower Klamath River has been recognized as potentially important component of total mortality. In conjunction with development of the Klamath SSS, we propose to implement a model for infection and mortality of Trinity River juveniles in the Lower Klamath River. This component will not be completed until the Trinity S3 model is connected to the Klamath River.
- **Add flow/velocity/freshet effects on movement** – As part of model calibration, the link between movement rate (km/d) water velocity will be investigated.

Task 8: Incorporating Stochasticity into the S3 Model

To better define and make the uncertainty associated with the parameters that drive the S3 Model transparent to users, the model and its various sub components will be implemented within a stochastic framework. Since the model needs to be run iteratively many times in order to characterize uncertainty, model run times must be on the order of a few minutes. To reduce run times, computationally burdensome parts of the model in R are currently being written in Fortran. Given quick run times and a calibrated model for the restoration reach, stochasticity will then be incorporated into S3.

Attachment 1. Responses from R. Perry, J. Plumb, N. Som, and T. Hardy addressing a variety of management scenarios or questions that were developed by TRRP partners

Scenarios that could be evaluated using the Trinity River salmonid production model

Background

On March 5, 2014, TRRP staff and the Trinity River salmonid production model (stream salmonid simulator, S³) developers met to: (1) Develop an understanding of the data that are needed to support the fish production model for the TRRP; (2) Identify what data are available; (3) Identify what data are needed and critical but not available; and (4) Develop a task list and schedule for accomplishing the tasks to support model development. It was agreed that TRRP staff would identify scenarios that could potentially be evaluated using the model. TRRP staff would share the scenarios with the model developers at the next meeting between the groups (foreseen in summer 2014).

Development of the salmonid production model was encouraged by the TRRP Science Advisory Board (SAB). Moreover, the SAB identified scenarios to be evaluated by the model. In their Review of the Trinity River Restoration Program following Phase 1, with emphasis on the Program's channel rehabilitation strategy (Buffington et al. 2014), the SAB has recommended that the model be used to:

1. Critically assess channel rehabilitation actions needed to achieve fish population objectives. What habitats and in which locations of the river are needed to achieve objectives at local and system scales? How do Program activities (rehabilitation projects and management of flow, temperature, and sediment) collectively affect salmonid populations? What are the synergistic effects and relative roles of different management activities?
2. Formally test the foundational hypothesis that a dynamic, complex channel can be created and that, together with other Program activities, will restore fish populations. To date, this has not been demonstrated, in part, because of slow physical and biological responses and the recency of restoration actions, which have not experienced many geomorphically effective flows. In this regard, modeling can help to test the above hypothesis and inform management actions in a more timely manner. Moreover, given the semi-alluvial nature of the river and limitations imposed by Record of Decision (ROD) flows and the volume of gravel introduced by augmentation, the original vision of a dynamic river with broad, active point bars may be too optimistic.
3. Critically evaluate the change in design strategy that has occurred (i.e., minimal vs. intensive mechanical intervention). A key factor to quantify in this regard is the response time for creating desired channel conditions and fish populations. The desired response time greatly influences the type of management actions (i.e., size, frequency, and degree of manipulation). Inherent in the Program's current approach of intensive, complex projects is the notion that more aggressive channel rehabilitation will shorten both the response time and the adaptive management learning cycle, thereby better informing Phase 2 designs. However, these assumptions remain to be tested and may be critically limited by the frequency and magnitude of ROD flows and the associated geomorphic work. In this regard, we also recommend that the Program pursue its investigation of

ways to reshape the wet-flow and extremely wet-flow allocations to increase the magnitude and efficiency of geomorphic work that it can accomplish in relation to desired channel conditions and resultant fish production. We also recommend that the Program consider the potential benefits of several large projects vs. many small ones. Are large channel rehabilitation projects more effective at meeting Program objectives than small ones, and which objectives are best met by each approach? Similarly, the benefits of projects designed to drive dynamic fluvial response in alluvial sections of the river vs. constructing static habitat in constrained and semi-alluvial reaches should be critically evaluated.

TRRP staff recognize that the model developers generally described the scenarios of interest to the Program on pages 1-2 of their 2013 investigation plan. In that plan the developers say that the model could support the TRRP's adaptive management efforts by:

- Evaluating the response of fish production to different flow management alternatives, including variable flow levels during specific life history stages
- Evaluating the response of fish production to different channel rehabilitation actions (these would be large scale changes, not at the channel rehabilitation feature scale)
- Evaluating the overall restoration strategy of the TRRP utilizing potential habitat estimates to attain fish population goals
- Evaluating the temperature response of fish growth and resulting production
- Evaluating the growth/size of fish in response to different flow/temperature alternatives and relate this to potential survival

Below, TRRP workgroups have added specificity to these general scenarios as well as potential scenarios presented in the Trinity River Flow Evaluation, Appendix O are included. After discussion with the modelers on the feasibility of these scenarios, TRRP staff will prioritize the list.

Scenarios of interest

Related to Flow Management

1. Evaluate the response of fish production to various flow management alternatives at annual and multi-year increments inclusive of the broadest portfolio of potential flow options. This would include scenarios where flow allocation was increased above current ROD levels (e.g. inclusion of the disputed 50,000 acre-feet supply from Trinity Reservoir for Humboldt County; fall flow augmentation).

Response: This is achievable at the annual scale for the initial rollout, but the multiyear evaluation would depend on completion of the full life cycle model and its extension to Weitchpec. It is assumed that specific flow management scenarios (i.e., 4 or 5 alternative hydrographs) would be provided to the modeling team. Any flow management scenario would necessitate running the water temperature model (using historical meteorological inputs).

2. Evaluate variable flow scenarios (e.g. real-time temperature management; variable winter base flows). This evaluation should be based on habitat time series and consider length of time at different inundation levels. Consider various return numbers and water year probabilities.

Response: This scenario seems closely related to scenario 1, therefore, we have the same response. If we are incorrect please clarify.

3. Evaluate the influence of flow on outmigration timing. Test what impact out migration timing has on fish populations and if moving that timing up or back during a given year would increase or decrease population numbers of adults in that class.

Response: Number 3 is not a scenario, per se, but rather a response to a flow scenario (i.e., a performance metric). For each set of scenarios tested, it is important to develop a set of performance metrics by which each scenario is evaluated. Outmigration timing is an example of one such performance metric. It is possible to test the effect of outmigration timing on adult returns, but that would depend on having the completed life cycle model.

4. Assess red dewatering / flooding based on water year probabilities.

Response: This should be evaluated with SRH2D, but not yet with S3.

5. Summer/Fall Baseflow transition from 450 cfs to 300 cfs (from Flow Evaluation Study Appendix O):
 - a. Evaluation of changes in spawning habitat availability and redd dewatering by changing the timing of the reduction of flow from 450 cfs to 300 cfs, possibly to as early as mid-September. This would also have to evaluate the potential temperature impacts that could occur changing the summer/fall flows which benefit holding adults and developing gametes.

Response: Because this is purely a habitat scenario, this scenario is best answered with SRH2D. If the scenario was extended to include consequences on juvenile or subsequent adult returns, then S3 could be used (after completion of full life for adults).

6. Fall/Winter Baseflow (from Flow Evaluation Study Appendix O):
 - a. Maximizing spawning habitat will increase spawning success and fry production.
 - b. Maximizing suitable rearing habitat area will increase growth rates, size at age, and production.
 - c. Real-time flow management will allow optimization of Lewiston releases to maximize production within a given year.

- d. Gradually increasing Lewiston releases from September to December will better distribute spawners, increasing spawning success.
- e. Broader distribution of redds will decrease the risk of cohort loss from redd scour during tributary generated flooding.
- f. Flow-habitat relationships will change in the new channel morphology, necessitating a reevaluation of spawning and rearing habitat flow releases.
- g. Rearing habitat was identified as the primary limiting factor within the existing (pre-ROD) channel morphology.
- h. Spawning habitat can become limiting as spawning escapement increases.

Response: Scenario 6 is another flow management scenario similar to 1 and 2, and therefore could be evaluated with S3. Point a – h are response variables or performance metrics by which Scenario 6 would be evaluated.

7. Fall/Winter Flood Flows (from Flow Evaluation Study Appendix O):

- a. Preventing fall/winter peak flows near Lewiston will reduce egg/embryo mortality associated with redd scour.

Response: This scenario is not relevant to S3 because it is not couched in the context of population dynamics. A separate red-scour model could be used to answer this question.

8. Snowmelt Peak (from Flow Evaluation Study Appendix O):

- a. Evaluate the hypothesis that there is no negative biological impact of the rapid up-ramp.
- b. Evaluate the hypothesis that there is no negative biological impact associated with the timing of the annual peak releases.
- c. Evaluate the hypothesis that the timing of the snowmelt peak reduces mortality of outmigrants by increasing turbidity, decreasing travel time, and reducing juvenile salmonid density.

Response: Scenario 8 is another flow management scenario. “Biological impact” should be explicitly defined in terms of juvenile production. Turbidity is not included as a driver in S3.

9. Descending Limb of the Snowmelt Peak (from Flow Evaluation Study Appendix O)

- a. Releases during this period that maintain water temperature near optimal levels will increase juvenile salmonid growth rates, increasing survival and production.
- b. Gradually decreasing releases, timed with increasing ambient air temperatures, causes mainstem water temperatures to rise which initiates smolting of salmonids.
- c. Smolt outmigration can be stimulated by one or more pulse flows that simulate freshets.

- d. Smolt outmigration is independent of flow and ramping rates.
- e. Evaluation of fish growth and survival as a function of water temperature.
- f. Assessment of primary factors that influence smolting and outmigration (pulse flows, degree-days, water temperature) and evaluation of whether management actions can improve outmigration success.
- g. Smolt survival in the Trinity River and lower Klamath River will increase as a result of better temperature conditions that promote smoltification.
- h. Smolt survival in the Trinity River and lower Klamath River is increased owing to reduced travel time associated with higher flows.

Response: Scenario 9 is another flow management scenario. Points a-h are response variables. S3 does not explicitly simulate the smoltification process, but indirectly captures smoltification via a length migration-rate relationship.

Related to Mechanical Channel Rehabilitation

1. Consider location, feature type, and feature scale to meet Program goals.

Response: Population dynamics, and therefore outputs from S3, are not sensitive enough to detect effects of single features.

2. Explore potential to meet management objectives. Bookend scenarios (extreme) to see maximum production. If we left river alone what would happen? See Beechie *et. al.* (2012)

Response: Given clear mgmt. objectives (fish production performance metrics), S3 can be used to address bookend scenarios.

3. Validate assumptions of value of cover.

Response: This is covered by the analysis of juvenile density data.

4. Rerun flow / habitat relationships systemically and at reach scale looking at bottleneck.

Response: S3 can be used to evaluate bottlenecks

5. Floodplain management issues – clearing valley bottom to afford maximum “range” for river meanders, avulsions and the like (e.g. removing tailings, managing land to promote riparian regeneration).

Response: S3 can be used to evaluate effects of changes in physical habitat on fish production.

6. Buy more private land and make floodplain bigger.

Response: S3 can be used to evaluate effects of changes in physical habitat on fish production.

Other Considerations

1. Evaluate adult escapement to smolt recruitment relationship. How important is adult escapement in limiting fish production? Annual output is an ASR.

Response: S3 can be used to simulate the relationship between an increasing number of spawners and resulting juvenile production.

2. Is food limiting fish production?

Response: Food limits production.

3. Is adult holding habitat limiting fish production?

Response: We recommend an analysis to determine the capacity of adult holding habitat, which would establish the upper limit to adult population size. If the current population size of spring Chinook salmon is under this capacity, then holding habitat is not limiting production.

4. Evaluate the fish production potential of habitat between Lewiston Dam and Trinity Dam and above Lewiston Dam using the appropriate assumptions of (a) historic conditions (b) a restored channel or (c) existing reservoirs. Include all mainstem and tributary potential.

Response: With 1) a habitat template, 2) flow habitat relationships by life stage, 3) hydrology and temperature inputs for the reach between the two Dams, then yes, S3 could be used.

5. Evaluate the response of fish production to increasing cover through targeted basin-wide (including tributaries) large wood augmentation. Evaluate differing wood loading rates and locations (e.g. tributaries vs. mainstem, upper vs. lower river).

Response: S3 can be used to evaluate the response of juvenile population dynamics to changes in physical habitat.

6. Evaluate the influence of (a) lower river and (b) ocean conditions.

Response: Currently, S3 is being built for the restoration reach. Part a can be answered when the model is extended to Weitchpec; part b can be answered when S3 is extended to the full life cycle.

7. Evaluate the response of natural and hatchery fish production changes to modifications of hatchery release numbers, sizes, and timing changes in strategies/changes in Trinity River Hatchery production

Response: Yes.

8. Consider tributary contributions.

Response: S3 considers tributary contributions of juveniles.

9. Tributary production comparison between unimpaired and impaired flows.

Response: Currently, S3 only model population dynamics in the mainstem. Juvenile contributions from tributaries are treated as inputs to the model.

10. Consider cold water pool management / Central Valley Operations to evaluate operational effects on fish production.

Response: Yes, given alternative flow and temperature scenarios as input to S3.

11. Integrated Trinity River flow management with Klamath operations.

Response: Yes, given alternative flow and temperature scenarios as input to S3, and given extension of Trinity S3 to Weitchpec.

12. What would happen if we had access to all tributaries below dams for habitat manipulation?

Response: Currently, S3 only model population dynamics in the mainstem. Juvenile contributions from tributaries are treated as inputs to the model.

13. Consider Lewiston Dam removal, including upper basin tributary potential production.

Response: Yes, if all the requisite inputs to S3 are developed. Also see response to number 4 in this section.

14. Evaluate the influence of potential management of fish predators on fish production including management of Brown Trout, hatchery Steelhead (changes in numbers, release timing, hatchery entry removal, directed selective fishery), and predator birds (e.g. mergansers).

Response: S3 will include a predation submodel.

15. Evaluate the effects of non-native fish and hatchery predation on wild fish production.

Response: S3 will include a predation submodel.

16. Evaluate the influence of a selective fishery (hatchery) on natural fish production at differing locations (e.g. Hoopa, adjacent to Lewiston) and harvest rates.

Response: Yes, when S3 is a completed full life cycle.

17. Climate change – sensitivity of production to changing temperatures.

Response: Yes, given the appropriate 1) meteorological inputs to drive the temperature model, and 2) flow inputs.

Links Beechie, T.; Pess, G.; Imaki, H. (2012) [Estimated changes to Chinook salmon \(*Oncorhynchus tshawytscha*\) and steelhead \(*Oncorhynchus mykiss*\) habitat carrying capacity from rehabilitation actions for the Trinity River, North Fork Trinity to Lewiston Dam](#). Report to the U.S. Fish and Wildlife Service, Arcata, CA by the U.S. National Marine Fisheries Service, Seattle, WA.

Buffington, J., C. Jordan, M. Merigliano, J. Peterson, and C. Stalnaker. 2014. [Review of the Trinity River Restoration Program following Phase 1, with emphasis on the Program's channel rehabilitation strategy](#). Prepared by the Trinity River Restoration Program's Science Advisory Board for the Trinity River Restoration Program with assistance from Anchor QEA, LLC, Stillwater Sciences, BioAnalysts, Inc., and Hinrichsen Environmental Services.

USFWS and HVT (1999) [Trinity River flow evaluation final report](#). U.S. Fish and Wildlife Service, Arcata, CA and Hoopa Valley Tribe, Hoopa, CA.