Conceptual Models and Hypotheses for the Trinity River Restoration Program

FINAL REPORT

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Prepared by staff, partners and interested parties of

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March 12, 2009

Citation: **Trinity River Restoration Program.** 2009. Conceptual models and hypotheses for the Trinity River Restoration Program. Final report prepared for the Trinity River Restoration Program, Weaverville, CA. 130 pp.

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Executive Summary

This document was originally prepared as a Backgrounder on Trinity River Restoration Program (TRRP) conceptual models for a meeting (Adaptive Environmental Assessment and Management (AEAM) Framework Workshop 1) held October 13th-15th, 2004 in Eureka, California. Leading up to this workshop, a team of about 16 people worked with ESSA Technologies Ltd. (ESSA) between May 2004 and August 2004 to prepare this document, which was distributed to the 55 participants who attended the October 2004 meeting (after three earlier rounds of review). The goal of AEAM Framework Workshop 1 was to improve both individual conceptual models and their integration, setting the stage for development of well-focused monitoring and adaptive management plans in the winter of 2004 and spring 2005.

Subsequent to the October 2004 workshop, this document has been updated to reflect changes to these conceptual models and to summarize feedback from meeting participants. Hence, this report serves 3 purposes:

1. To document ‘state-of-the science’ conceptual models for the TRRP;
2. To summarize the main points from workshop participants; and
3. To initiate more formal development of monitoring/modeling plans and Adaptive Management protocols for the TRRP program.

Workshop background and objectives

The primary focus of this first AEAM Framework workshop was to improve both individual conceptual models and their integration across subsystems. It was recognized at the outset that some conceptual models (e.g., fish) needed a lot of improvement, due to significant TMAG/TRRP staffing shortages over the May to August 2004 period.

The TMAG, TRRP partners and ESSA had jointly formulated the following objectives for the meeting:

1. Intensively review and revise working drafts of the conceptual models developed by TRRP leads, improving their policy relevance, scientific defensibility and integration. All participants will work together constructively to advance the draft conceptual models.
2. Bring together scientists and water/resource managers so that scientists better understand the critical information needs of decision makers and the roles of the AEAM framework in supporting management decisions, and decision makers have a better grasp of the current state of scientific understanding.
3. Develop a priority set of quantitative performance measures to assess overall ecosystem responses to restoration actions and inform decision making on both annual and longer time scales.
4. Stimulate thinking on an integrated monitoring plan centered on these quantitative performance measures (focus of planned follow-on workshop to be held spring 2005).

The workshop’s ambitious objectives and agenda were implemented to the greatest degree possible within the 2.5 day meeting. Despite considerable progress made at the workshop, further work is required on Objective 3. Clear definition and prioritization of performance measures is essential for development of an integrated monitoring plan. The remainder of this executive summary outlines the progress made for each subsystem, and ends with a review of cross-cutting issues.

Physical subsystem

The physical subsystem collectively refers to mainstem Trinity River hydrology and fluvial geomorphic processes. This subsystem has the widest range of dependencies as all other ecosystem elements either directly or indirectly link to Trinity River hydrology and geomorphology. The overarching hypothesis guiding development of the geomorphic monitoring program is whether a 3 to 4 fold increase in salmonid *rearing habitat* will occur **and** lead to a doubling of *smolt* production. Restoration actions and monitoring must therefore evaluate ecosystem-scale physical changes over the upper 40 miles of the Trinity River mainstem and not be overly focused on fine-scale physical changes. This system-scale monitoring requires high resolution / index reach[1] assessments at a handful of sites to build process level understanding from which observations may be extrapolated to the entire 40 miles of the Trinity River mainstem.

Participants at the workshop felt that the hypotheses identified in the Backgrounder document for the October 2004 workshop were all important and feasible to test. Discussions therefore focused on clarifying and prioritizing specific performance measures associated with the various hypotheses of effect, and 'tools/techniques' for collecting data. All agreed that it is important to carefully distinguish between *objectives* (e.g., reduce in channel fine sediment storage), *performance measures* (e.g., % fines in surface and subsurface sediments), and *monitoring methods* (e.g., sampling grain size distributions in certain locations, times and depths). The group agreed that empirical hypothesis testing/data collection and model-based refinement/updating were mutually reinforcing and beneficial. While the group endorsed many of the performance measures listed in the background document, further work is required to define *specific performance measures* for various concepts (primarily for geomorphic and hydraulic diversity), the *relative precision* of different monitoring methods (e.g., LiDAR bathymetry vs. bedload rating curves) and *target criteria* to differentiate "poor," "satisfactory" and "good" restoration performance.

It is critical to ensure the hydrologic and geomorphic variables selected for monitoring include those which are key to other ecosystem components, especially fish. Due to time constraints and the size of the Fish Subgroup at the October workshop, it was not possible for fisheries specialists to refine and clarify the *specific* geomorphic variables that are critical for various life stages and species. Further discussions are needed with fisheries biologists to determine the extent to which candidate performance measures suggested by the Physical Subgroup (e.g., 2-D physical habitat simulation and remote sensing) ought to be used in the Trinity River. Such discussions should be **led by fisheries biologists** after considering: "*What do we need to know about hydrologic, geomorphic and riparian conditions to be able to explain changes in juvenile fish survival and production, and reliably attribute fish responses to restoration actions*?" Some fish biologists expressed concerns on the last morning of the workshop that some of the candidate physical habitat performance measures proposed by members of the Physical Subgroup were a "Cadillac," when a "Hyundai" would suffice. The bird, herpetology and macro-invertebrate data requirements were specified through inter-group dialogue at the Thursday "Integration" session. The requested data included: maps of vegetation, geomorphic form, substrate facies, inundation and post-construction rehabilitation sites; water temperatures in the mainstem thalweg, tributary and river's edge; air temperatures; flow at various locations; turbidity; gravel distribution and permeability; and flow (major tributaries, geological transitions). These data requests require further review, clarification and *prioritization*.

[1] ~ 0.5 to 2 mile segments, chosen using non-random, "representative" sampling.

Riparian subsystem

Participants in the Physical/Riparian Subgroup placed a priority on reviewing the physical subsystem performance measures and monitoring methods, with only one hour allocated to a review of the riparian subsystem. In general, participants were impressed by the clarity and level of development of the riparian subsystem conceptual model, performance measures and proposed monitoring methods. However, it was emphasized by John Bair that the current Trinity River riparian restoration effort emphasized low flow channel margin seedling initiation and bed mobility/scour monitoring (as emphasized in the TRFE, ROD) rather than floodplain restoration. John Bair emphasized that the restoration goals/vision for the riparian component would be strongly affected by prevailing views on the TMC regarding the endpoints sought for *floodplain* riparian restoration and its links with wildlife and birds.

Several participants at the workshop independently raised the question of why riparian restoration actions and monitoring stopped at the establishment stage, and did not go on to consider riparian stand development and succession (e.g., in regards to the needs of wildlife and birds). Immediate guidance from the TMC is needed to definitively clarify whether floodplain riparian restoration should be: 1) limited to a strict compliance focus; 2) geared towards the notion of "no net loss" of riparian obligate wildlife/birds; or 3) targeting the production of a patchy, structurally diverse riparian zone. The subgroup reviewed and endorsed John Bair's description of the critical scientific uncertainties for both riparian *initiation* and riparian *establishment*.

Another class of uncertainty that is relevant to Trinity River riparian restoration is unexpected events. For instance, there will be a need to re-evaluate flow release priorities following a string of dry years (e.g., trade-offs with temperature control). Desiccation was identified as a tactic that could be used to mitigate against low-water margin vegetation establishment. Increased ramping down of flows could also place plants in depth zones where they are more susceptible to scour. Likewise, high flows during seed dispersal would "wash away" seeds, preventing germination.

The subgroup briefly discussed the issue of "micromanagement" of the riparian system, in relation to optimizing conditions for fish. Some fisheries biologists suggested that young seedlings were desirable cover elements for certain species and life-stages of fish, if these plants were under a certain age. Hydrologists/dam operators countered that it would be impossible to provide such a fine level of control. With respect to performance measures, the subgroup coach suggested that consideration should be given to extending simple "presence/absence" indicators to some index of relative density or short-term seed deposition potential.

The present plan calls for implementing 24 channel rehabilitation sites within three years. The subgroup discussed whether this approach strikes the best balance between learning and maximizing the reduction of time needed to observe system scale benefits, and what contrast can/ought to be designed into the 24 channel rehabilitation sites.

The TARGETS model will also be used to generate planform maps (at study sites) for the expected riparian establishment consequences of particular cross-section designs and hydrographs. These predictions can be compared with field data to ascertain the predictive ability of this model. If model results represent observed conditions in a reasonable fashion, the model may be used to help inform the types of hydrographs that best meet riparian restoration objectives.

The proposed next steps are to: 1) have the TMC clarify goals/vision for riparian *floodplain* plantings; 2) continue discussions with bird, herpetology, and fish subsystem leads to make more explicit the information needs from the riparian subsystem (e.g., solicit fisheries biologists to determine what vegetation cover types are beneficial to rearing fish); 3) further review the conceptual model and performance measures presented in the October 2004 Backgrounder report and provide feedback to John Bair (not sufficient time available at the workshop); and 4) clarify an approach towards riparian site designs (floodplain scope and desired levels of learning).

Fish subsystem

The Fish subgroup had the largest challenges, for several reasons: a large number of participants (~25); a wide diversity of perspectives (e.g., 'lumpers' who favor looking at overall responses, and 'splitters' interested in a mechanistic understanding); and the complexity of the fish section in the Background document (four conceptual models plus supporting text). Additionally, some participants felt that the meeting should have focused on continuing the monitoring discussions from the February 2002 meeting, rather than focusing on the workshop objectives set by the TMAG. The subgroup agreed to focus on ***natural juvenile production*** and ***smolt production***, rather than alevin and adult life stages.

Several participants were familiar with SALMOD and its past application in the ROD, and were less familiar with the conceptual models in the Backgrounder document. Therefore, the subgroup adapted the agenda and spent 2.5 hours reviewing the juvenile and smolt production components of SALMOD in the context of the Backgrounder's fish conceptual models and hypotheses. The subgroup agreed that SALMOD is a useful aggregate set of hypotheses for exploring the consequences of TRRP actions, and that the critical hypotheses need to be validated or tested. However, the subgroup also felt that SALMOD is not ready to be used for making annual operational decisions on flow, for three reasons:

1. There are some key functional relationships in SALMOD which are not well understood (e.g., temperature-growth relationships, movement rates and survival when moving);
2. Some potentially important factors are not considered by SALMOD (e.g., food limitation, chinook responses after June 6th, steelhead and coho responses, hatchery / natural fish interactions); and
3. The model does not have current input data (e.g., weighted usable rearing area has changed since model was first built).

While improvements could be made to SALMOD, the subgroup felt that it was important to first determine empirically whether or not a given factor was significant (e.g., use growth measurements to assess the food limitation hypothesis) before expending resources on documenting the shape of a given functional relationship in the model or adding new ones. The fact that restoration actions are being implemented over several years (i.e., a Before-During-After experiment, rather than a Before-After situation) means that a model-based approach may be required to infer the effects of the TRRP, in addition to empirical measurements of habitat, spawners and smolts.

The subgroup spent close to three hours reviewing, revising and prioritizing the 24 hypotheses in the Backgrounder Document for the juvenile and smolt life-history stages. The group used the SALMOD conceptual structure for discussion purposes rather than the diagrams in the Backgrounder. The subgroup discussed improvements to the clarity of the hypotheses, how they overlapped with SALMOD, and various methods by which they could be tested using either existing information or future monitoring data.

The Fish Subgroup had a short focused discussion of performance measures (only half an hour, which was not nearly enough time). The lumpers and splitters all agreed on the need for three key sets of measurements: 1) returning spawners; 2) some measure of changing amount and quality of rearing habitat; and 3) the abundance, size and quality of emigrating fry and smolts. Further work is required to better define the spatial / temporal resolution of monitoring and the protocols to be used for these performance measures. The Fish Subgroup briefly discussed their needs for habitat information with the Physical / Riparian Subgroup, but did not converge on precise definitions of these requirements. This is a key priority for future discussions, as it forms the focus for much of the Physical Subsystem monitoring. The Physical / Riparian Subgroup proposed some candidate methods of habitat description which appear to exceed the perceived requirements of the Fish Subgroup.

Revisions to the Fish conceptual model will include: additional introductory points (clarifying the link to SALMOD); revised diagrams including the SALMOD conceptual model; a short summary of SALMOD (original purpose, key uncertainties, factors not considered); updated hypothesis tables and descriptions for juveniles and smolts; revised performance measures; updated description of key uncertainties and methods for resolving them; updated Looking Outward Matrix; and comments from the SAB.

Bird subsystem

The ROD established that the TRRP must consider potential impacts on federal and state listed plant and wildlife species (USDOI 2000:24). Species of concern include those listed under NEPA/CEQA requirements, USFS birds of concern and international commitments under the Migratory Bird Treaty Act. The subgroup and external reviewer confirmed that the Redwood Sciences Lab's bird monitoring protocols, survey designs (300-350 sample points) and habitat-population models will allow statistically powerful inferences, at multiple spatial scales, about the effects on various focal bird species of TRRP restoration actions. Compliance monitoring of birds is in place at channel rehabilitation sites, but is focused only on identifying direct localized effects. A more comprehensive bird monitoring and modeling program will permit evaluation of cumulative *direct* and *indirect* effects of TRRP actions on birds across the entire Trinity system, relative to historical conditions, current conditions and California habitat/population targets. The monitoring program will also provide useful feedback on the design of channel rehabilitation sites.

The subgroup identified both TRRP actions of importance for birds (i.e., channel rehabilitation, pond development, flow), as well as potential confounding actions which need to be monitored as potential alternative causal mechanisms (e.g., wildfires, floods, hatchery releases, tree removal, mosquito control). The subgroup prioritized the Backgrounder document's impact hypotheses based on perceived importance and feasibility. The 7 hypotheses originally proposed for **riparian** birds were filtered down to a smaller set of the 3 highest priority management hypotheses; these center on the effects of riparian habitat removal, channel rehabilitation, and riparian initiation on numbers of breeding adults and juveniles, and species diversity. These effects are expected to be initially negative, and then become positive over time. Use of the Categorical Regression Tree (CART) model, developed for riparian birds, will permit both retrospective and prospective predictions of changes in bird abundance as a function of historical and future estimates (respectively) of habitat conditions.

Similarly the 7 management hypotheses originally proposed for **aquatic** birds were filtered down to 2 key hypotheses, centered on the expected positive effects of bank rehabilitation and flow increases on bird prey abundance and diversity, leading to higher abundances of aquatic birds. The remaining hypotheses were considered low priority because either they were likely to be difficult to evaluate or the responses they predict were unlikely to occur, or both.

The primary performance measures to be used to evaluate these key causal pathways are: abundances of juveniles, adults and breeding adults; bird species diversity; nest success for riparian birds; prey abundance (especially fish for aquatic birds); and predator abundance. Finally, the subgroup updated the information they would like to receive from the Physical, Riparian and Fish subgroups. The participants found the workshop to be a very worthwhile experience.

Reptiles and amphibians subsystem

The subgroup identified four reasons for including a monitoring/evaluation program for reptiles and amphibians within the TRRP program. First, proposed management actions in the Trinity are hypothesized to have numerous direct and indirect affects on these animals (both positive and negative. Second, one reptile species (Western Pond Turtle) and one amphibian species (Foothill Yellow-legged Frog) have already been identified as focal species of concern in the ROD. Third, there is a suite of readily measurable performance measures (PMs) that could be used to evaluate the impacts of management actions on these animals at multiple spatial scales. Finally, the USFS Redwood Sciences Lab already has in place amphibian/reptile monitoring protocols for the Trinity. Long-term baseline datasets (including control sites) could be easily expanded to encompass any proposed TRRP monitoring design. The subgroup recognized that the management actions of the TRRP will be focused on benefiting fish, but the ROD also indicates concern for wildlife within the Trinity watershed. Management impacts on wildlife can be evaluated only through development of a comprehensive monitoring program for the river's varied wildlife biota. Beyond this goal, monitoring of assemblages of reptiles and amphibian species can provide integrative indicators of habitat conditions both in-river and within the larger floodplain, as the composite of aquatic/terrestrial life-histories requires a full range of properly functioning riverine conditions for population persistence.

Subgroup discussions concentrated on refining and prioritizing the impact hypotheses proposed for Western Pond Turtle and Yellow-legged Frog (the two focal species), based on tighter linkage with direct management actions planned for the Trinity. The 13 hypotheses originally proposed for Western Pond Turtle were filtered down to a more workable set of 6 management hypotheses. The remaining 7 hypotheses were considered of interest as alternative hypotheses (and should be evaluated/ quantified as potential confounding factors), but are outside TRRP management control and therefore not directly testable within the Trinity AEAM framework. The 8 hypotheses proposed for Yellow-legged Frog were filtered down to a smaller set of 6 primary management hypotheses. Further refinement/prioritization work in this regard is required.

Aquatic macro-invertebrates subsystem

The subgroup discussed the overall rationale for including a monitoring/evaluation program for aquatic macro-invertebrates within the TRRP. The subgroup participants' professional judgment (based on limited existing evidence) is that fish populations within the Trinity Basin are not food limited, at least currently. It is expected that the abundance of macro-invertebrates should increase with the more diverse flow regimes and habitat configurations created by TRRP restoration efforts. However, no level of monitoring for macro-invertebrates is currently in place to evaluate this, nor are there any baseline datasets with which to make comparisons.

The subgroup proposed the following three reasons for monitoring aquatic macro-invertebrates:

- Although TRRP actions may be expected to increase macro-invertebrate abundance, the increase could be in taxa of macro-invertebrates unavailable to fish as food. As such the system could become food limiting to fish despite an overall increase in invertebrate biomass. This could only be evaluated through a program designed to monitor changes in macro-invertebrate abundance and community composition.

- Macro-invertebrates represent the best integrative metric for quick and localized detection of major habitat/water quality changes, much faster and more tightly delineated than fish responses. They therefore have great utility in examining the effects of localized restoration activities (positive or negative) within operational time frames.
- Knowledge of baseline and changing macro-invertebrate abundance and community structure will likely provide a basis for understanding and predicting not only the potential population trajectories of fish but also of monitored wildlife biota (birds, reptiles and amphibians).

The subgroup recognized that it would only be useful to monitor macro-invertebrates if techniques are developed that can be employed/analyzed within relevant time frames (e.g., Rapid BioAssessment Protocols). Developing such techniques would require some period of focused strategic sampling within the Trinity to establish key benchmarks/indicators, which would then provide the basis for more rapid assessment methods. The level of information generated (i.e., taxonomic detail, sampling effort) would have to be tightly linked to the data needs of other TRRP subsystems, and would have to recognize the realities of TRRP budgetary constraints.

The subgroup distilled the 5 hypotheses originally proposed for this subsystem into a smaller set of 4 hypotheses. One of these hypotheses related to a general assessment of the value of using macro-invertebrates as significant indicators of lotic conditions in the Trinity (although this could be split into whether assessments would be made at subbasin or else tributary scales), requiring a focused effort to define key benchmarks and taxonomic indictors for the Trinity. The other 3 management hypotheses link intended management actions in the Trinity to predicted responses within the macro-invertebrate biota.

Key cross-cutting issues requiring resolution prior to the development of monitoring plans

Integration among subsystems: This Draft Conceptual Modeling Document provides a mechanism for specifying the linkages among subsystems. The “Looking Outward Matrix” outlines exactly what variables are needed by each ‘biotic subsystem’ (i.e., riparian, fish, birds, herpetology, benthos) from other subsystems (i.e., physical, riparian) to test hypotheses concerning action ⇒ process ⇒ habitat ⇒ biota causal pathways. These information requests need to be specified in terms of precise units, spatial resolution and sampling frequency, and “negotiated” among all subgroups so that there is a cost-effective, consistent base of physical monitoring. The draft Looking Outward Matrix (Table 2.1, pg. 8) provides a start for this process, but much more specificity is required.

Spatial resolution: The integration described above will be facilitated by defining a consistent spatial resolution to be used across different subsystems. Andreas Krause proposed defining 5 to 8 index reaches, each ~ 0.5 to 2 miles in length. The intention is to have 1 to 2 index reaches in each physiographic river section, preferably randomly chosen from a defined list of candidate index reaches that fulfill a set of criteria. One possible criterion is that each index reach would have a channel rehabilitation site at its upstream and downstream end, so that the sections in between will form a quasi-control. There are many advantages to choosing index reaches through a rigorous process that will allow convincing extrapolation to the entire 40 mile study area.

Suitable baseline: This is a key issue for all subgroups, and needs to be addressed in the monitoring plan. Against what baseline will TRRP changes be assessed? In particular, what is the baseline that is to be used to assess whether or not smolt abundance has doubled?

Maximizing learning from channel rehabilitation: Testing hypotheses of habitat-biota responses requires spatial and temporal contrasts. What spatial/temporal contrasts can, or ought to be designed into the 24 channel rehabilitation sites that are currently being implemented?

Process of monitoring plan development: On the final day of the workshop, David Marmorek of ESSA Technologies Ltd. presented a process for moving towards definition of a monitoring plan for all subsystems, which was well received by workshop participants. The process is modified from EPA's Data Quality Objectives (DQO) process, which has been used to develop hundreds of monitoring plans. The DQO process is a 7-step template that can help to clarify program objectives, define the appropriate types of data to collect/analyze, and specify tolerable limits on potential decision errors.

1.0 Background / Foundation

The Record of Decision (ROD) (USDOI 2000) outlines a recovery plan for the Trinity River and its fish and wildlife populations. This plan includes direct in-channel actions, as well as continued watershed restoration activities, replacement of bridges and structures within the floodplain, and a rigorous program to monitor and improve effectiveness of restoration activities. Appendix C to the ROD provides a detailed Implementation Plan for these management actions. The Trinity River Flow Evaluation study (TRFE, USFWS and HVT 1999) provided the historical perspective, initial science survey and recommendations that form the basis of the ROD. The TRFE and ROD recommended more natural and variable flow releases sufficient to clean spawning gravels, build gravel/cobble bars, scour sand from fish spawning areas, provide adequate temperature and habitat conditions for fish and wildlife at different life stages, control riparian vegetation encroachment and assist many other ecological functions.

The ROD and TRFE recognized the need for scientific rigor when it incorporated an Adaptive Environmental Assessment and Management (AEAM) approach into the Trinity River Restoration Program (TRRP). AEAM is a process that emphasizes iterative learning from the outcomes of carefully designed and monitored management actions. It can be represented as a 6-step feedback loop (Figure 1.1):

1. problem *assessment* to make explicit our current understanding of the system, develop a strategy to meet management goals, predict the outcomes of actions, and identify key uncertainties in these predictions in the form of testable hypotheses;
2. careful *design* of management actions and associated monitoring to concurrently meet management goals and reduce key uncertainties;
3. *implement* actions according to the design;
4. *monitor* key performance measures to test hypotheses and assess progress towards goals;
5. *evaluate* outcomes against predictions made in the assessment phase; and
6. *adjust* the understanding of the system and management actions, and proceed back to step 1.

An equally important focus of the AEAM process includes scientists working closely with managers to bridge the gap between science and policy, and support better management decisions.

The TRFE and ROD provided a solid foundation for applying an AEAM approach to the Trinity River. Much progress was made in these documents towards many of the required elements in Figure 1.1. To make AEAM operational, however, more work is required. Therefore the TRRP has undertaken the development of an Integrated AEAM Framework and Monitoring Plan, to be developed over a 16-month period. This plan will provide three critical elements:

1. *conceptual and quantitative models* that make explicit our current understanding of the system, the underlying hypotheses driving the restoration program, and key uncertainties;
2. *rigorous monitoring plans* focused on both reducing the uncertainties most critical to management decisions and clearly evaluating progress towards program goals; and
3. a scientifically defensible, practical *AEAM Framework* and *Integrated Information Management System (IIMS)* to provide rapid feedback from monitored outcomes through databases and models to revised annual management decisions. The AEAM Framework should provide a clear set of rules/guidelines for how flow and sediment management protocols will be revised in response to new evidence.

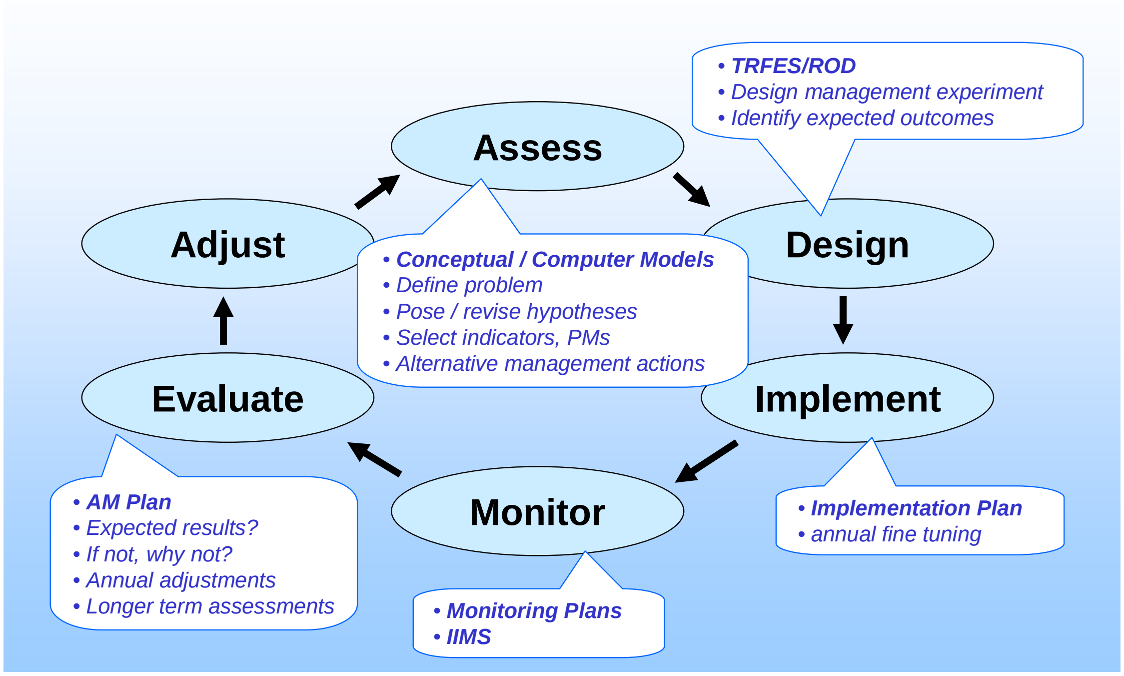


Figure 1.1. The AEAM process, and the components required to make it work in the Trinity River Restoration Program. TRFE = Trinity River Flow Evaluation study. ROD = 2000 Record of Decision. IIMS = Integrated Information Management System. AM = Adaptive Management. PM = Performance Measure.

The Technical Modeling and Analysis Group (TMAG) is responsible for implementing the science component of the ROD and TRFE, and is managing the AEAM Framework process. The TMAG is being assisted in this endeavor by its program partners, experts in AEAM from ESSA Technologies Ltd., technical representatives of stakeholders on the Trinity Adaptive Management Work Group (TAMWG), and the Scientific Advisory Board (Figure 1.2). In addition to increasing the rigor and focus of the TRRP, the Framework process will promote cooperation and partnership among agencies, organizations and the public. This will help to minimize policy conflicts, maximize efficiency, and assure the financial and technical resources necessary to continue a successful program.

The AEAM Framework process focuses on development of an integrated conceptual model of the Trinity River system as the foundation for developing quantitative performance measures and monitoring plans. The process for developing the substantive components/products above is illustrated in Figure 1.3. This process involves two facilitated multi-disciplinary workshops to provide interaction with stakeholders and technical experts, as well as external peer review. During the period from May to August 2004, a TRRP team of about sixteen people made good progress in developing draft conceptual models, with coaching assistance from ESSA Technologies Ltd. These draft conceptual models were described in a Backgrounder Document distributed to the 55 participants who attended AEAM Framework Workshop 1 in October 2004. The goal of this workshop was to improve individual conceptual models and their integration, setting the stage for development of well-focused monitoring plans. The agenda for Workshop 1 is provided in Appendix A, while a listing of participants at the workshop is provided in Appendix B. Subsequent to Workshop 1, work is now being undertaken to transform the general approaches discussed at the workshop into rigorous monitoring plans and an AEAM Framework for updating decisions in response to monitoring. These work products will be reviewed at Workshop 2.

Additionally, an integrated information management system is currently being designed that will serve the needs of the program, and a working prototype is being developed for the most critical monitoring data.

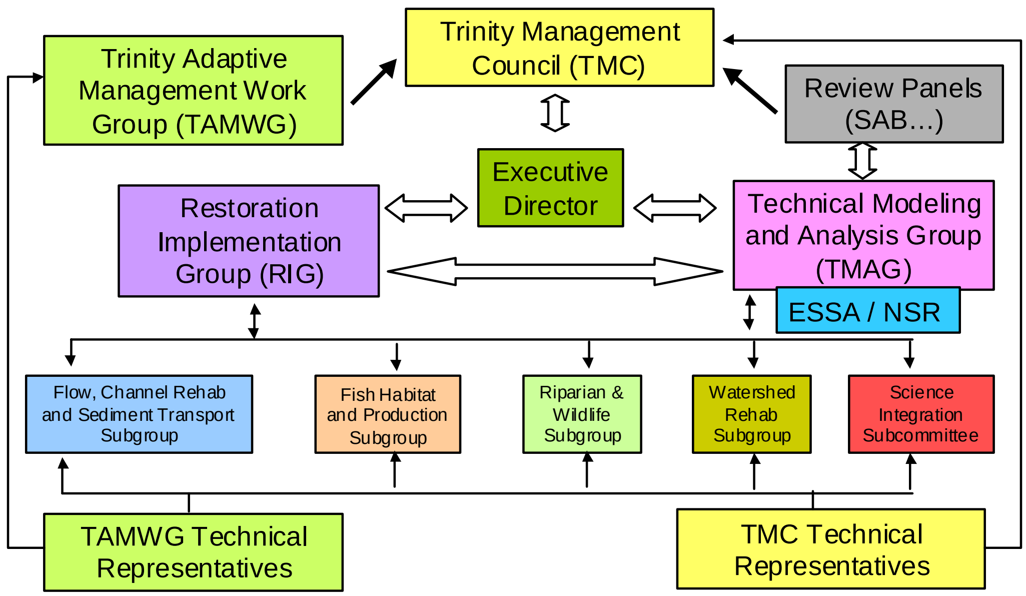


Figure 1.2. Proposed subgroup structure to guide development of conceptual model and AEAM Framework development.

TASKS (M = meeting; R = report; S=software)	2004									2005								
	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	**Mar**	Apr	May	Jun	Jul	Aug	Sep
1. Initial Core Planning Activities	M																	
Review conceptual models; meet with TAMWG, TMC, model leads																		
2. Workshop Preparation					R													
Refine conceptual models, review reports, develop workshop agenda / materials																		
3. Workshop 1 - Conceptual Models & Hypotheses							M	R										
Facilitate 3-day workshop; revise conceptual models; summarize mtg.																		
4. Monitoring Support and Program Integration									M				R					
Meetings to Develop AM Protocol & Monitoring/Modeling Approach																		
Draft / Revised Docs (AM Protocol, Monitoring/Modeling Plan)																		
5. Workshop 2 - AM Framework & Monitoring Plan													M	R				
Prepare Agenda / Draft Materials for Workshop 2																		
Facilitate 3-day workshop; revise plans; summarize mtg.																		
6. Framework Synthesis, Review, Revision (+ Project Management)																R	R	
Synthesize pieces into Scientific Framework Document																		
Team revision in response to peer reviewer comments																		
7. Design / Build Prototype for Database -- IIMS																		
Scoping / Review of Data Holdings																		
Meeting to Define Functional Requirements / Design Options			M															
Prepare / Revise Design Report			R															
Develop & Review Data / Technology & Interface Options						M												
Design Specs / Detailed Data Models								R										
Develop Prototype w Example Data										S								
Draft Database Templates for Partners												S						
Project Management / Client Liasion / Logistics Support																		

Figure 1.3. Overall schedule of timing of tasks and work products.

1.1 Conceptual models

Conceptual models are meant to provide a concise statement of our current understanding of the system, and focus our attention on critical uncertainties. Conceptual models come in many different forms and styles. The purpose of the conceptual models presented here is to clearly illustrate the physical-biological linkages by which we expect management actions to achieve stated goals for valued ecosystem components, including critical uncertainties in these cause-effect chains.[2] Conceptual models thus provide a foundation for developing detailed monitoring plans to both assess overall impacts and to resolve key questions affecting management decisions.

The major components of the conceptual models included in this document, and reviewed at Workshop 1, are as follows:

1. An *overall conceptual model* of the problem (Section 2), showing management actions, the processes by which these actions affect habitat, the habitat features likely to be affected, and the valued ecosystem components that we expect to respond to changed habitat. This overall conceptual model also shows the critical linkages among different subsystems, in the form of a matrix of information dependencies.
2. Individual subsystem conceptual models (Sections 3-7), including:
    - a list of *management actions* which directly affect the subsystem (as opposed to indirect effects via another subsystem);
    - a list of key *performance measures* that express the overall state of Valued Ecosystem Components (VECs) over time (e.g., smolts / spawner);
    - *life-history vs. time illustrations*, to clarify which life stages of representative species are likely to be directly affected by changes in the flow regime, helping to refine selected performance measures;
    - *box and arrow diagrams* expressing our assumptions about how management actions affect physical habitat changes and ultimately change valued ecosystem components;
    - *text statements* of selected cause-effect chains from the box and arrow diagrams in the form *of testable hypotheses* (including alternative hypotheses), with associated performance measures that would be monitored to test these hypotheses; and
    - a general approach towards *testing these hypotheses* (e.g., Before-After-Control-Impact design), indicating what historical or reference system data will be used.

In summary, the conceptual models in this document represent explicit statements of the current understanding of the Trinity River system and key candidate monitoring variables (performance measures), and will be revised as our understanding increases. These models will serve as a framework for incorporating alternative perspectives, hypotheses and performance measures. They will also be used to converge on the most critical monitoring needs and contribute to the design of a well-targeted monitoring strategy and adaptive management plan.

[2] A useful summary of the "impact hypothesis approach" adopted for this workshop can be found in Jones et al. (1996).

2.0 Overall Conceptual Model

The overall conceptual model for the Trinity River system is given in Figure 2.1.

TRRP management actions will restore the physical processes that create and maintain the habitats required to support salmon, steelhead and riparian vegetation, while also assisting other fish species, birds, reptiles and amphibians.

5

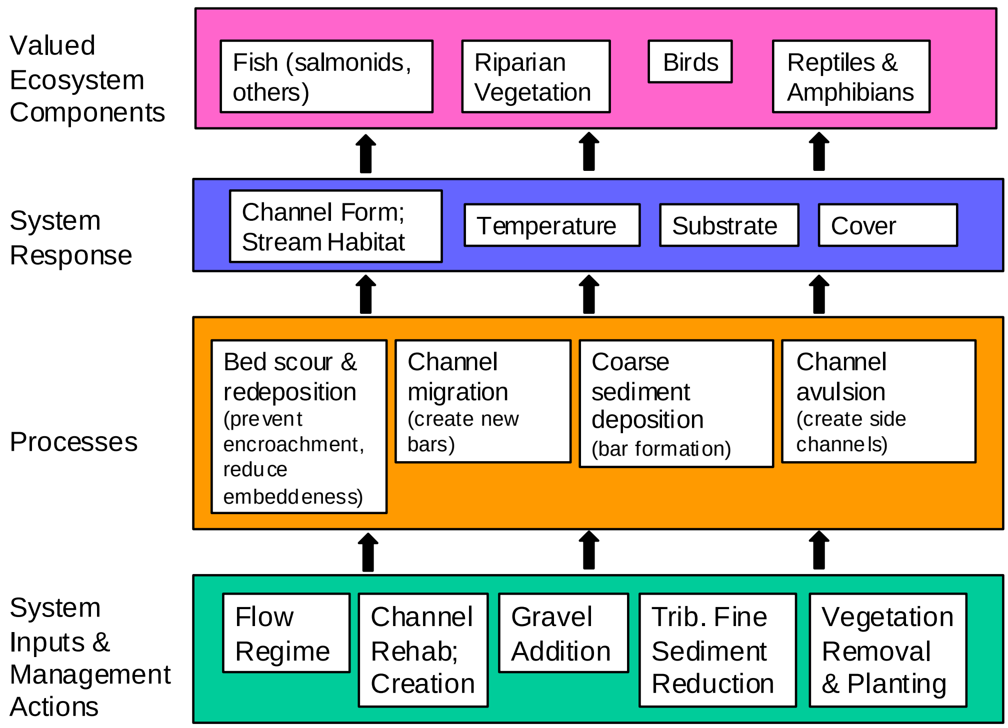


Figure 2.1. Conceptual model of overall system.

2.1 Submodel definition and integration: looking outward matrix

A "looking outward matrix" is a useful technique for helping to describe how the components of the overall system fit together and interact. A looking outward matrix is formed by arraying subsystem components as follows:

To: / From:	**Subsystem 1**	**Subsystem 2**	**Subsystem 3**
Subsystem 1			
Subsystem 2			
Subsystem 3			
Actions			
Driving Variables			

Each cell in the matrix represents a potential transfer of information between subsystems. When building computer simulation models, these cells are variables that need to be provided by one submodel to another to permit predictions of changes over time. However, when building an integrated monitoring program, these are data that will be required by one subsystem's scientists to explain the patterns observed in their subsystem and better ascribe causes to those changes. For example, did juvenile fish survival improve due to higher flows and cooler temperatures, or natural variation in air temperatures?

We completed the Looking Outward Matrix (Table 2.1) by asking the following question of the specialists within each subsystem:

> *What do you need to know about all the* ***other*** *subsystems to be able to explain the behavior of your subsystem, and reliably attribute its responses to changes in management actions?*

This is quite different from an approach where we ask the specialists within subgroups to predict how their own subsystem will behave (that comes later). This steers participants away from an over-elaboration of their own (beloved) area and promotes attention to interdisciplinary links between subsystems. The process defines the responsibility of each participant: they are required to answer the demands put to them by all the other participants (and to produce their own system's performance measures)—and that is all. The Looking Outward Matrix is intended to be a dynamic framework that will change as the information needs of each subsystem become more defined. Table 2.1 of this report represents the status of the Looking Outward Matrix at the completion of Workshop 1.

It is sometimes helpful to place actions and driving variables within the Looking Outward Matrix. Monitoring the actual implementation of actions (as opposed to their planned implementation) is an essential companion effort to monitoring action effectiveness. Driving variables are things typically outside the control of the humans managing the system of interest, but still need to be tracked as potential explanatory variables (either enhancing or negating the effects of restoration actions). Examples of driving variables include interannual variation in precipitation and air temperatures.

2.2 Spatial extent/bounds

Figure 2.2 shows the Trinity River and surrounding area, while Figure 2.3 shows the primary management reach of the Trinity River between Lewiston Dam and the North Fork Trinity River. Dam-induced changes to aquatic and terrestrial habitats have been most severe in this 40-mile reach. This reach can be divided into subreaches based on differences in sediment supply, valley confinement, valley slope, land use, and residential encroachment (Table 2.2).

2.3 Spatial resolution

The spatial resolution of proposed performance measures currently varies by subsystem. A critical issue yet to be fully resolved is exactly what spatial resolution to use for each subsystem's performance measures. Decisions on spatial resolution are critical. They affect the reliability of statements on the overall condition of VECs throughout the study area (i.e., stratified random samples will permit extrapolation to a larger area). Decisions on the spatial resolution of monitoring or modeling also affect the ability to conduct analyses of cause-effect linkages (e.g., changes in riparian vegetation in spatial unit *x* caused changes in bird species abundance within that spatial unit). The integration of subsystem information will be facilitated by defining a consistent spatial resolution to be used across different subsystems. Andreas Krause has proposed defining 5 to 8 index reaches, each ~ 0.5 to 2 miles in length. The intention is to have 1 to 2 index reaches in each physiographic river section, preferably randomly chosen from a defined list of candidate index reaches that fulfill a set of criteria. One possible criterion is that each index reach would have a channel rehabilitation site at its upstream and downstream end, so that the sections in between will form a quasi-control. There are many advantages to choosing index reaches through a rigorous process that will allow convincing extrapolation to the entire 40 mile study area.

Table 2.1. Draft Looking Outward Matrix (LOM) developed by the TRRP in April/May 2004, and revised at the October AEAM Framework workshop. The lead scientists for each subsystem represented by a column indicated what information they required from other subsystems represented by rows, so as to generate the performance measures (PMs) for their subsystem (shown in italics in the highlighted diagonal cells). The information transferred could be sampled information (e.g., flow) or modeled indicators.* The Looking Outward Matrix is a dynamic framework that will change as information needs become more defined; the current table represents the status of the LOM at the completion of Workshop 1.

To ↑ From →	**Hydrology / Temp**	**Channel/ Sediment**	**Riparian**	**Fish**	**Birds**	**Amphibians/ Reptiles**	**Aquatic Macro-invertebrates**
Hydrology/ Temp/ water quality	Flow rate (hourly, daily) Water temp (hourly, daily) Predicted water temp? Turbidity (hourly) DO (hourly) Inundation map of index flows (at 5 index sites) including showing <1m water depth areas for index flows Hydraulic diversity index (based on 3D plots of velocity, depth and cover)	Flow rate (hourly, daily) Turbidity (hourly)	Daily Average discharge magnitude, duration, frequency, timing, ramping rates, Exceedence probability/ recurrence interval Groundwater fluctuation	Daily flow and water temperature by "reach" (hourly flow during ramping) – have to extend flow measures below N. Fork Trinity Time series flow information is required for long-term evaluations of changes on fish production SALMOD needs edge water temperature and temperature at every major tributary, will have to extend sampling below the N. Fork Trinity Turbidity (hourly) DO (hourly)	Daily flow rate to estimate potential for nest flooding	Daily flow rate Mainstem water temperatures (both of these required to estimate life stage initiations and potential for egg/juveniles scour and/or dewatering) Inundation map	Flow timing, duration, magnitude and velocity Mainstem water temperatures Water temperature in tributaries
Channel/ Sediment	None	Sediment transport and storage (modeled and actual) Bed scour and mobility Geomorphic features Topo / Bathymetry Substrate size distribution Facies map for index reaches Geomorphic planform map (40 miles)	At a site (floodplain) arrangement of differing substrate patches (facies), the size class distribution of facies Site geomorphic units. Design surface hydrologic performance; Constructed geomorphic units	Particle size distribution (or permeability?) at representative locations in each reach, at depth where eggs are/above after major events which change condition Scour depth (redd scour) Geomorphic features Bathymetry to develop cross-sections for SALMOD Pool depths and volumes	Area of various types of exposed sediments (after major events) as foraging and nesting habitat Channel typing a measure of foraging area for aquatic species In-Channel foraging areas(continuous map, updated after major changes occur – shallow, feathered edges; riffles; pools and runs; bathymetry) *(general geomorphic map for whole 40 miles providing major habitat features + detailed maps for representative reaches of 1.5 miles) ~ 7.5 miles total mapped in detail and used to extrapolate*	Substrate facies map that can show area of various types of exposed sediments at restoration sites Geomorphic planform map	Substrate quality Channel change/ formation Fine sediment removal Coarse sediment injection sites and migration extents Restoration site design CAD drawings Post bank rehab construction site maps Substrate facies map that can show area of various types of exposed sediments at restoration sites

To ↑ From →	Hydrology / Temp	Channel/ Sediment	Riparian	Fish	Birds	Amphibians/ Reptiles	Aquatic Macro-invertebrates
Riparian	None	None	*Vegetation type & age map (40 miles), including vegetation map from orthorectified 1961 aerial photos*	Area of open gravel bars by reach	Major vegetation types currently in place (continuous map, updated after major changes occur; preferably from satellite imagery); Scenarios of future vegetation composition; Digitized, orthorectified maps of historical vegetation from 1961	Major vegetation types currently in place (continuous map, updated after major changes occur; preferably from satellite imagery); Scenarios of future vegetation composition	Removal of riparian vegetation during bank rehabilitation
Fish	Need feedback from fish group on the proposed sectioning of the river (The physical group proposes index reaches, with channel rehab sites at the top and bottom, unimpacted / restored habitat in between)	None	None	*Smolt production/year;* *Usable habitat (by 40 m lengths & life stage)*	Hatchery releases Juvenile fish densities (subdivided into different size classes to match bird prey size preferences annual index + monthly estimates at finest spatial resolution possible) General location and abundance of salmonid prey (fish utilization map)	General location and abundance of salmonid predators (fish utilization map)	None
Birds	None	None	None	Density of mergansers and kingfishers (# per reach in spring/early summer) *Might be able to use merganser and kingfisher abundances as indicator of juvenile fish abundance*	*Productivity, abundance, of wide variety of species at various scales (reach to watershed)*	General location and abundance of key predators	None
Amphibians/ Reptiles	None	None	None	None	Location and abundance of various species as potential food	*Total number & size of frog egg masses / reach;* *location and abundance of potential bull frog predators*	*None*
Aquatic Macro-arthropods	None	Macro-invertebrate production Macro-invertebrate biomass Macro-invertebrate diversity *- as potential surrogate substrate quality indicator?*	None	Macro-invertebrate production Macro-invertebrate biomass Macro-invertebrate diversity	Macro-invertebrate production Macro-invertebrate biomass Macro-invertebrate diversity	Macro-invertebrate production Macro-invertebrate biomass Macro-invertebrate diversity	*Macro-invertebrate production* *Macro-invertebrate biomass* *Macro-invertebrate diversity*

To ↑ From →	Hydrology / Temp	Channel/ Sediment	Riparian	Fish	Birds	Amphibians/ Reptiles	Aquatic Macro-invertebrates
Driving variables	Precipitation Air temperatures						
Actions	Implementation of **dam releases for fluvial geomorphic benefits and water temperature regimes**	**Fine sediment reduction;** **Gravel augmentation** **Channel rehabilitation (bank rehab, side channel construction, delta manipulation)** Design surface hydrologic performance Constructed geomorphic units	**Vegetation removal, planting** **Bank rehab site design** (see Channel/Sediment).	**Dam releases and changes in sediment quantity/ movements** through the lens of considering spawning, scour, de-watering, temperatures	**Vegetation removal /planting** through the lens of considering nesting/foraging habitat	**Dam releases and changes in sediment quantity/movements** through the lens of considering breeding, scour, de-watering, temperatures	**Dam releases and changes in sediment quantity/movements** through the lens of considering scour, de-watering, temperatures, productivity

* For many categories in the matrix there is still a need to clearly specify the desired spatial scale of the information (i.e., how is "location" to be defined – reach, site, habitat unit, etc.), and the temporal scale of resolution (i.e., information on this metric required daily, weekly, seasonally, yearly, etc.).

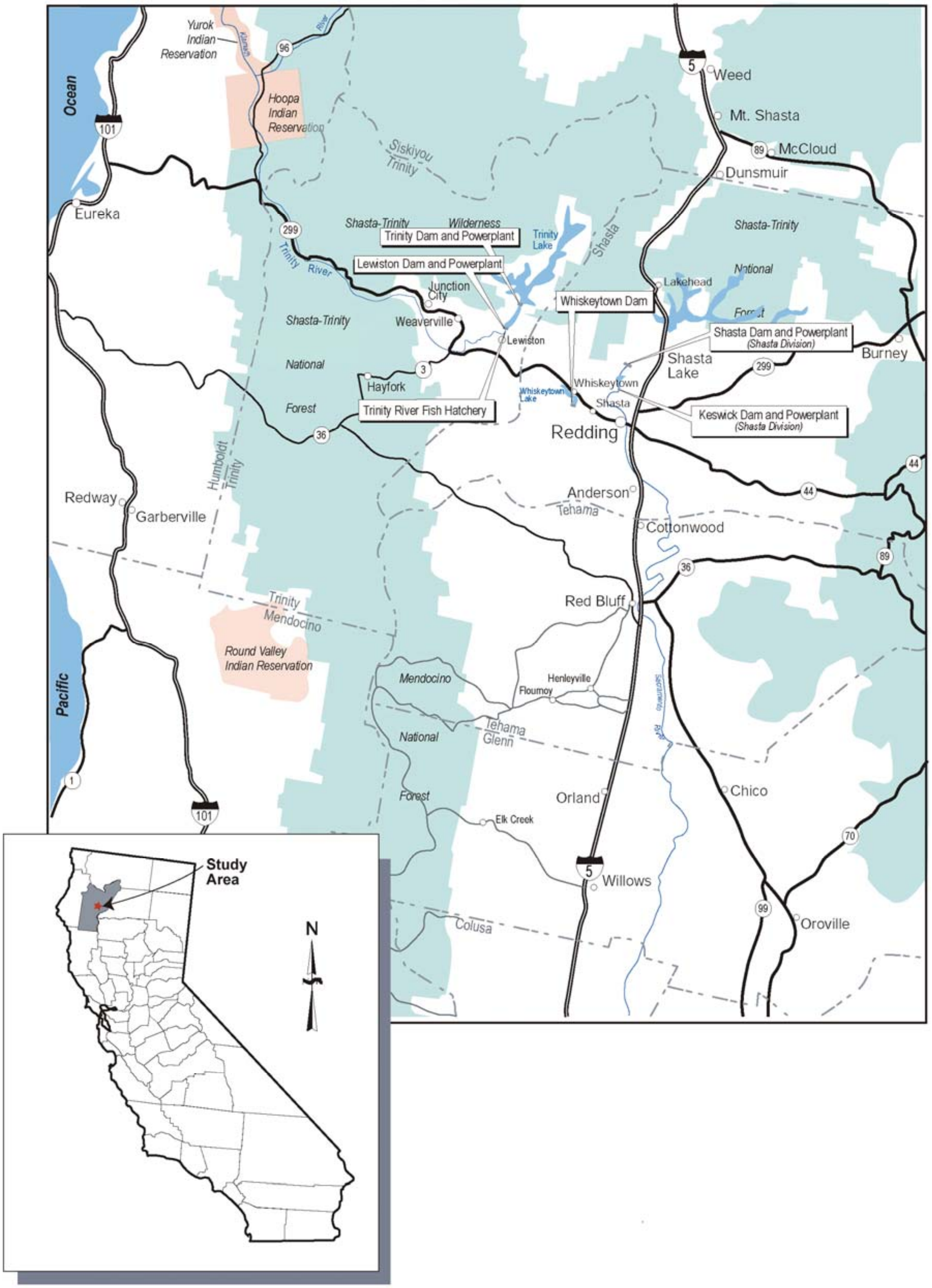


Figure 2.2. Map of the Trinity River and surrounding area. Dashed grey lines represent county boundaries. *Source:* North State Resources, Inc. Hocker Flat Rehabilitation Project.

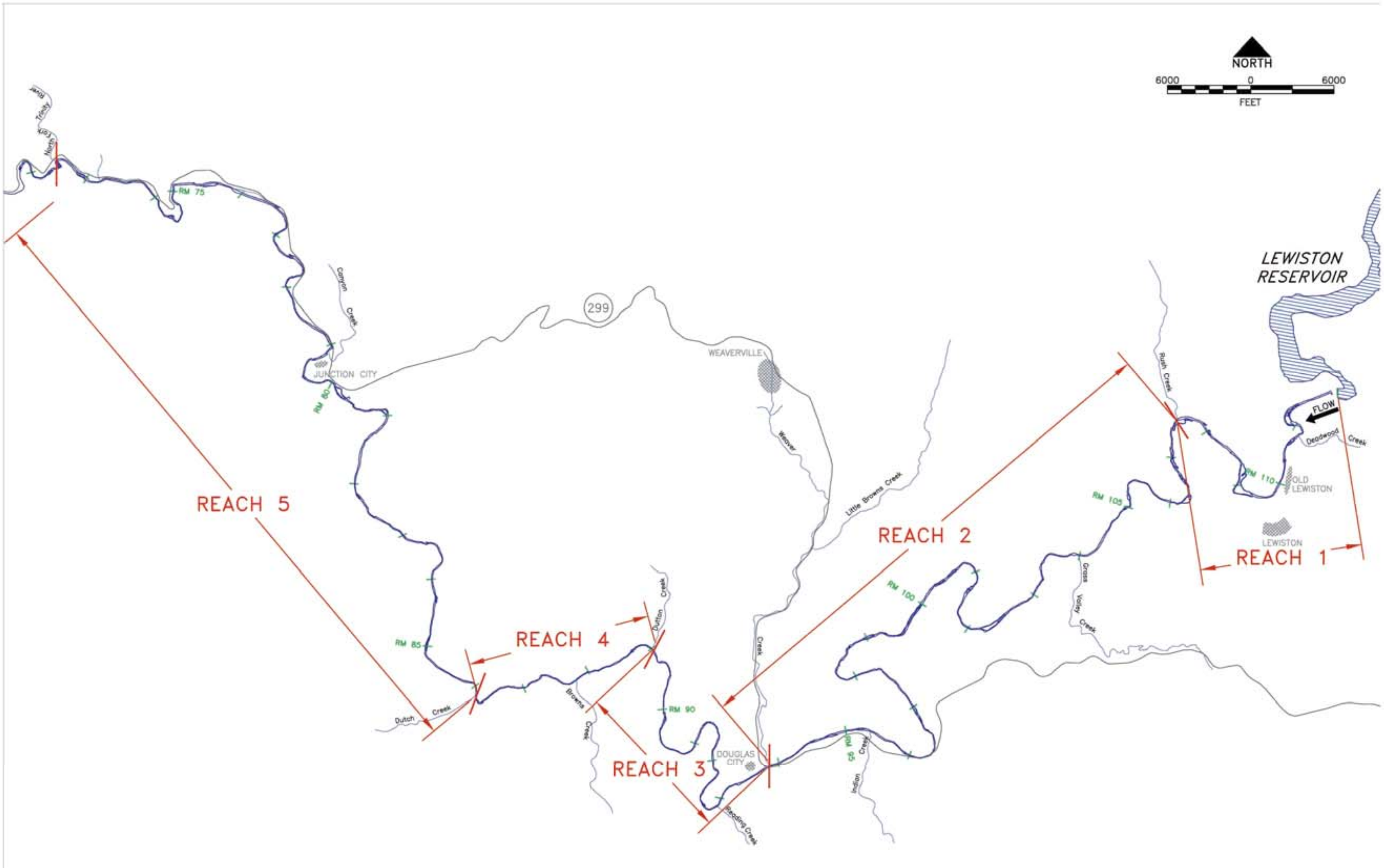


Figure 2.3. Study area of interest between Lewiston Dam and the North Fork of the Trinity River, showing proposed sub-reach boundaries (Table 2.2).

Table 2.2. Physiographic Reach Delineation for the Trinity River mainstem between TRD and the Trinity River North Fork.

Reach	RM	Description	Valley width	Coarse sediment deficit/routing	Tributary-induced impacts on mainstem	Residential density and encroachment	Hydrologic related riparian berm disturbance	Dredger mining impacts
1	111.0 to 107.8	Lewiston Dam to Rush Creek Boat Launch	Moderately Confined Valley	High	High	Moderate	None-Low	Moderate-Low
2	107.8 to 93.8	Rush Creek Boat Launch to Weaver Creek	Moderately Confined Valley	Moderate	Moderate	Moderate-high	Low	Moderate
3	93.8 to 89.0	Weaver Creek to Dutton Creek	Moderately Confined Valley	None	Low	Moderate-low	Moderate	Moderate-High
4	89.0 to 86.3	Dutton Creek to Dutch Creek	Confined Canyon Reach	None	Low	Low	High	None
5	86.3 to 72.4	Dutch Creek to the North Fork Trinity River	Unconfined Valley bottom	None	Low	Moderate-high	High	High

3.0 Physical Subsystem

The physical subsystem collectively refers to mainstem Trinity River hydrology and fluvial geomorphic processes such as sediment transport/deposition, bed scour and large woody debris supply. This subsystem has the widest range of dependencies as all other submodels either directly or indirectly hold physical and/or process linkages to Trinity River hydrology and geomorphology.

3.1 Management actions directly affecting this subsystem

A distinctive feature of the physical subsystem is that it affects most other submodels. The principal management actions implemented by the physical subsystem are flow releases from Lewiston Dam, fine and coarse sediment management downstream of Lewiston Dam, and channel rehabilitation between Lewiston Dam and the North Fork Trinity River. These three categories of management actions are described in more detail below and listed in Table 3.1.

3.1.1 Flow releases from Lewiston Dam

The magnitude, duration, and timing of flow releases from Lewiston Dam are unique for each water year, and are intended to satisfy unique geomorphic and biological objectives for each water year. Cumulatively, satisfying these yearly objectives is intended to satisfy program goals (e.g., restoring salmonid smolt production, increasing adult salmonid escapement, restoring riparian habitat). The flow magnitude, duration, and timing are recommended in the TRFE, but the specific release patterns can be adjusted within the AEAM process to best achieve objectives on a yearly basis. This release flexibility is constrained by fixed annual flow release volumes as mandated in the ROD. Descriptions of the annual flow releases below focus on the portion of the hydrograph intended for achieving objectives of the Physical Subsystem.

Extremely Wet water year:	11,000 cfs for approximately five days, followed by 6,000 cfs for approximately five days.
Wet water year:	8,500 cfs for approximately five days, followed by 6,000 cfs for approximately five days.
Normal water year:	6,000 cfs for approximately five days.
Dry water year:	4,500 cfs for approximately five days.
Critically Dry water year:	1,500 cfs for approximately 36 days.

Certain water years may have substantial changes to the flow magnitude and duration in response to year-specific needs (e.g., a Normal water year following consecutive dry years may need a higher magnitude, shorter duration peak flow to scour the bed surface and remove encroaching riparian seedlings).

Water Temperature

In addition to providing and restoring fish and riparian habitats and improving fluvial geomorphic processes, ROD flows are also expected to provide temperature regimes suitable for anadromous salmonids and other aquatic species of concern. Under the TRFE/ROD, Lewiston Dam will be operated to release additional water to the Trinity River and the timing of exports to the Central Valley shifted to later in the summer if needed to help meet Trinity River instream temperature requirements. Historical temperature objectives specify flows of at least 450 cfs be provided during the summer until October 15th, after which ambient conditions are typically cool enough to warrant reducing flows (e.g., State Water Resources Control Board 1991). The associated temperature objectives these flows are meant to support in the Trinity River are in the 56 to 58°F (13.3 to 14.4°C) range between July 1st and December 31st, but depend on species, life-stage and location. Flow releases prescribed in the ROD that attempt to satisfy temperature objectives occur: (1) immediately before the spring high flows (usually May) in wetter years for steelhead smolt outmigration; (2) at the end of the snowmelt recession for Chinook and coho smolt outmigration; and (3) through the summer and early fall for adult spring-run Chinook salmon holding (Figure 3.1).

While real-time water temperature loggers are highly practical for tactical fine-tuning during in-season decision making, water temperature models are helpful for developing water temperature expectations under different climate years and reservoir operation alternatives. For instance, the Stream Network TEMPerature model (SNTEMP) is a one-dimensional heat transport model for branched stream networks that has been applied in the Trinity River. It predicts mean and maximum water temperatures as a function of stream distance and environmental heat flux. Net heat flux is calculated as the sum of heat to or from long-wave atmospheric radiation, direct short wave solar radiation, convection, evaporation, streamside vegetation (shading), streambed fluid friction, and the water's back radiation. The heat transport model is based on a dynamic temperature-steady flow equation and assumes that all input data, including meteorological and hydrological variables, can be represented by 24-hour averages. Typical applications include predicting the consequences of reservoir discharge on water temperatures.

The suitability and need of various water temperature models for developing water temperature expectations for different hydrographs is a topic requiring further attention and investigation.

3.1.2 Sediment management downstream of Lewiston Dam

Sediment can be divided into two size fractions: fine sediment (<8 mm) and coarse sediment (>8 mm). Fine sediment management will focus on *reducing fine sediment* supply via upslope watershed rehabilitation, trapping in sedimentation basins, potential net flushing during high flow releases, and if needed in the future, mechanical dredging from the channel itself. Additionally, many of the channel rehabilitation projects will be reducing fine sediment from the channel by removing riparian berms and spoiling the fine sediment out of the bankfull channel.

Coarse sediment management will consist of *augmenting gravels and cobbles* between 8 mm (5/16") and 152 mm (6") downstream of Lewiston Dam (RM 112) to Indian Creek (RM 95). Coarse sediment will likely be added through a variety of placement methods, including bank placement, bar placement, riffle placement, and direct placement into the river during high flows. The TRFE recommends yearly coarse sediment augmentation volumes ranging from up to 67,000 yd^3 during Extremely Wet years to 0 yd^3 during Critically Dry years. The actual coarse sediment volumes placed each water year will likely be altered from that recommended in the TRFE to ease implementation (less yearly variation) while achieving the intended long-term objective of increased coarse sediment storage, a balanced coarse sediment budget, and coarse sediment routing continuity.

3.1.3 Channel rehabilitation between Lewiston Dam and North Fork Trinity River

The controlled outlet works of Trinity Dam cannot release flows greater than 13,750 cfs (Cohen and Wahl 1998); flows significantly greater than 13,750 cfs are required to remove mature riparian vegetation and associated berms along the Trinity River. Therefore, mechanical removal of the riparian berm and rehabilitation of the channel morphology between Lewiston Dam and the North Fork Trinity River (RM 72.5) will be required. After berm removal and channel rehabilitation, the ROD flow regime is intended to improve and maintain this restored channel morphology. Channel rehabilitation will occur at approximately 46 sites, with the majority consisting of bank rehabilitation sites (43), and a smaller number of side channel creation sites (3). The locations and precise number of these sites may be adjusted as implementation proceeds and the sites are evaluated. Additionally, manipulation of two tributary deltas may be considered if the ROD flow regime is insufficient to adequately route the coarser sediments delivered by the tributaries.

Bank rehabilitation

Bank rehabilitation actions may include one or more of the following actions: riparian berm removal on the outside of meander bends; riparian berm removal on the insides of meander bends; creation of exposed gravel/cobble point bars; construction of floodplains; construction of backwater alcoves; construction of high flow scour channels; strategic placement of large wood in alcoves, side channels, and high flow scour channels; and construction of low flow side channels. Specific design elements will be determined by individual site conditions (e.g., existing meander geometry, bedrock control, human infrastructure, risk assessment, existing habitat features).

Side channel construction

The TRFE identified three potential sites for side channels to be constructed that are independent of bank rehabilitation sites. These side channels are intended to increase fry and juvenile salmonid rearing areas, and to be self-maintaining. As mentioned above, additional side channels may be constructed within individual bank rehabilitation sites, and may include placement of large wood to improve rearing habitat.

Delta manipulation

Due to the reduction in post-dam high flow regimes, problematic aggradation has occurred at the Rush Creek, Grass Valley Creek, and Indian Creek tributary deltas. This aggradation has created large backwater pools upstream of the deltas, prevented full sediment routing through these pools, and has increased flooding of human infrastructure. The Grass Valley Creek aggradation problem has been alleviated by the construction and maintenance of the Hamilton Ponds sedimentation basin; however, aggradation continues at the Rush Creek and Indian Creek deltas. If the ROD high flow regime is insufficient to reverse aggradation at these deltas, then physical manipulation of these two deltas may be considered (e.g., mechanical removal, debris basins, channelization).

Table 3.1. Flow and channel rehabilitation management actions in the ROD that target physical process objectives.

#	Action	Description
A	Extremely wet year flow releases*	11,000 cfs peak flow release for approximately 5 days
B	Wet year flow releases*	8,500 cfs peak flow release for approximately 5 days
C	Normal year flow releases*	6,000 cfs peak flow release for approximately 5 days
D	Dry year flow releases*	4,500 cfs peak flow release for approximately 5 days
E	Critically dry year flow releases*	1,500 cfs peak flow release for approximately 36 days
F	Channel rehabilitation	At approximately 46 sites: -Remove riparian berm -Reconstruct functional floodplains -Construct side channels and high flow scour channels on floodplains -Place large wood
G	Coarse sediment augmentation	Volumes range from zero during drier years to tens of thousands of yd^3 during wetter years Placement methods may include in-channel placement, high flow placement, recruitment piles, and gravel bars Grain size will range between 8 mm and 152 mm Placement will be between Lewiston Dam and Indian Creek, and occur on a yearly basis (except possibly during drier years)
H	Fine sediment source control	Tributary watershed restoration efforts targeted to reduce management related fine sediment yield Sedimentation basins on Grass Valley Creek High flow releases from Trinity and Lewiston dams Riparian berm removal and spoils of berms outside of the post-dam floodway
I	Mechanical fine sediment storage reduction (optional)	Consider mechanical methods for reducing mainstem fine sediment storage if tributary fine sediment source control and increased flow releases do not adequately reduce mainstem fine sediment storage
J	Mechanical delta manipulation (optional)	Consider mechanical manipulation of Rush Creek and Indian Creek tributary deltas to improve sediment routing if tributary fine sediment source control and increased flow releases do not adequately control delta formation

* Ignores “piggybacking” releases with tributary floods, specific magnitude and duration may vary each year to balance various restoration objectives.

3.2 Key performance measures

Physical system performance measures serve as the foundation for biological performance measures. The Trinity River Flow Evaluation study identified ten attributes of alluvial river integrity that guide the physical subsystem performance measures. These performance measures (e.g. coarse sediment budget) need to be interpreted with a regard for biological relevance. As the physical subsystem is principally a supplier of information to biological subsystems, the value of actions implemented there is generally measured by the biological performance measures. The physical system performance measures address a variety of spatial scales, and these performance measures are summarized in Table 3.2. The primary goal of the physical system changes is a conversion to a scaled down dynamic alluvial channel; we hypothesize that achieving the objectives listed in Table 3.2 will create a dynamic alluvial channel. However, in general the following features are believed to be desirable:

- a more sinuous channel;
- increased diversity in the longitudinal profile and number of dynamic alternate bar sequences;
- a floodplain frequently accessible by the future flow regime;

- fine sediment deposition on the floodplain during over-bank flows;
- flow releases that provide suitable temperature regimes for salmonids;
- increased channel morphology and hydraulic complexity;
- increased exposed gravel bars;
- increased secondary high-flow channels; and
- increase in number of off-channel wetlands and side-channels (where appropriate/practicable).

Table 3.2. Potential physical system performance measures mapped to management objectives, with supplementary information on candidate monitoring approaches.

#	Objective	Performance Measure	Description	Candidate monitoring approach	Spatial Scale
1	Increase coarse sediment storage, balance coarse sediment budget, and achieve full coarse sediment routing.	Coarse sediment budget	Annually calculate the mainstem coarse sediment (>8mm) budget (Input - Output = Change in Storage) between Lewiston Dam and Weaver Creek. This 19-mile stretch is broken into 4 sediment budget cells to isolate the major management zones e.g., Lewiston Dam, Rush Creek, Grass Valley Creek, and Indian Creek.	Sediment budget cell input and output are developed from sediment monitoring (bedload sampling). The sediment storage is developed from bathymetric and tributary delta surveys.	Reach unit
		Exposed cobble/gravel bars	Surface area and/or volume of exposed cobble/gravel bars as defined by an aerial photograph taken at a 450 cfs baseflow.	Use low altitude, orthorectified aerial photographs taken at a 450 cfs baseflow in the fall to map exposed bars. Frequency of this monitoring should be on the order of every few years, or after a significant high flow event.	Lewiston Dam to the NF Trinity River
		Coarse sediment storage	Topographic change in storage.	Bathymetry either from ADP unit or from LIDAR, depending on cost and accuracy.	Lewiston Dam to Weaver Creek
2	Reduce fine sediment supply, create deficit in fine sediment budget, and decrease in-channel fine sediment storage.	Fine sediment budget	Annually calculate the mainstem fine sediment (<8mm) budget (input, output, storage) between Lewiston Dam and Weaver Creek. This 19-mile stretch is broken into 4 sediment budget cells to isolate the major management zones e.g., Lewiston Dam, Rush Creek, Grass Valley Creek, and Indian Creek.	Sediment budget cell input and output are developed from sediment monitoring (suspended load and bedload sampling). The sediment storage is developed from bathymetric and tributary delta surveys.	Reach unit
		Fine sediment storage (% fines)	Reduce fine sediment storage in the following units: - Pools - Spawning gravels - Bars Increase fine sediment storage in the following units: - Floodplains	Map surficial fine sediment storage in mainstem and floodplain after significant high flow events. For Pools, perform topographic surveying and surficial mapping. Can key out specific pools that are prone to sand storage and/or have been dredged in the past (see Wilcock et al 1995 for those pools). Scale for this could be the 8 dredged pools in the upper river. However, likely cannot extrapolate these because they have been dredged historically and are still evolving. For spawning gravels, a combination of bulk samples and permeability might be used, particularly within index reaches. There is substantial variability for both, so need stratified sampling via geomorphic features, and due to large sample size, may need to rely on index reaches only. For bars, consider surface bulk samples in stratified units as well as facies mapping to support bulk sample results. Scale would be on bars within index reach. For floodplains, cross section surveys and facies mapping.	Whole system Perhaps more appropriate on an index reach and bank rehab site scale

#	Objective	Performance Measure	Description	Candidate monitoring approach	Spatial Scale
3	Increase **amount** and diversity of rearing habitat types preferred by target aquatic organisms, esp. anadromous salmonids.	Geomorphic /planform aerial extent *{further work is required to define the specific PMs for this concept (i.e., variables measured in field or input into models, their units, etc.)}* *For bank rehab sites, fish and amphibian folks will likely need:* *1) Substrate map and size* *2) topography* *3) water surfaces* *4) local hydraulics* *5) scaled map* *6) changes in water surface stage and planform location as a function of flow* *7) cover*	Map geomorphic features in mainstem and floodplain after significant high flow events. Quantify change, aerial extent, patch size. *{Due to time constraints at Workshop 1, it was not possible for fisheries specialists to refine and clarify the specific geomorphic variables that are critical for various life stages and species. Further discussions are needed with fisheries biologists to determine the extent to which this variable ought to be used in the Trinity River}* Seems like we should focus on the PMs that the fish and amphibian folks will need, and not get too drawn into the fish PMs (e.g., Hydraulic diversity index)	Quantify fish habitat produced by geomorphic change at index sites. Candidate methods: a. substrate facies map b. cover element/vegetation map c. fish utilization mapping (experts) d. modeling @ chosen index flow levels (Tom Hardy's model – Utah State University) Overall: map the geomorph. planform (2d) and use as overall multiplier for entire 40 mi.	Index Reaches extrapolating to Whole system
4	Increase **diversity** of rearing habitat types preferred by target aquatic organisms, esp. anadromous salmonids.	Hydraulic diversity index (e.g., Tom Hardy) *{further work is required to define the specific PMs for this concept ((i.e., variables measured in field or input into models, their units, etc.)}*	Important in addition to fish habitat Hydraulic diversity index as described by Tom Hardy using 3-D plots of velocity, depth, cover. As geomorphic diversity increases, hydraulic diversity should also increase. Mapping or 2-D hydraulic model could document hydraulic diversity at a range of flows. *{Due to time constraints, it was not possible for fisheries specialists to refine and clarify the specific geomorphic variables that are critical for various life stages and species. Further discussions are needed with fisheries biologists to determine the extent to which this variable ought to be used in the Trinity River}*	Model based.	Geomorphic unit

#	Objective	Performance Measure	Description	Candidate monitoring approach	Spatial Scale
5	Mobilize and scour bed at a magnitude and frequency to prevent future riparian encroachment and thereby maintain a dynamic alluvial channel.	Bed mobility	Mobilize pool tails and other smaller grained gravel deposits by releases greater than 4,500 cfs (88% of years). Mobilize point bars, riffles, and other larger grained cobble/gravel deposits by releases greater than 6,000 cfs (60% of years).	Measure bed mobility on key geomorphic features by surveying cross-sections and installing tracer rocks.[deleted because we want this info for tributary floods as well]. Focus on key index reaches and bank rehabilitation sites.	Geomorphic unit
		Bed scour	Scour cobble/gravel point bars to a depth greater than 1D84 by releases greater than 8,500 cfs (40% of years). Scour cobble/gravel point bars to a depth greater than 1D84 by releases greater than 8,500 cfs (40% of years).	Measure bed scour on key geomorphic features by surveying cross-sections and installing scour cores/chains. Focus on key index reaches and bank rehabilitation sites.	Geomorphic unit
6	Improve substrate characteristics to increase survival of target aquatic organisms.	Substrate quality Gravel permeability		Characterize substrate particle size distribution (surface and subsurface) and aerial extent of major D_{50} size classes using pebble counts, bulk samples, and video monitoring after significant flow events. Facies map for index reaches. <u>Questions/uncertainties:</u> Target criteria to differentiate “poor”, “satisfactory” and “good” restoration performance?	Hydraulic or Reach unit
7	Ensure that dam release hydrographs occur as prescribed in the ROD and accurately document flow magnitude in key tributaries and mainstem Trinity River locations.	Flow magnitude, duration, and timing	Gaging station at Lewiston and stations on Rush Creek, GVC, Indian Creek, Limekiln Gulch, Douglas City, Junction City, and Burnt Ranch (priority sites).	Operate and maintain a network of stream gages to accurately quantify 15-minute and daily flow rates.	Lewiston Dam to Burnt Ranch
8	Increase inundation area during flows greater than defined threshold, perhaps > 1,000 cfs.	Inundation area as a function of flow magnitude	High water mark staking during peak releases during significant flow events to determine inundated area and calibrate computer models (including those that calculate the WUA for various flow rates).	Inundation map for index flow levels, also cross section plots.	Reach unit
9	Reduce magnitude and duration of chronic turbidity.	Turbidity	Need to verify biological significance from a fish feeding perspective. With respect to fine sediment budget, turbidity may not be needed if we are collecting lots of suspended sediment samples. Care taken to eliminate costs with marginal informational benefits.	Turbidity probes at Lewiston, Douglas City, and Junction City would address potential fish impacts. Turbidity probes at other gages would be needed for using for fine sediment transport estimates.	Lewiston Dam to Junction City for fish, Specific gage locations upstream of Weaver Creek for fine sediment budget calculations

#	Objective	Performance Measure	Description	Candidate monitoring approach	Spatial Scale
10	Improve seasonal shallow groundwater fluctuation.	Floodplain and off-channel wetland groundwater elevation	Increased flow variability and improvement of seasonal high flows should improve shallow groundwater table elevations, which may be important for amphibians, turtles, birds, and other species. It is also very important for riparian vegetation initiation and establishment.	Continue monitoring existing piezometer networks to assess post-bank rehab construction ground water responses. Survey cross sections to relate water table to plants and geomorphic features.	Geomorphic unit
11	Provide suitable temperature regimes for salmonids based on TRFE life-history specific targets.	Water temperature	Thalweg/longitudinal temperatures (mile scale). Waters edge (microhabitat scale, collected by biologists). Tributary (for macro-invertebrates). Likely additional site specific temperatures in important habitats that may have different temperature regimes than the main body of the flow (e.g., backwaters, off channel wetlands, etc).	Thermographs at compliance points, as well as locations needed to run and calibrate the temperature model (additional mainstem nodes, as well as larger tributaries).	Reach unit

3.3 Target flow vs. time diagram

The physical subsystem does not itself 'have' any biota, so a *life*-history diagram is inappropriate. However, the TRFE suggests possible flow regimes for different water years (to go with the definitive total water volume allocations provided by the ROD). Thus, the timing, duration and magnitude of water year specific TRFE flows serve as an important *starting point* or reference in regards to how specific objectives are thought to be achieved (e.g., see Figure 3.1). Here it is important to recognize that the actual flow magnitude, duration, and timing release patterns can be adjusted within the AEAM process to best achieve objectives on a year-to-year basis.

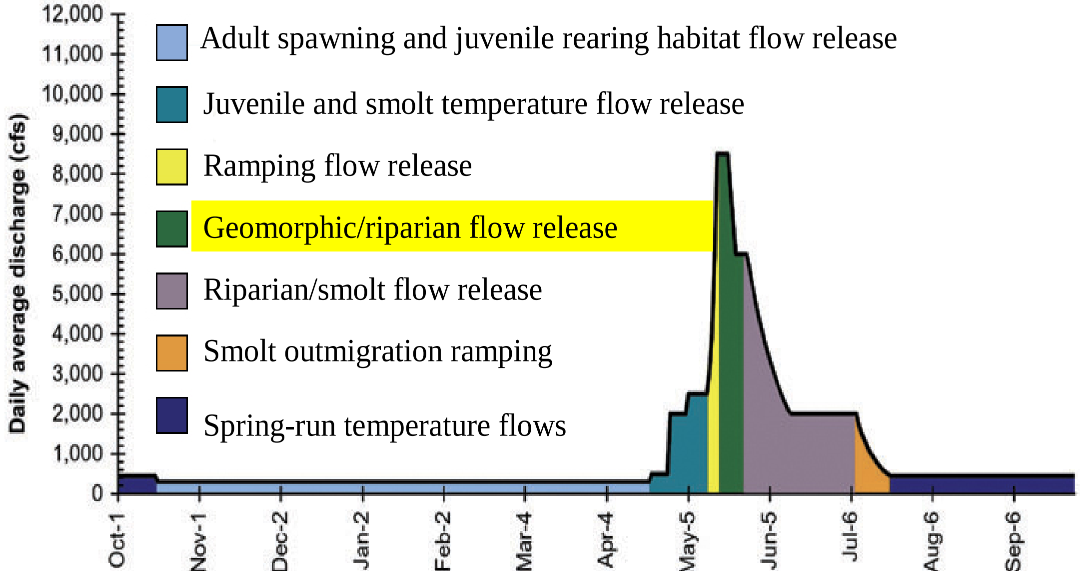


Figure 3.1. *Example* Trinity River hydrograph and flow related objectives (wet water year).

3.4 Conceptual diagram

The physical and biological components of an alluvial river are the product of how the flow regime interacts with the sediment regime, the large wood regime, and the underlying geology (Figure 3.2). Within this broader ecosystem perspective, more detail can be provided that links how management actions are intended to change the physical nature of the Trinity River, which enables biological conceptual models (riparian, birds, etc.) to interface with the physical process conceptual model. How will flow management, sediment management, and channel rehabilitation *change the physical state* of the river in a way that will restore salmonid production from the Trinity River?

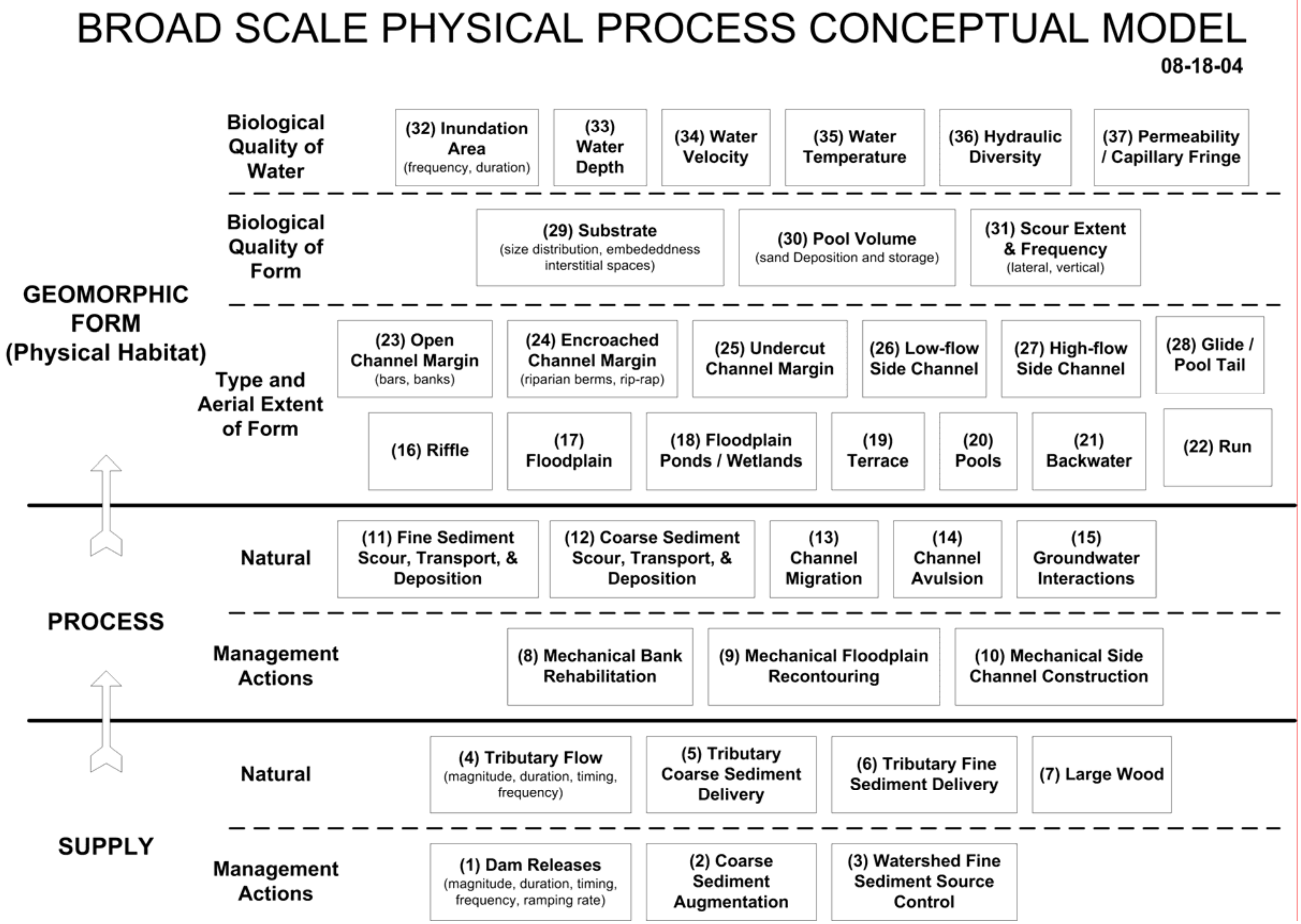


Figure 3.2. Broad scale physical process conceptual model. {Note: some of the geomorphic feature descriptions in this figure need to be updated, especially for cobble bars. Also the open channel margin box needs to be expanded to have more clarity on the issue of diversity. These updates were not available at press time}.

3.5 Statements of hypotheses/linkages and performance measures

Two scales of hypotheses have been developed for the physical system. Fine scale hypotheses are functionally the specific physical objectives developed in the TRFE, and the corresponding management actions developed to achieve those objectives (Table 3.3). Finer scale hypotheses mirror the Attributes of Alluvial River Integrity (USFWS and HVT 1999:180), and include bed mobility and scour of different geomorphic features, coarse sediment budget and routing, fine sediment reduction, channel migration and avulsion, floodplain formation, and shallow groundwater dynamics. The broader scale hypotheses (Table 3.4) result from the cumulative integration of the finer scale hypotheses, and provide linkages to the biological submodels. These broader scale hypotheses focus on creating and maintaining a dynamic alluvial river, increasing structural and hydraulic diversity of aquatic habitats, increasing quantity and quality of aquatic habitats, and increasing quantity and quality of riparian habitat. The most clearly understood and 'broadest' scale hypothesis for the physical system states that a 3 to 4 fold increase in salmon *rearing* habitat will result in a doubling of smolt production (Figure 3.3).

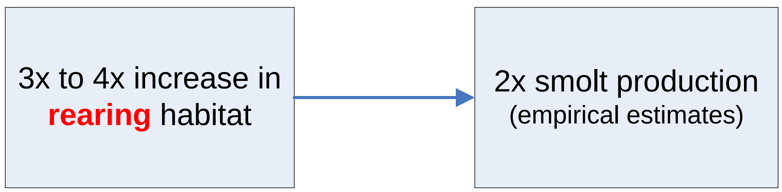


Figure 3.3. Overall hypothesis ("H_{big}") for upper 40 miles of Trinity River mainstem.

The performance measures of the finer scale hypotheses are fairly easy to measure and evaluate (e.g., bed mobility and scour). The larger-scale hypotheses are also fairly easy to evaluate (e.g., is the channel alluvial and free of riparian encroachment?), but monitoring and evaluating the intermediate linkages between the fine scale and large scale hypotheses are less clear.

Table 3.3. Hypothesis statement for restoration of alluvial process (fine scale).

#	Hypothesis	Linkage from broad scale physical process concept model	Management Actions from Table 3.1	Performance Measures from Table 3.2
AP1	Dam releases of 4,500 cfs will cause bed mobility in pool tails and medial bars.	1, 12, 20, 23, 28, 30, 31, 33, 37	D,G	7, 8, 9
AP2	Dam releases of 6,000 cfs will cause bed mobility in riffles and exposed point bars	1, 12, 16, 20, 23, 28, 30, 31, 33, 37	C, G	7, 8, 9
AP3	Dam releases of 8,500 cfs will cause shallow bed scour (1 D_{84} depth) on riffles and exposed point bars	1, 12, 16, 20, 23, 28, 30, 31, 33, 37	B, G	7, 8, 9
AP4	Dam releases of 11,000 cfs will cause shallow bed scour (>2 D_{84} depth) on riffles and exposed point bars	1, 12, 16, 20, 23, 28, 30, 31, 33, 37	A, G	7, 8, 9
AP5	Dam releases greater than 6,000 cfs, combined with riparian berm removal and coarse sediment augmentation, will initiate channel migration	1, 2, 8, 13, 16, 17, 18, 20, 23	A, B, C, F, G	1, 4, 5, 9
AP6	Flows greater than 30,000 cfs are required for channel avulsion and create, maintain, and abandon side channels	1, 2, 8, 9, 10, 14, 26, 27, 36	A, B, C, F, G	1, 4, 5, 9
AP7	Dam releases greater than 6,000 cfs, combined with riparian berm removal, will initiate floodplain formation and create functional floodplains	1, 2, 6, 8, 9, 11, 12, 15, 17, 32, 33, 37	A, B, C, F, G	2, 3, 9, 10

#	Hypothesis	Linkage from broad scale physical process concept model	Management Actions from Table 3.1	Performance Measures from Table 3.2
AP8	Dam releases greater than 6,000 cfs, combined with riparian berm removal, will initiate scour channel formation and maintenance	1, 2, 8, 9, 11, 12, 15, 17, 18, 27, 32, 33, 37	A, B, C, F, G	1, 4, 5, 9
AP9	Dam releases greater than 6,000 cfs, combined with coarse sediment augmentation, will restore full coarse sediment (>8 mm) routing in the mainstem Trinity River	1, 2, 8	A, B, C, F, G, J	1, 4, 5, 6, 8, 9
AP10	Dam releases greater than 6,000 cfs, combined with riparian berm removal, will restore a balanced coarse sediment budget in the mainstem Trinity River	1, 2, 8	A, B, C, F, G, J	1, 4, 5, 6, 8, 9
AP11	Dam releases greater than 2,000 cfs, combined with reduction of fine sediment supply from tributaries, will reduce fine sediment (<8 mm) storage in the mainstem Trinity River Reduce fine sediment storage in bed surface Reduce fine sediment storage in bed subsurface Deposit fine sediment on floodplains	1, 3, 8, 11, 16, 17, 28, 29, 30, 37	A, B, C, D, F, H, I	2, 3, 8, 9, 11
AP12	Dam releases greater than 6,000 cfs, combined with fine sediment reduction, will maintain or increase residual pool depth	1, 3, 8, 11, 20, 30, 33	A, B, C, F, H, I	2, 3, 4, 5, 9
AP15	Inter-annual and intra-annual dam release variability will result in correspondingly variable groundwater table fluctuation.	1, 15, 18, 37	A, B, C, D, E, F	9, 10, 12
AP16	Increased coarse sediment supply and transport will increase riparian seedling mortality along the low flow channel, reducing risk of riparian encroachment.	1, 2, 8, 12, 23	A, B, C, F, G	1, 7, 9

Table 3.4. Hypothesis statements for increasing physical habitat (broad scale).

#	Hypothesis	Management Actions from Table 3.1
1	Implementing restoration management actions will restore a scaled down dynamic alluvial river	A-G
2	Hypothesis 1 will increase geomorphic extent and diversity (pools, riffles, open channel margins, backwaters, side channels, floodplains, wetlands, etc.)	A-C, F, G
3	Hypothesis 1 will increase particle size diversity. (Within a reach, we expect a greater number of patches due to increased hydraulic complexity. Instead of a long run with homogeneous 8-inch cobbles, we want alternate bars and other complex habitat features, with patches of large cobbles in some areas, and small gravels in other areas.)	A-C, F, G
4	Geomorphic and substrate diversity, combined with variable flow releases, will create hydraulic diversity (water depth, velocity, inter-gravel flow)	A-G
5	Hypothesis 1 will increase floodplain diversity and complexity	A-C, F, G
6	Hypothesis 1 will maintain open channel margins by preventing future riparian encroachment	A-C, F-H
7	Hydraulic and substrate diversity, combined with Hypothesis 2 and 6, will increase aquatic habitat quality, quantity, and diversity.	A-H
8	Hypothesis 4 and 5 will increase riparian habitat quality, quantity, and diversity.	A-G

3.6 Identification of critical uncertainties and proposed method of testing alternative hypotheses

The primary physical process uncertainty in the ROD is whether a scaled-down alluvial river can be created and maintained in a regulated system by a combination of high flow releases, fine and coarse sediment management and mechanical channel rehabilitation. This approach, while intuitively feasible and logical, has not been attempted in the United States to date. Ultimately, the method of evaluating this uncertainty is simple: after implementing the channel rehabilitation, high flow regime, and coarse sediment augmentation actions, ask 1) does riparian encroachment recur and 2) are the attributes of alluvial rivers re-established and maintained? Additional physical process uncertainties are listed below, with initial suggestions on methods to address these uncertainties. It is worth stating that empirical hypothesis testing/data collection and model-based refinement/updating are *mutually reinforcing* and beneficial (Figure 3.4). For instance, empirical observations of smolt production are required if "H_{big}" is to be evaluated (Figure 3.3).

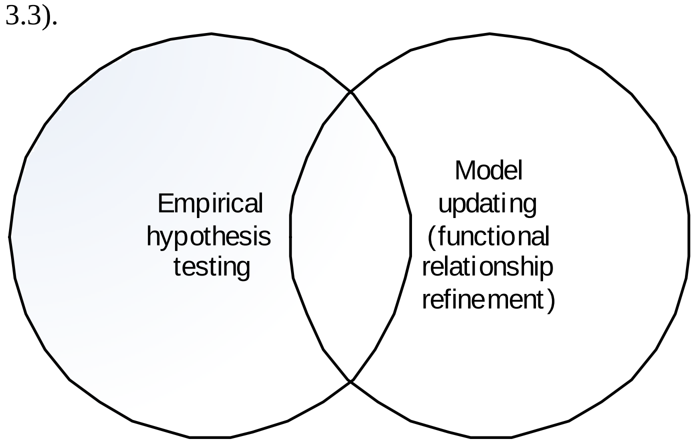


Figure 3.4. Monitoring aimed at evaluating management actions and reducing critical uncertainties requires a combination of empirical hypothesis testing and model updating.

Is the magnitude and frequency of high flows sufficient to prevent riparian encroachment and thus preserve a dynamic alluvial channel morphology? Are the magnitude and frequency of high flows sufficient to overcome riparian initiation along the low water edge during sequences of dry water years? What is the impact of eliminating the winter floods that historically occurred?

- Geomorphic / sediment monitoring: bed mobility monitoring, bed scour monitoring, hydrologic monitoring
- Geomorphic /sediment modeling: 2-D hydraulic and bed scour modeling
- Riparian monitoring: band transect monitoring of riparian seedlings before and after high flow events, and before and after seed dispersal and riparian growth
- Flow monitoring: streamflow gaging, having good accuracy at high flows

Are the magnitude, duration, and frequency of high flows sufficient to restore coarse sediment routing through the Rush Creek and Indian Creek tributary deltas without mechanical maintenance? Are the magnitude, duration, and frequency of high flows sufficient to prevent further aggradation at the Rush Creek and Indian Creek tributary deltas without mechanical maintenance?

- Geomorphic monitoring: topographic surveys, particle size distributions
- Geomorphic modeling: sediment transport modeling (one or two dimensional)

Are the magnitude, duration, and frequency of high flows, combined with fine sediment (sand) reduction efforts on tributaries, sufficient to reduce fine sediment storage in the Trinity River? Will mechanical fine sediment removal (e.g., pool dredging) be needed?

- Geomorphic monitoring: fine bedload sediment transport measurements (e.g., Helly-Smith sampler or modified Bunte sampler), suspended sediment sampling on mainstem and tributaries, change in bed storage of fine sediment monitoring (surface coverage, VSTAR, residual pool volume, change in pool volume), change in fine sediment transport rating curves, hydrologic monitoring
- Geomorphic modeling/computations: fine bedload sediment transport rating curves, suspended sediment rating curves, fine sediment budget computations

Will the magnitude, duration, and frequency of high flows, combined with fine sediment reduction efforts, result in reduced fine sediment storage in alluvial features used for spawning and rearing?

- Geomorphic monitoring: surficial fine sediment storage mapping (e.g., Kondolf, Matthews, and Wilcock), use index reaches to evaluate surface and subsurface storage of fine sediment (bulk samples, embeddedness, pebble counts, permeability)
- Geomorphic modeling/computations: none

Are the magnitude, duration, and frequency of high flows, combined with strategic channel rehabilitation projects, sufficient to restore channel migration through pre-dam floodplain substrates?

- Geomorphic monitoring: channel planform monitoring via orthorectified air photos, channel migration at specific sites via cross section monitoring, hydrologic monitoring
- Geomorphic modeling: Channel migration modeling

Will silt and fine sand deposition on floodplains occur given that upstream dams trap silts and fine sands, and dam releases are out of phase with downstream tributary floods that supply silts and fine sands?

- Geomorphic monitoring: fine sediment deposition monitoring on constructed floodplains, roughness mapping, substrate mapping, hydrologic monitoring, suspended sediment and/or turbidity monitoring on mainstem and tributaries
- Geomorphic modeling: hydraulic modeling, compare local shear velocity to particle settling velocity

Should coarse sediment augmentation and high flow release efforts be conducted to maintain a balanced coarse sediment budget on a yearly basis or a multi-year basis?

- Geomorphic monitoring: change in bed storage monitoring
- Geomorphic modeling: GSTARS, Sediment wave dispersal modeling (Cui, Parker, Lisle)

Can available sediment monitoring and modeling tools provide an adequate level of precision to be useful in developing yearly high flow release magnitude and duration, as well as long-term coarse sediment augmentation volumes?

- Geomorphic monitoring: sediment transport measurements (e.g., Helly-Smith sampler, modified Bunte sampler), volumetric sampling (tributary deltas, depositional zones, erosion zones), change in bed storage monitoring, hydrologic monitoring
- Geomorphic modeling/computations: GSTARS, sediment transport rating curves

3.7 Summary of Workshop 1 discussions (Physical Subsystem)

Subgroup participants agreed that the overarching hypothesis guiding development of the geomorphic monitoring program is whether a 3 to 4 fold increase in salmonid *rearing habitat* will lead to a doubling of *smolt* production.[3] It is therefore essential that restoration actions and monitoring must evaluate ecosystem-scale change over the upper 40 miles of the Trinity River mainstem and not be overly focused on fine-scale physical changes. Ideally, both scales of monitoring should be conducted, with the fine scale illustrating the cause-and-effect mechanism for the ecosystem-scale change.

Participants at the workshop felt that the hypotheses identified in Section 3.5 were all important and feasible to test. Discussions therefore focused on clarifying and prioritizing specific performance measures associated with the various hypotheses of effect. This was principally done by discussing the appropriate scale and general methodology that should be used to measure these performance measures. Because of this approach (which was strongly preferred by participants), there was a blurring of terminology in discussions with respect to ‘objectives,’ ‘performance measures’ and ‘tools/techniques’ for collecting data.

Performance measures

There was consensus that:

- Variables to be measured in the field—i.e., performance measures—need to be distinguished from objectives. For example, “reduce in-channel fine sediment storage” is an objective. A key performance measure for this objective might be “the % fines in surface and subsurface sediments.”
- The list of specific performance measures which map to “geomorphic diversity,” “hydraulic diversity” and “sediment quality” still need to be **explicitly** defined.
- Monitoring methods need to be distinguished from performance measures.
- Pilot studies are needed to quantify the relative measurement error levels associated with different methods of gathering data (e.g., LiDAR bathymetry vs. bedload rating curves).
- Target criteria for individual performance measures are needed, even if subjective, to differentiate “poor,” “satisfactory” and “good” restoration performance.
- Water temperature is a critical physical performance measure.
- Need clearer definition of baseline conditions against witch future TRRP flows and restoration actions will be compared.
- Empirical hypothesis testing/data collection and model-based refinement/updating are mutually reinforcing and beneficial.

Subgroup participants agreed that it is critical to ensure the hydrologic and geomorphic variables selected for monitoring include those which are key to other ecosystem components. This is especially important for fish. Due to time constraints and the size of the fish subgroup at the October workshop, it was not possible for fisheries specialists to refine and clarify the *specific* geomorphic variables that are critical for various life stages and species. As a consequence, uncertainty surrounds the extent and composition of

[3] Thus – while the TRRP geomorphic monitoring program must be able to quantify/characterize the amount of juvenile salmon rearing habitat created, tripling habitat alone is NOT a measure of restoration success if the concomitant smolt production–*empirically estimated*–does not show a doubling. This further reinforces the need for both physical and fish subsystems to be explicit about the baseline time-frame and observational data against which habitat and smolt production changes will be gaged.

variables most critical for the geomorphic and hydraulic diversity performance measures. Within the physical subgroup, Thomas Hardy's work on the Klamath River and research at Utah State University related to 2-D hydraulic simulation techniques for fish population habitat quantification, and multispectral remote sensing techniques for the classification of these habitats figured prominently in discussions.

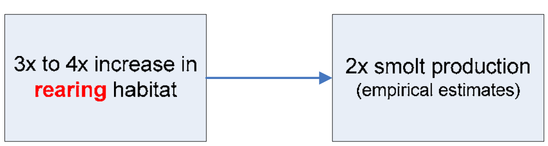
Further discussions are needed with fisheries biologists to determine the extent to which 2-D physical habitat simulation and remote sensing ought to be used in the Trinity River. Such discussions should follow the Looking Outward Matrix methodology. That is, the discussion should be led by fisheries biologists after considering this question: "*what do fisheries biologists need to know about the hydrologic and geomorphic subsystem to be able to explain the behavior of fish populations, and reliably attribute their responses to restoration actions*?" This explicitly acknowledges that hydrologists and geomorphologists are required to answer the demands put to them by fisheries biologists (and to produce their own system's performance measures)—and that is all.

Spatial scale and general approach for monitoring

System scale (40 miles Trinity River mainstem) change is the scale at which efforts of the TRRP will be judged. System scale monitoring requires high resolution / index reach[4] assessments at a handful of sites to build process level understanding from which observations may be extrapolated to the entire 40 miles of the Trinity River mainstem. Geomorphic planform mapping of the entire 40 mile mainstem will be used to classify habitat types and serve as the foundation for expanding the index reach observations of physical variables. This extrapolation will be based on the proportional area of these habitat types found on the 2-D planform map for the 40 mile stretch of Trinity mainstem.

By way of a **highly** simplified example, if the parameter of interest *x* were the number of spawning redds, one would estimate this number at a randomly sampled subset of viewing locations within the index segments. In addition to other important forms of sampling protocol standardization, a sufficient degree of random sampling will be critical to avoid convenience sampling and the inevitable sampling biases (i.e., unrepresentativeness) that this practice engenders.[5] For our example, let's say the average number of redds observed on sampled viewing locations was 300. Assuming then that the mesohabitat type these redds occurred on was best categorized as "riffle," and these riffles constituted 5% of the overall habitat area from our planform map, and the fraction of total riffle area observable at our randomly chosen viewing locations was 60%, the total number of spawning redds over the 40 mile mainstem would be 300/0.05/0.6 = 10,000 redds.

The question of what constitutes a suitable geomorphic baseline for these studies was raised in passing, but not addressed in any detail. For instance, in the case of "H_{big}", what is the baseline rearing habitat area that is to be used to quantify a tripling or quadrupling?



4 ~ 0.5 to 2 mile segments, chosen using non-random, "representative" sampling.

5 e.g., consider EMAP approach (EPA 2002) for site selection, where one divides channel distance by some standardized interval often based on channel width, then randomly samples these river miles.

Data requests made by other subsystems

Considerable emphasis was placed on various types of map-based information for the future monitoring program. The details of the specific data needed requires further review, exposition and *prioritization*.

Suggested next steps / questions

- Define the locations/extent of 5–8 index reaches, ~ 1–2 miles in length (1–2 in each physiographic river section). Define sub-areas within these locations to develop a sampling frame and subsampling scheme that allows for **random** selection to limit convenience sampling and other biases.
- Baseline condition. What information must be known prior to the next 8500 cfs release?
- If feasible, identify suitable control sites. How are fish populations responding in other systems, e.g., North Fork Trinity River? Rogue River? Eel River? Non-CVP River? These control sites would be used for fish population responses, not physical response differences.
- Define set of index flows suitable across subsystems to quantify biological habitat at index reaches.
- From needs identified by fisheries biologists, clarify extent/importance of—and methodology for—generating hydraulic diversity index for fish populations.
- What contrast can/ought to be designed into 24 channel rehabilitation sites.
- Solicit fisheries biologists to determine what vegetation cover types are beneficial to rearing fish.
- What broad scale mesohabitat classification scheme will be used for 40 miles of Trinity? At Workshop 1, Rod Wittler referred to a classification scheme with 43 mesohabitat types. Is this appropriate here? How fine does the TRRP want to go?

4.0 Riparian Vegetation

Simplified channel geometry in the Trinity River is a result of riparian vegetation encroachment following significant flow reduction with the completion of the Trinity River Division (TRD). The current post-dam flow regime is incapable of removing currently encroaching riparian vegetation and of inhibiting future encroachment, from the North Fork to the Lewiston Dam along the 40 miles of the mainstem. The Trinity River Flow Evaluation study (TRFE) showed that simplified channel geometry as a result of vegetation encroachment has resulted in a loss of fish habitat. Conditions along the mainstem should improve with implementation of hydrological and geomorphic restoration activities directed in the ROD.

4.1 Management actions directly affecting this subsystem

The key *geomorphic* management actions for the restoration of riparian vegetation are:

1. bank rehabilitation site design, emphasizing inundation area, frequency and scour zones;
2. constructed geomorphic units where inundation and scour should occur; and
3. vegetation removal and replanting.

A key to successful revegetation of riverine systems is linking a re-scaled alternate bar morphology to annual variation in hydrologic conditions. Natural variation in the frequency of: 1) hydrologic scour of the channelbed; 2) inundation; and 3) duration of flood events are reflective of a healthy alluvial river system. Physical rehabilitation intends to remove encroaching vegetation and construct ecologically functional floodplains, recreating the ecological processes that riparian hardwoods require. Computer simulations of spring snowmelt through dam releases show that semi-annual inundation of these re-scaled functional floodplains will promote riparian plant regeneration on constructed floodplain surfaces while restricting riparian plant regeneration along the low water where encroachment begins. These data will be used to simulate physical conditions and to make informed decisions. Ultimately through both physical and streamflow rehabilitation our goal is to promote a patchy and diverse riparian vegetation in association with a heterogeneous upland ecotone typical of the Trinity River Basin, while inhibiting vegetation encroachment along low water edge.

4.2 Key performance measures

The primary goal of the Trinity River Restoration Program at proposed bank rehabilitation sites is to physically rehabilitate the geomorphic form and function of a natural alluvial river channel that is scaled to the contemporary hydrologic regime of the Trinity River mainstem. The result will be a smaller, alluvial channel that exhibits most of the geomorphic, fluvial, and biological characteristics of a healthy alluvial system given a managed and predictable flow regime. Physical rehabilitation combined with active revegetation and natural regeneration should help promote attributes of a healthy river system including development of:

- self-maintaining riparian vegetation;
- off-channel pocket wetland complexes of various sizes;
- diversified riparian and upland plant assemblages; and
- structurally diverse upland ecozones.

Section 4.5 provides a more detailed listing of specific performance measures, mapped to individual hypotheses/linkages.

4.3 Life-history vs. time diagram

Two riparian hardwood species (black cottonwood and narrowleaf willow) and their principal life-history events (seed dispersal period, active growth, and dormancy) are shown in Figure 4.1. The figure highlights the differences in water releases to the Trinity River mainstem relative to pre- and post-Lewiston Dam periods.

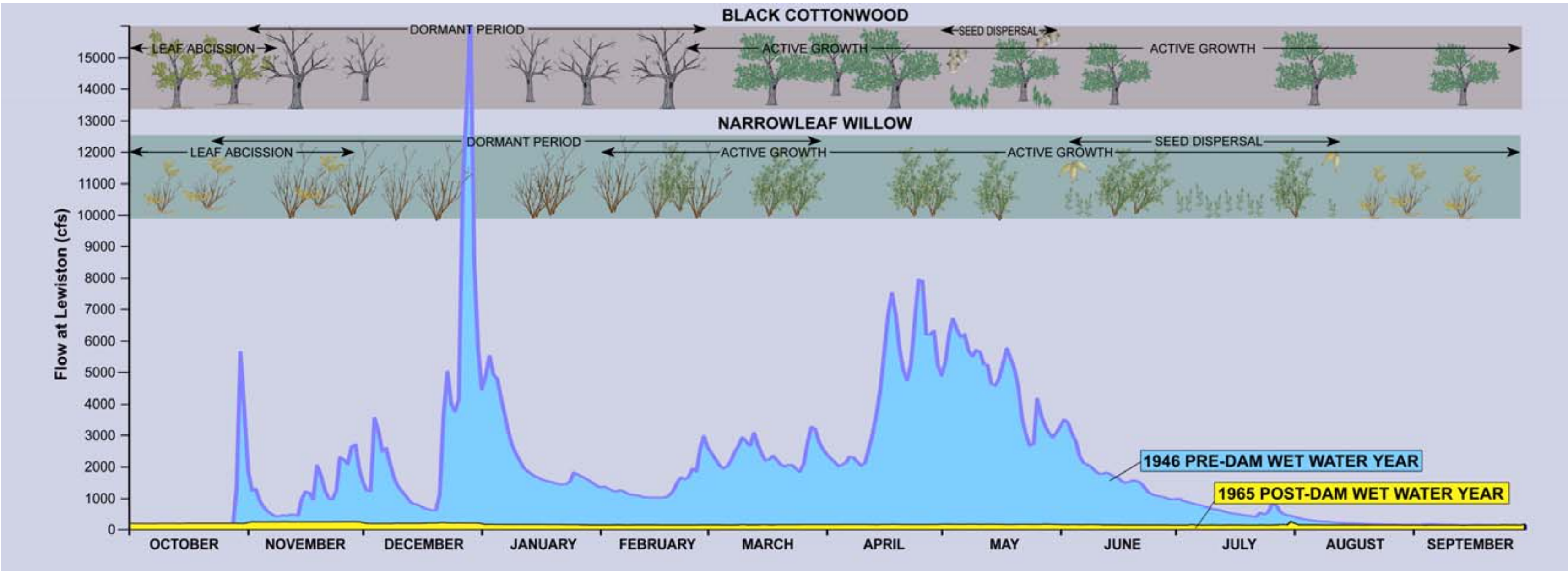


Figure 4.1. Overall life-history event timing for black cottonwood and narrowleaf willow relative to pre- and post- Lewiston Dam water regulation.

Riparian plants have developed strategies that allow them to persist along rivers indefinitely. Major factors that influence survival of plant seedlings include:

- streamflow magnitude due to winter precipitation and snow melt;
- frequency of overbank events due to winter precipitation and snow melt;
- the timing of peak streamflows related to winter precipitation and snow melt;
- rate of flow recession following snowmelt flood; and
- stability of summer baseflows.

Environmental conditions created by wet and dry years create the variation in annual flow regimes that influence regeneration success for riparian plant species. Thus, because variation in the success of regeneration is highly correlated with variation in the hydrological system, factors that lead to successful regeneration are largely associated with the hydrologic “niche” of the plant species (Table 4.1). The hydrological niche of the primary plant series found along the Trinity River functions as the draft template for revegetation designs at initial rehabilitation sites along the mainstem.

Table 4.1. Common cover types found along the Trinity River mainstem, associated discharge ranges within which each cover type falls, and the recurrence intervals of discharges before and after flow impairment at Lewiston Dam (river mile 112).

Cover Type	Recurrence Interval Range	Pre-Impairment Magnitudes (cfs)	Post-Impairment Magnitudes (cfs)
Narrowleaf willow	Summer baseflow to 1.5 yr flood	150–10,700	450–6,000
White alder	1.5–2 yr flood	9,000–17,100	6,000–8,000
Black cottonwood	1.5–10 yr flood	17,100–36,700	6,000–11,000

4.4 Conceptual diagram

Figure 4.2 provides the overall conceptual model for riparian initiation and establishment. Figure 4.2 also provides two high-level statements that characterize the aggregate hypotheses for riparian plant initiation and establishment processes (H1 and H2 respectively).

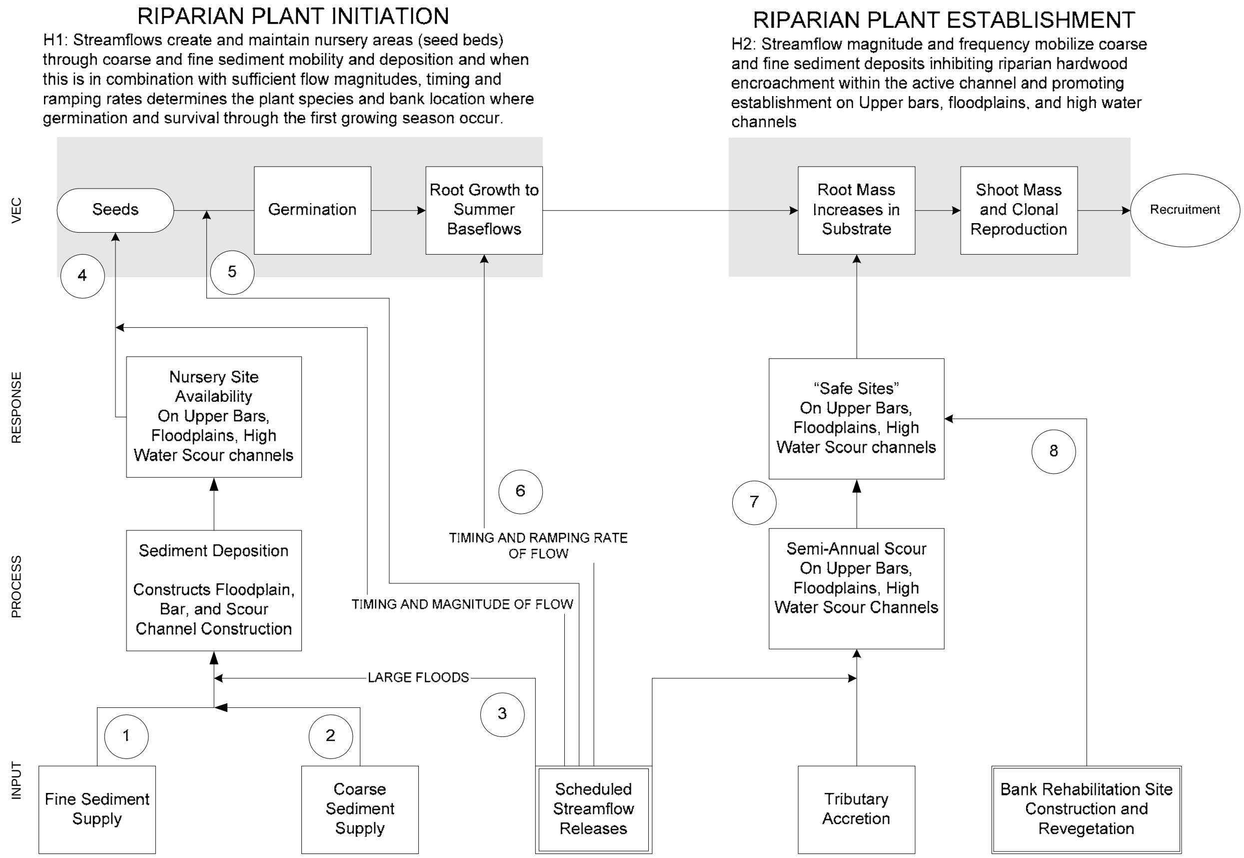


Figure 4.2. Conceptual model for riparian initiation and establishment. Numbered arrows refer to specific linkages/hypotheses. These hypothesis statements are provided in Section 4.5 below.

4.5 Statements of hypotheses / linkages and performance measures

Tables 4.2 and 4.3 summarize the process specific hypotheses and key performance measures associated with riparian initiation and establishment (as illustrated in Figure 4.2). Table 4.4. provides a more detailed description of the performance measures and analyses required to evaluate these hypotheses.

Table 4.2. Riparian hardwood initiation (A) linkages and (B) performance measures.

(A) -

Riparian Initiation Linkages

Link	Description	Performance measure	Class
1	Fine sediment deposition on floodplains increases the potential capillary fringe	1	Natural
2+3	Coarse sediment supply (i.e., gravel, cobble) and high flows create upper bars, floodplains and high flow scour channels via scour and deposition	2	Natural
1+3	Fine sediment supply (i.e., silt, washload) and high flows create seed beds via fine sediment deposition on floodplains and high flow scour channels	3	TRRP Action+Natural
4,5	High flows before or during seed dispersal creates moist seed beds for germination to occur	4	TRRP Action
6	Receding streamflow rates that are slower than root growth rates facilitates seedling survival	5	TRRP Action
1+6	More fine sediment (i.e., silt) on floodplains increases capillary fringe allowing a faster flow recession while facilitating riparian hardwood initiation	6	TRRP Action+Natural
7a	High flows are insufficient magnitude to cause frontal scour on upper bar, floodplain, and high flow scour channels allowing riparian hardwood establishment	7	TRRP Action
7b	High flows are sufficient in magnitude to cause local lateral scour mortality (i.e., channel migration) to prevent local establishment and maturation	8	TRRP Action
8	Riparian plantings on existing and constructed floodplains will maintain or increase established vegetation	9	TRRP Action

(B) -

Riparian Initiation Performance Measures

PM	Performance measures	Sampling scale
1	Area, distribution, and quantity of <2mm size classes at a site	Site
2	Area, distribution, and quantity of >2mm size classes at a site	Site
3	Age class distributions within different substrate areas (facies)	Site
4	Observable surface soil moisture during various species seed dispersal periods	Site/Reach
5	Presence/absence of <1 yr-old hardwoods at bank locations above the summer baseflow capillary fringe	Site
6	Presence/absence of <1 yr-old hardwoods in different substrate facies	Site
7	Presence/absence of <2yr-old hardwoods at bank locations above 2 year recurrence interval flood	Site/Reach
8	Presence/absence of <2yr-old hardwoods at bank locations below 2 year recurrence interval flood at migrating cross sections	Site
9	Riparian vegetation area preconstruction compared to post construction (over several yeas)	Site/Reach

Table 4.3. Riparian hardwood establishment (A) linkages and (B) performance measures.

(A) -

Riparian Establishment Linkages

Link#	Description	Performance measure	Class
7a	High flow magnitudes of 11,000 cfs will cause 2x the D84 scour resulting in the mortality of 3-yr old and younger riparian hardwoods on exposed bars within the bankfull channel	10	TRRP Action
7b	High flow magnitudes of 8,500 cfs will cause 1x the D84 scour resulting in the mortality of 2-yr old and younger riparian hardwoods on exposed bars within the bankfull channel	11	TRRP Action
7c	High flow magnitudes of 6,000 cfs will cause surficial channel bed mobility resulting in the mortality of 1-yr old and younger riparian hardwoods on exposed bars within the bankfull channel	12	TRRP Action
7d	High flow magnitudes greater than 6,000 cfs in combination with bank rehabilitation site construction will cause channel migration and associated lateral scour mortality of all riparian hardwood age classes	13	TRRP Action
7e	High flow magnitudes less than 6,000 cfs will not cause surficial or lateral scour mortality to establishing riparian hardwoods	14	TRRP Action
7f	A series of three or more consecutive years with flows less than 6,000 cfs will allow riparian hardwoods to grow beyond the ability of dam releases to scour them, causing encroachment	15	TRRP Action+Natural

(B) -

Riparian Establishment Performance Measures

PM	Performance measures	Sampling scale
10	Presence/absence of >3 yr-old hardwoods on exposed bars within the bankfull channel	Microhabitat/Site
11	Presence/absence of >2 yr-old hardwoods on exposed bars within the bankfull channel	Microhabitat/Site
12	Presence/absence of >1 yr-old hardwoods on exposed bars within the bankfull channel	Microhabitat/Site
13	Presence/absence of hardwoods at locations along migrating cross sections	Site
14	Presence/absence of hardwoods at locations along cross sections	Site
15	Presence/absence of hardwoods at locations along cross sections	Site

Table 4.4. More detailed description of proposed performance measures and information on methods for testing hypotheses to be used within overall riparian monitoring program, (A) initiation and (B) establishment.

(A)-

Performance Measure	Hypotheses/ links to which this PM applies	Overall spatial extent	Spatial resolution (s) at which PM will be measured / modeled (whole system, reach, 'smaller unit')[6]	Site selection procedure / rationale	Expected time for PM to respond to TRRP management actions	Recommended duration and frequency of monitoring	Baseline data holdings	Statistical analysis procedures for quantitatively testing hypotheses
1	1	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units where ecologically functional floodplains, and high water scour channel are constructed or currently exist	Location and extent to vary annually as a response to managed and natural streamflow	Annually	1996-1998, 2002,2003 facies maps	None
2	2+3	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units where ecologically functional floodplains, and high water scour channel are constructed or currently exist	Location and extent to vary annually as a response to managed streamflow	Annually	1996-1998, 2002,2003 facies maps	None
3	1+3	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units where ecologically functional floodplains, and high water scour channel are constructed or currently exist	Location and extent to vary annually as a response to managed and natural streamflow	Annually after seed dispersal, but before leaf drop	None	None
4	4,5	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	Daily and weekly with changes in streamflow stage	Annually during simulated snowmelt hydrographs and after the growing season is completed	1995-2003 sampling at pilot bank rehabilitation sites	None
5	6	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	Location and extent to vary annually as a response to managed and natural streamflow	Annually during simulated snowmelt hydrographs and after the growing season is completed	None	None

[6] Please specify what the smaller unit is (e.g., Geomorphic Unit Mesohabitat, Hydraulic Unit Microhabitat, Channel Rehabilitation site, Bird Census Site).

Performance Measure	Hypotheses/ links to which this PM applies	Overall spatial extent	Spatial resolution (s) at which PM will be measured / modeled (whole system, reach, 'smaller unit')[6]	Site selection procedure / rationale	Expected time for PM to respond to TRRP management actions	Recommended duration and frequency of monitoring	Baseline data holdings	Statistical analysis procedures for quantitatively testing hypotheses
6	1+6	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	Location and extent to vary annually as a response to managed and natural streamflow	Annually during simulated snowmelt hydrographs and after the growing season is completed	None	None
7	7a	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units where ecologically functional floodplains, high water scour channels and upper bars are constructed or currently exist	Location and extent to vary annually as a response to managed and natural streamflow	Annually before leaf drop	1995-2003 sampling at pilot bank rehabilitation sites	None
8	7b	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	Location and extent to vary annually as a response to managed and natural streamflow	Annually before leaf drop	1995-2003 sampling at pilot bank rehabilitation sites	None
9	8	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	All geomorphic units in a reach where bank rehabilitation site are constructed	Location and extent to vary annually as a response to managed and natural streamflow	0,1,3,5,10 years or after streamflows >6,000cfs	None	None

(B) -

Performance measure	Hypotheses/ links to which this PM applies	Overall spatial extent	Spatial resolution (s) at which PM will be measured / modeled (whole system, reach, 'smaller unit')[7]	Site selection procedure / rationale	Expected time for PM to respond to TRRP management actions	Recommended duration and frequency of monitoring	Baseline data holdings	Statistical analysis procedures for quantitatively testing hypotheses
10	7a	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	The growing season after streamflow magnitudes >= 11,000cfs	One growing season after streamflow magnitudes>= 11,000cfs	1995-2003 sampling at pilot bank rehabilitation sites	None
11	7b	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	The growing season after streamflow magnitudes >= 8,500cfs	One growing season after streamflow magnitudes >= 8,500cfs	1995-2003 sampling at pilot bank rehabilitation sites	None
12	7c	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	The growing season after streamflow magnitudes >= 6,000cfs	One growing season after streamflow magnitudes >= 6,000cfs	1995-2003 sampling at pilot bank rehabilitation sites	None
13	7d	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches at bank rehabilitation sites	Geomorphic units at bank rehabilitation site that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	The growing season after streamflow magnitudes >= 6,000cfs	One growing season after streamflow magnitudes >= 6,000cfs	1995-2003 sampling at pilot bank rehabilitation sites	None
14	7e	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	The growing season after streamflow magnitudes <6,000cfs	One growing season after streamflow magnitudes <6,000cfs	1995-2003 sampling at pilot bank rehabilitation sites	None
15	7f	All Reach Units between Lewiston Dam and the North Fork Trinity	Geomorphic Units within Reaches	Geomorphic units that are susceptible to riparian encroachment and/or where ecologically functional floodplains are constructed or currently exist	The growing season after 3yrs of flows <6,000cfs	One growing season after 3yrs of flows <6,000cfs	1995-2003 sampling at pilot bank rehabilitation sites	None

[7] Please specify what the smaller unit is (e.g., Geomorphic Unit Mesohabitat, Hydraulic Unit Microhabitat, Channel Rehabilitation site, Bird Census Site).

4.6 Identification of critical uncertainties and proposed method of testing alternative hypotheses

For riparian *initiation*, the overriding hypothesis to be tested is:

H_i: Streamflows create and maintain nursery areas (seed beds) through coarse and fine sediment mobility and deposition and, when combined with sufficient flow magnitudes, timing and ramping rates, this determines the plant species and bank location where germination and survival through the first growing season occur.

The associated critical scientific uncertainties surrounding this hypothesis are:

- The capillary fringe supported by the <2mm sediment size class is in excess of the river's water surface elevation, and provides a "buffer" to rapid changes in streamflow elevation.
- Riparian vegetation at restoration sites will cover a greater area and be structurally more complex than is currently the case.
- High flows remain at an elevation that is sufficient to create moist seed beds at desirable bank locations (i.e., floodplains).

In the case of riparian *establishment*, the overriding hypothesis to be tested is:

H_e: Streamflow magnitude and frequency mobilize coarse and fine sediment deposits, inhibiting riparian hardwood encroachment within the active channel and promoting establishment on upper bars, floodplains, and high water channels.

The associated critical scientific uncertainties surrounding this hypothesis are:

- Scour that is deeper than root depth is sufficient to kill the hardwood: there is no root density dependent function to scourability.
- The window of scour vulnerability is three years, not less.
- Planform location can enhance or hinder channel bed scour influence on hardwood mortality.
- A small number of establishing survivors (<5%) along the low water margin can lead to encroachment.

4.6.1 Monitoring design to assist with testing of hypotheses

The success of the TRRP at managing riparian vegetation should be determined by whether planted riparian hardwoods are thriving in their planted environments, less frequently occurring hardwood species are regenerating on constructed floodplains, and encroachment is being inhibited at bank rehabilitation sites along the low water edge. Riparian plant recruitment into revegetated floodplains should be similar in composition to less disturbed rivers in the same inundation regime in the region. A thriving riparian stand should have an increasing canopy cover and understory that is increasing in species richness, whereas the predicted pattern of riparian encroachment into the low water channel should be nonexistent. To evaluate our hypothesis, permanent plots established within each planted patch type and band transects sampled along cross sections will be used to quantify the following attributes:

- plant species composition;
- species-specific percent cover;

- maximum and average height;
- youngest and oldest hardwood age;
- stem number (for hardwoods < 7.5cm);
- root collar diameter and stem number (for plants > 7.5 cm);
- location of hardwoods relative to the low water margin and constructed floodplain surfaces;
- location of hardwood regeneration relative to the capillary fringe during initiation; and
- substrate practice size distributions at locations where hardwoods regenerate.

Additionally, groundwater elevations should be monitored and related to changes in river stage, which should complement band transect-based vegetation data. Evaluating the groundwater to river-stage relationship will facilitate understanding of the physical parameters that relate to the annual success or failure of initiating hardwoods at constructed bank rehabilitation sites.

It is expected that riparian vegetation will begin to encroach on the rehabilitated channel if plants are not semi-annually scoured from within the active channel. Band transect monitoring has been successfully used in the past to quantify the rate and degree of encroachment.

Monitoring should begin immediately following construction of each bank rehabilitation site. Monitoring should occur again at the end of the first growing season, or following two years of drought, or at the end of growing seasons in years where floods exceed bankfull, and at the end of the third, fifth, seventh, and tenth growing seasons.

4.7 Summary of Workshop 1 discussions (Riparian Subsystem)

Participants at the workshop placed a priority on reviewing hydrologic and geomorphic performance measures and possible monitoring methods. This resulted in only 50 to 60 minutes being allocated to a review of the riparian subsystem. While this time allocation was insufficient, in the opinion of the subgroup facilitator, participants appeared thoroughly impressed by the clarity and level of development of the riparian subsystem conceptual model, performance measures and proposed monitoring methods.

However, it was pointed out by John Bair that the current Trinity River riparian restoration effort emphasized low flow channel margin seedling initiation and bed mobility/scour monitoring (as per the TRFE, ROD) rather than floodplain restoration. John then emphasized that the restoration goals/vision for the riparian component would be strongly affected by prevailing views on the TMC regarding the endpoints sought for *floodplain* riparian restoration and its links with wildlife and birds. Several participants at the workshop independently raised the question of why riparian restoration actions and monitoring stopped at the establishment stage, and did not go on to consider riparian stand development and succession (e.g., in regards to the needs of wildlife and birds). Immediate guidance from the TMC is needed to definitively clarify whether floodplain riparian restoration should be: 1) limited to a strict compliance focus; 2) geared towards the notion of “no net loss” of riparian obligate wildlife/birds; or 3) targeting the production of a patchy, structurally diverse riparian zone.

Critical uncertainties

Another class of uncertainty that is relevant to Trinity River riparian restoration is unexpected events. For instance, there will be a need to re-evaluate flow release priorities following a string of dry years (e.g., trade-offs with temperature control).

Tactically, it was identified that desiccation can be used to mitigate against low-water margin vegetation establishment as could more rapid ramping down of flows, to place plants in zones where they are more susceptible to scour. Likewise, high flows during seed dispersal would "wash away" seeds, preventing germination.

The issue of "micromanagement" of the riparian system arose in relation to optimizing conditions for fish. Some fisheries biologists suggested that young seedlings were desirable cover elements for certain species and life-stages of fish, if these plants were under a certain age. Hydrologists/dam operators countered it would be impossible to provide such a fine level of control.

Performance measures

Consideration should be given to extending simple "presence/absence" indicators with some index of relative density or short-term seed deposition potential. Are one or two seedlings along *x* meters of bank as big a problem as 50 to 100?

General approach towards channel/riparian rehabilitation

The present plan calls for "banging all 24 sites down" within three years. Does this approach strike the best balance between learning and maximizing the reduction of time needed to observe system-scale benefits? What contrast can/ought to be designed into the 24 channel rehabilitation sites?

The TARGETS model will also be used to generate planform maps (at study sites) for the expected riparian establishment consequences of particular cross-section designs and hydrographs. These predictions can be compared with field data to ascertain the predictive ability of this model. If model results represent observed conditions in a reasonable fashion, the model may be used to help inform the types of hydrographs that best meet riparian restoration objectives.

Suggested next steps/questions

- Urgent—TMC to clarify goals/vision for riparian *floodplain* plantings.
- Hold discussions with bird, herpetology, and fish subsystem leads to make more explicit the information needs from the riparian subsystem (e.g., solicit fisheries biologists to determine what vegetation cover types are beneficial to rearing fish). Do the conceptual model and performance measures presented in the October 2004 Backgrounder Document cover what is needed? This was not well addressed at Workshop 1.
- Clarify approach towards riparian site designs (floodplain scope and desired levels of learning). Really "bang down" all 24 sites in 3 years?
- Clarify ecological baseline for 'post-restoration' riparian comparisons. What information must absolutely be known prior to the next 8,500 cfs release?

5.0 Fish

In the context of the TRRP, the overall restoration hypothesis for fish populations is:

Restoration of the fluvial nature of the river through mechanical alterations, managed high-flow releases, coarse sediment augmentation, and fine sediment reduction coupled with managed flow releases to provide suitable spawning/ rearing habitats and temperature regimes for salmonids will restore naturally produced salmonid populations in the Trinity River.

The purpose of this section is to provide background information suitable for beginning the process of designing a monitoring and evaluation program to track the short and long-term effectiveness of TRRP management actions. The content is structured as in the previous sections, using impact hypotheses to express the key linkages between management actions and fish. Section 2 provides details on the impact hypothesis approach. The content of this section is a synthesis of material provided by the TRRP Fish Subgroup prior to and during the October 2004 workshop.

Section 5 is organized as follows:

- Section 5.1 lists the TRRP ***management actions that directly affect the fish subsystem***. We refer readers to Sections 3.1 and 4.1 for details of the flow, physical and riparian actions rather than repeating that information here.
- Section 5.2 presents a list of candidate ***key performance measures*** for measuring the response of the fish subsystem to management actions. A key task for the Fish Subgroup between the first and second workshops is to filter and refine this long list down to a small subset of performance measures. These performance measures will be used to measure both long and short-term responses, and to improve the models used to guide annual management decisions about shaping flows for fish.
- Section 5.3 presents life-history vs. time diagrams for each of the fish species (coho, chinook and steelhead) and races (e.g., winter and summer steelhead) of primary interest. This information is provided to help with determining the timing and duration of monitoring relative to important life stage processes.
- Section 5.4 presents the conceptual models for the fish subsystem. These “impact hypothesis” diagrams are a graphic representation of the various hypothesized cause and effect “linkage pathways” between management actions, other system inputs such as tributary flows, and subsequent changes in alevin, juvenile, smolt, and adult spawner production.
- Section 5.5 presents explicit text statements of hypotheses/linkages and performance measures for the cause and effect pathways shown in the conceptual diagrams.
- Section 5.6 seeks to ***identify critical uncertainties and propose methods of testing alternative hypotheses***. This is where we have begun to collect information and ideas about how to integrate the information provided in Sections 5.1–5.5 into an integrated monitoring plan.

Summary of format of Fish Subgroup discussions from AEAM Framework Workshop 1

Given the large number of participants (~25), the complexity of the fish section in the Backgrounder Document (four conceptual models plus supporting text), and the tight schedule (about 45 minutes per conceptual model and hypothesis table combination), the fish subgroup focused on ***natural juvenile production*** and ***smolt production***. The subgroup discussions covered the following topics:

Format of Fish Subgroup discussions

- Reviewed/discussed the SALMOD model used for ROD analyses:
    - key uncertainties in the SALMOD conceptual model;
    - missing linkages—key uncertainties not currently considered by SALMOD;
    - data requirements / performance measures.

  This approach saved time since most members of the group were familiar with SALMOD from historic work on ROD issues. SALMOD has a lot of overlap with the fish conceptual models included in the workshop Backgrounder Document (the revised figures in this section indicate where overlap occurs).
- Reviewed / revised / prioritized the natural juvenile and smolt production hypotheses. The group used the SALMOD conceptual structure for discussion purposes (rather than the diagrams in the Backgrounder Document). Some performance measures were identified during the hypothesis review, but the group did not spend a lot of time discussing them at that time.
- Short focused discussion of performance measures.
- Looking Outward discussions with other subgroups.
- Further discussion of fish issues at the final plenary session , including SAB comments.

The information from all workshop discussions was integrated into the fish section of this document as follows:

1. Added a short summary of SALMOD, its original purpose, and key uncertainties—those captured and not captured in the version of SALMOD—and key points raised during subgroup discussions.
2. Added key SALMOD discussion points to the introduction.
3. Added a new figure to illustrate the SALMOD Conceptual Model (Figure 5a).
4. Revised the alevin, natural juvenile, smolt and adult production conceptual model diagrams to highlight the linkages that capture SALMOD conceptual hypotheses and assumptions.
5. Revised the Performance Measures section based on subgroup discussions (Table 5.1a and 5.1b).
6. Updated the hypothesis tables for natural juvenile and smolt production (Tables 5.2 and 5.3) based on subgroup discussions.
7. Updated the Uncertainties section with ideas raised at the workshop.
8. Updated the Looking Outward Matrix (Table 2.1).
9. Integrated the SAB comments made at the final plenary into the relevant sections.

10. Included information from a previous workshop[8] that focused on fish hypotheses and monitoring questions to bring this information forward for the next round of Fish Subgroup discussions (Appendix C). These hypotheses overlap significantly with the impact hypotheses presented in this document.

SALMOD Discussion

This summary reflects comments made during the workshop discussions around SALMOD. Given the short time spent on this discussion, these summary comments cannot reflect the depth of understanding and many years of research that have gone into SALMOD's development. Some additional information has been added to provide context for certain statements. The following references describe SALMOD's conceptual model and results of its application to the Trinity River for fall chinook: Williamson et al. 1993; Bartholow et al. 1993; Bartholow 1996; Bartholow et al. 2001. A description of SALMOD and its application during the Trinity River Flow Evaluation study can be found in Chapter 5, Section 5.6 of that report (USFWS and HVT 1999).

Results of SALMOD modeling led to the assertion that a 4-fold increase in fish habitat would lead to a two–fold increase in smolt production (USFWS and HVT 1999). SALMOD helped show that mechanical restoration of the river alone was not enough. Restoration had to be combined with natural processes driven by flow to achieve the goal. A 10-fold increase in habitat was required to achieve the doubling goal without flow increases. This result was the foundation of the Record of Decision; SALMOD helped convince decision-makers that restoration actions alone would not be sufficient for recovery of the Trinity system. However, SALMOD relationships represent important model-based hypotheses, which would need to be tested if the model were to be upgraded and used to support the ***annual*** decision-making cycle.

There was a great deal of discussion prior to the workshop between members of the Scientific Advisory Board about the utility and role of SALMOD for short and long-term TRRP monitoring needs. At the request of several participants, Sam Williamson provided a handout of the SALMOD conceptual model (Figure 5a) and a brief summary of SALMOD to the subgroup. His presentation was followed by general discussion.

[8] Trinity River AEAM Sampling and Monitoring Workshop, February 4-6, 2002, Weaverville CA.

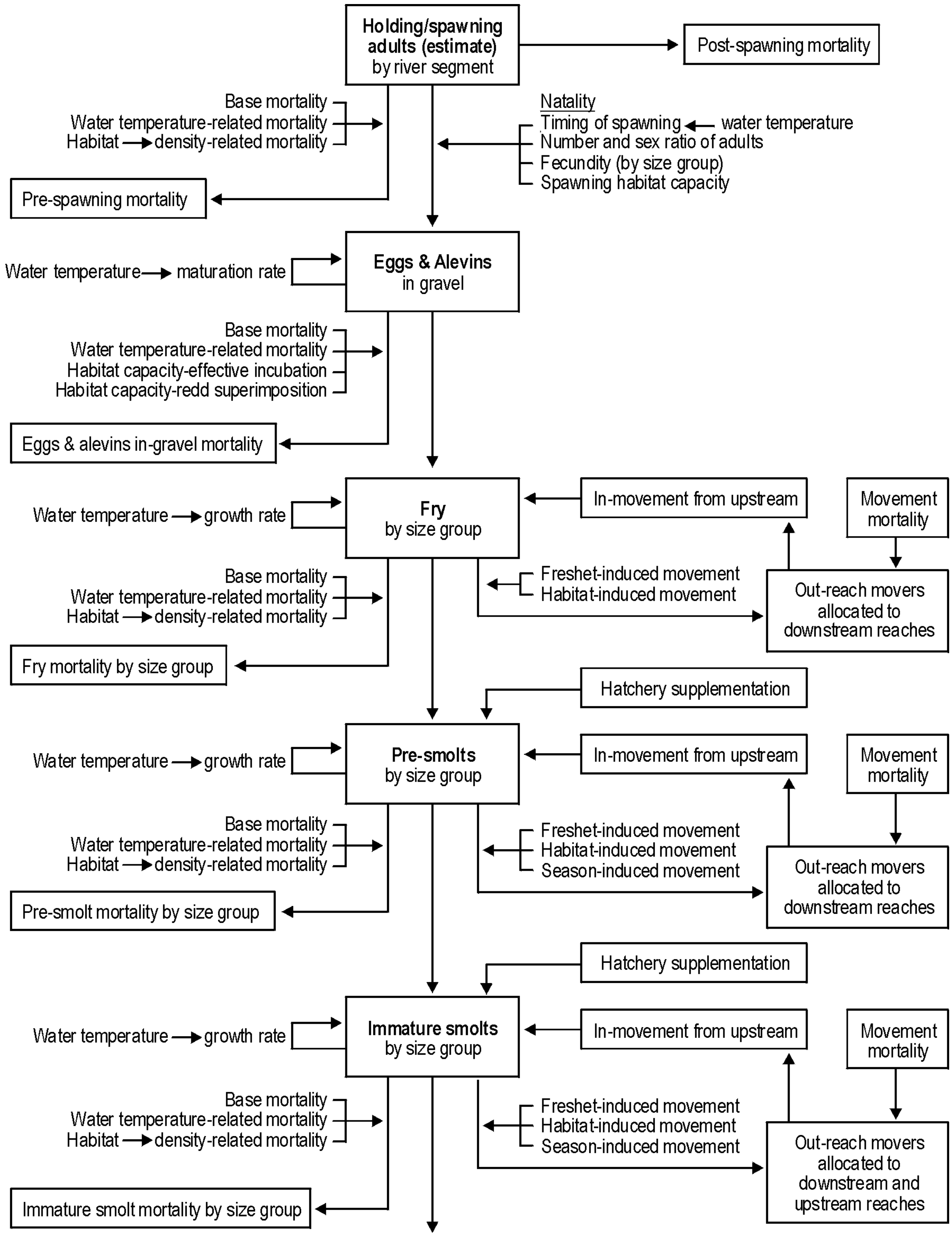


Figure 5a. SALMOD conceptual model. *Source:* Bartholow et al. 1993.

SALMOD uses flow, temperature and habitat (e.g., weighted usable area, WUA) information to predict the relative number of juvenile chinook produced at different flows and temperatures. SALMOD WUA is a combination of quantity and quality of habitat, which is defined by flow, velocity and substrate, with an emphasis on velocity. Transect-based measures of habitat were linked to fish preference through Habitat Suitability Index (HSI) curves. SALMOD was developed for a specific range of flows (e.g., 300–3000 cfs); outside of this range, predictions are uncertain. SALMOD results are more sensitive to flow changes than habitat changes (e.g., river restoration), and more sensitive to temperature than flow.

The following points emerged during the discussion of SALMOD.

SALMOD data requirements (see left side SALMOD conceptual diagram, Figure 5a)

- Enumerate the number of emigrating fry and pre-smolts. Good measures of emigrating pre-smolts were not available when SALMOD was developed in the late 80s and early 90s. Joel Green (HVT) now has good rotary screw trap (RST) results from 2002/2003, and this approach could be used to estimate the number of emigrating fish. {Joel gave a presentation on this work at the end of the workshop on October 15th. A formal report of this work will be available soon.}
- Enumerate the number of carcasses (more easily surveyed).
- Number of spawning adults (from hatchery).
- Base mortality (get information from the hatchery).
- Redd mortality (get information from the hatchery).
- Water temperature at the water's edge.
- Measure of juvenile rearing habitat area and usability at different flows. To use SALMOD for other species will also need similar habitat measurements for all life stages.

The three key SALMOD performance measures:

1. Number, size and health of emigrating fry and pre-smolts by week.
2. Rearing habitat for young, available throughout rearing season.
3. Number of returning and successfully spawning adults.

Key relationships:

- Relative response of smolts to flow (movement).
- Water temperature driven mortality.

Spatial, temporal and species scope:

- The spatial scope of the model is the upper 40 miles of the river. This area is spatially distinct with respect to fish position in the river system, but not position in the river cross-section.
- The temporal scope of the model is the period from spawning (September-October for fall chinook) to about June 6th, by which time all chinook pre-smolts are assumed to have emigrated from the upper river.
- The scope of species considered by the model is limited to chinook salmon. It makes no differentiation between spring and fall runs; timing of spawning is a key model uncertainty.

Key model assumptions, which may need to be addressed in future:

- Food is not a limiting factor.
- Inter-specific competition and predation are not important.
- Interactions with hatchery fish are not important.

Key model uncertainties:

- Egg-to-fry mortality rate (redd capping does not work in Trinity).
- Temperature-mortality relationship.
- Movement and movement mortality rates.
- When fish spawn. Recent radio tagging work from the University of Washington found three runs of fish: spring, fall and possibly September, though these results were based on a small sample size.
- Spawning habitat capacity.

Additional points/comments/questions from SALMOD discussion:

- The ***definition of "pre-smolts"*** is subjective. For SALMOD, the definition is based on behavior and size—a 50 mm threshold above which fish tend to move out from shallower areas to deeper and faster water (50 mm is also a popular definition in the literature).
- ***Fish Health*** needs to be better defined. Condition factors (e.g., RNA/DNA ratios, lipid content) could be used as diagnostics to trigger deeper investigation into things like food availability. Fish health is an important component of the "more habitat = more fish" equation, since the fish need to get to the habitat and find food and shelter, otherwise the habitat is useless.
- ***Food as a limiting factor to fish production*** is a critical uncertainty that needs to be tested. Fish condition should be added as a performance measure for habitat quality. One approach to indexing fish condition would be to sample emigrants to determine RNA/DNA ratios, or lipid content. These are alternate ways for determining whether food is limiting.
- ***Interactions between hatchery and natural fish.*** The nature of the relationship between hatchery and naturally produced fish appears to be changing from when SALMOD was developed; it is more critical now to consider these interactions explicitly. Recently hatchery returns have been more dominant.
- ***Variability in smolt output.*** The number of returning adults can be highly variable and may result from factors other than ROD actions (e.g., ocean conditions). Variability in adult return will in turn cause variability in the numbers of successful spawners and thus on smolt output, so this inter-annual variability should be included in the model. The ratio of smolts to spawners is an important annual performance measure; it indexes smolt productivity that accounts for variable adult returns (see Section 5.6).
- ***How do you evaluate the effects of restoration?*** Enumerating the number of smolts emigrating from the system is not enough to evaluate the effects of restoration. Location specific sampling is required as well. Measurable objectives against which to evaluate project effectiveness at sites could be determined by reviewing project- or site-specific goals. Counter point: There are about 50 sites being changed, far too many to measure in detail; thus the overall response is more important than the site-specific response. Additionally, we need to measure habitat use at the restoration sites and compare this to off-site measurements at unrestored sites.

- ***How do you link salmon numbers to the flow managemen*t*?*** Performance measures are of two types: production and restoration response. The ROD goal is to increase pre-smolt outmigration, not escapement numbers. A metric is required to assess whether the ROD actions have increased the potential productivity of fish habitat—one that can link actions to the biology.
- How long does it take until habitat is usable after restoration actions at channel restoration sites?
- How do you measure changes in cross-section associated with bank restoration activities?
- What is the improvement in habitat quality as a function of actions?
- The ***minimum effect-size important to detect*** is the doubling of pre-smolt production as per the goal ensconced in the ROD. {Relative to what period?} {Example performance measure: Difference in pre-smolt production between Before and After periods.}

SAB comment on SALMOD validation/development:

- SALMOD currently stops at N. Fork of the Trinity (Edge Creek). Its spatial scope will need to be expanded to account for conditions further downstream. For example, information from smolt traps at Willow Creek will not be accounted for in the current version of SALMOD. Monitoring programs should include more smolt trapping further downstream.

5.1 Management actions directly affecting this subsystem

The primary TRRP management actions that affect the fish subsystem are:

- flow manipulation (scheduled adjustments to meet various criteria such as temperature, bed scour, maintenance of floodplain water table, etc);
- gravel/cobble augmentation;
- fine sediment removal (catchment ponds);
- riparian berm removal;
- side channel construction;
- road construction (stream bank protection); and
- bridge construction/retrofitting (Salt Flat, Poker Bar, Biggers Road).

Sections 3.1 and 4.1 provide details on the flow, physical and riparian actions.

Non-TRRP management actions will also directly affect the fish subsystem:

- Releases of hatchery fish. The number, species mix and size of hatchery releases affect the level of density dependence experienced by juvenile salmon that were naturally produced. This density dependence could be experienced in the Trinity River, Klamath River, or estuary and early ocean phase. The Trinity River Hatchery releases spring and fall chinook as either smolts or yearlings, and coho as yearlings.
- Spawning escapement. The number of adult fish that escape to spawn in the Trinity River between the North Fork and Lewiston Dam will be partially a function of harvest management in ocean and the lower Trinity and Klamath Rivers.
- Late summer flow releases to cool Lower Klamath river.

5.2 Key performance measures

Table 5.1 lists a preliminary set of candidate biological and habitat performance measures (PMs). Context is provided for some of these PMs in the Section 5.5 hypothesis tables and in Table 5.2, which shows the performance measures discussed during the brief Fish Subgroup discussions of this topic at the workshop. A key task for the Fish Subgroup between AEAM Framework Workshop 1 and the subsequent monitoring design workshop will be to converge to a smaller set of quantitatively and accurately measured PMs. Section 5.6 provides some guidance on what to consider when thinking about candidate PMs.

Table 5.1. Candidate fish performance measures. The table is arranged to show which performance measures are generally applicable to the fish life stage components captured in the conceptual diagrams (Section 5.4). “Alevin” = Alevin Production (egg to emergence), “Juvenile” = Natural Juvenile Production (successful fry rearing), “Smolt” = Natural Smolt Production (successful outmigration), and “Adult” = Adult Spawner Production. The PMs are grouped into the general categories of biological, habitat, and stock assessment measures. The “Scale” column indicates what scales a PM may be measured at, but the specific temporal and spatial scale for each PM is yet to be determined. The “Description” column provides additional information on spatial and temporal scale and methods, and indicates where particular performance measures may be important for application, development, or validation of the SALMOD model.

Category	Candidate Performance Measure	Life Stage				Scale	Description
		Alevin	Juvenile	Smolt	Adult		
Biological							
	Egg burial depth	4				Site	Provide indication of vulnerability to scour.
	Redd stranding	4				Site	Pre- and post-high flow surveys of redds, redd surveys following SOD releases.
	Timing of spawning	4			4	River	A key uncertainty in **SALMOD**.
	Timing of migration			4		River	e.g., Rotary-screw traps, important for validation of **SALMOD**.
	Timing of immigration (run timing)				4	River	Junction city and Willow Creek Adult weirs.
	Stranding		4			Site/Reach	Number stranded; Post-release surveys in areas of rehabilitated and current channel.
	Movement mortality		4			Site/Reach	Mark-recapture between treated and untreated sites. Key uncertainty in **SALMOD**.
	Movement		4		4	Reach/River	Juvenile movement rates between habitat/ reaches- a key uncertainty in SALMOD. During adult immigration – especially at tributary mouths.
	Growth rates		4			Reach/River	Growth with respect to temperature – a key uncertainty in **SALMOD**. Growth as a function of habitat quality is also a key uncertainty useful for validation of **SALMOD**.
	Abundance		4	4	4	Site/Reach	*Juveniles* - Mark-recapture population estimates. *Smolts* – RST immediately above NF Trinity R. and at Weitchpec. *Adults* – adult surveys, weirs, carcass surveys.
	Distribution				4	Reach/River	Adult surveys.
	Predator surveys		4			Site/Reach/River	
	Hatchery influence		4			Reach/River	Hatchery production rearing, Mark-recapture, radio tracking, diet, food habits surveys of hatchery produced fish. Improved understanding of hatchery/natural interactions is a key requirement for updating **SALMOD**.

Category	Candidate Performance Measure	Life Stage: Alevin	Juvenile	Smolt	Adult	Scale	Description
	Health		4	4	4	River	Above NF Trinity R. At Weitchpec. Use fish health investigations including pathology monitoring at trap sites (incidence and severity of disease). Pre-spawning mortality necropsies. Health of outmigrants is a key data requirement for validating **SALMOD.**
	Temperature tolerance		4	4		Site/Reach/River	Temperature tolerance investigations. **SALMOD**
	Density adults/pool				4	Reach/River	Adult surveys.
	Redd superimposition rate	4			4	Site/Reach	Redd mapping. Mapping the distribution of redds could also be useful input data for **SALMOD**.
Habitat							
Substrate							
	Substrate composition (dominant and subdominant)	4	4		4	Site	
	Permeability	4			4	Site	
	% fine sediments				4	Site	
	Particle size distribution	4				Site	For *juvenile rearing (winter)* –in riffles.
	Scour depth	4				Site	
	Redd scour risk				4	Site/Reach	
	Cobble embeddedness		4		4	Site	For *juvenile rearing (winter)* –in riffles.
	Distribution of sand storage in spawning area	4				Site	Surficial mapping of sand storage.
	Apparent velocity	4				Site	
Flow							
	Water depths	4				Site	
	Velocities	4			4	Site	
	Hourly flows				4	Site/Reach/River	Adult immigration – Lewiston to Terwer.
Temperature							
	Water temperature	4	4		4	Micro and macro habitat/Site/Reach/ Upper 40 miles	*juvenile rearing (summer)*, along Trinity to confluence with Klamath. **SALMOD**
	Cumulative temperature units	4				Site/Reach/River	
	Hourly temp.				4	Site/Reach/River	Adult immigration – Lewiston to Terwer.
	Fall temperatures				4	Reach/River	Adult immigration - <= 23C
	Quantity and distribution of adult thermal refugia				4	Reach/River	Lower Klamath and Trinity Rivers.
Groundwater upwelling							
	Groundwater upwelling				4	Site	
Pools							
	Number and depth of pools				4	Reach, River	Upper Trinity River.
Cover							
	Cover type	4	4		4	Site	Object/velocity, refuge, substrate cover, vegetative cover.
	Distance to cover	4	4		4	Site	Distance to cover type.
Indices							
	Habitat complexity	4				Site/Reach	
	Habitat diversity	4				Site/Reach	

Category	Candidate Performance Measure	Life Stage: Alevin	Juvenile	Smolt	Adult	Scale	Description
Fish Use							
	Density/Abundance		4			Site/Reach/River	Direct (e.g., snorkel) or indirect (e.g., electroshocking) observation, over a range of flows. Important for updating / validating SALMOD habitat suitability indices.
	Distribution of redds across channel section/ spawning areas throughout spawning season				4	Site	Distribution of redds could be an important **SALMOD** input.
	Redd location				4	Site/Reach	Redd mapping. Distribution of redds could be an important **SALMOD** input.
Spatial							
	Distance of suitable habitat from spawning area	4				Site/Reach	Useful as an index of movement mortality for input to **SALMOD**.
	Distribution of fry rearing habitat relative to spawner distribution (redds).	4				Reach/River	
	Distribution of suitable spawning habitat				4	Reach/River	
Quantity							
	Area (m2)	4	4			Site/reach	At specific rehabilitation sites, over a range of flows.
	Total area of available spawning and rearing habitat over the spawning and rearing seasons for chinook, steelhead and coho.	4	4		4	Site/reach	In Upper 40 miles: (e.g., with , Weighted Usable Area estimated using 1D or 2D PHABSIM methods, or Expert mapping.), over a range of flows. Adult – area of suitable spawning habitat. SALMOD
	Area of exposed gravel bar during an index flow		4			Site/Reach/River	
	# of suitable spawning sites				4	Reach/River	
Stock Assessment							
	In-River Harvest				4	Reach/River	Tribal net harvest, in-river recreational fishery. Lower Klamath, Lower Trinity, Annual. Junction City and Willow Creek adult weirs.
	Spawning escapement				4	River	Mark-recapture. Junction City and Willow Creek adult weirs.
	Carcass surveys				4	Reach/River	Annual, mainstem Trinity River.
	Natural hatchery escapement estimate				4	River	Mainstem Trinity River; Trinity River Hatchery returns – arrival timing, magnitude and duration.
	Male/Female ratio				4	River	Mainstem Trinity River
	Size/fecundity				4	River	Mainstem Trinity River
	Pre-spawning mortality				4	Reach/River	Mainstem Trinity River
	Age analysis/cohort reconstruction				4	River	CWT recovery; mainstem Trinity River.
	Redd abundance				4	Reach/Upper 40 miles	Redd abundance by reach from Lewiston to North Fork, North Fork to Cedar Flat.
	Redd distribution				4	Upper 40 miles	Longitudinal redd distribution (river scale).
	Redd distribution trends				4	Site	At channel rehabilitation and coarse sediment introduction sites.

5.2.1 Performance measures discussion from Workshop I, October 2004

The subgroup discussed performance measures generally throughout the meeting, but only had time to focus intensively on those associated with hypotheses S.14 and S.15 (Table 5.5), two key hypotheses that address the long-term aggregate effects of TRRP actions. Table 5b is a summary of the performance measures mentioned during Fish Subgroup discussions.

Hypothesis S.14 requires both smolt abundance (Sm) (e.g., using rotary screw trap estimates) and returning spawner abundance (Sp). These data can be used to derive annual performance measures of Sm/Sp, Sp/Sm and Sp/Sp. These types of performance measures could be used for analyses that explore the relationship between annual actions (e.g., flow releases) and brood year smolt or spawner production. Time series of these data can be used to estimate the parameters of spawner-recruit curves, thus another management level performance measure could be the change in the parameters of these curves before and after implementation of TRRP actions. Such analyses will require measures of pre-smolt, or smolt abundance and brood year spawner abundance for each species, along with some measure of smolt health.

Performance measure discussion points:

- Are bigger smolts better?
  - Josh Korman (SAB) noted that Bill Trush has data suggesting that the size of the scales on returning fish gives an indication of the size of the fish when it hit the ocean. One could therefore potentially backcast the scale data to determine the size of outgoing fish.
  - George Kautsky (HVT) suggested getting at the smolt size/ocean survival hypothesis using hatchery CWT data. Wade Sinnen (CDFG) thought it might be possible to do this using existing data. An important uncertainty with this analysis is whether hatchery fish are reasonable surrogates for natural fish. George Kautsky noted that to get at this question it may be necessary to reinstate natural stock tagging.
- Bill Pinnix (USFWS) noted that the size of the smolt is not the key element of survival when it hits the ocean, but rather its growth rate. The faster the growth rate prior to hitting the ocean, the higher the ocean survival rate—irrespective of size.
- Both smolt growth and health should be measured, as this is useful for several hypotheses. RNA/DNA ratio and lipid content are practical indicators.
- Estimating natural spawner returns by brood year will be challenging and will require cohort age-structure, harvest numbers, and the hatchery fraction. Sam Williamson (USGS) suggested that it may be feasible to back out hatchery returns from carcass surveys assuming a constant 25% hatchery fraction.
- Habitat performance measures were not discussed in great detail during the Fish Subgroup discussions, though further points were added during the subsequent plenary session.

SAB comments on Performance measures (October 15th)

- It is important to quickly determine what aspect of habitat should be measured, as this PM is obviously important.
- The number, size and condition (health) of outmigrating fry and pre-smolts is critical. We also need to know post-system survival, timing of ocean entry, and physiological measures such as the rate of growth when the smolts enter the ocean (SALMOD stops at smolt size). Though we clearly need smolt abundance data, can we measure it precisely enough to detect changes of

interest? This will require a review of the HVT work. What is the TRRP budget for evaluating smolt methodologies? It is important to sort this out right away.

- We need adult escapement data, collected by CDFG.

5.2.2 Habitat performance measures discussed during the Looking Outward Matrix plenary discussion (end of day, October 14th)

The fish and physical/riparian subgroups reconvened at the end of the day to discuss the data requirements they would need from each other to assess functional relationships between habitat and fish responses, and then formalize these links by updating the Looking Outward matrix. The primary topic of this discussion was habitat data. While the fish subgroup agreed that some habitat data would need to come from the physical group, they did not have time to discuss what specific level of habitat description would be required.

The physical subgroup had discussed one view of how fish habitat information could be quantified and they summarized this approach for the larger group. This is a habitat modeling approach described by Thom Hardy that uses flow, cover, depth and velocity to derive an index of hydraulic diversity, which can be combined with the HSI curves previously developed for the Trinity River. While some members of the Fish Subgroup expressed interest in principle, other members commented that the core elements of the approach were available through other modeling approaches and that it would be best to do a comparison of methods before committing to any one approach. Thom noted that changes in habitat over time could be determined using Before and After stratified random sampling to detect changes in habitat over time. If so, then the Before work would need to be done prior to the next round of restoration work. Thom also noted that it is vital to check SALMOD predictions of fish use to ensure that we accurately understand fish habitat quality. This is a two-step process:

1. quantify spatial distribution of fry habitat; and
2. then go monitor a range of assumed habitat qualities for fish utilization.

Other habitat points raised during the Looking Outward Matrix plenary discussion:

- As with any model-based approach to habitat assessment, there needs to be short term validation to confirm that the model can predict where the fish are distributed.
- The fish submodel should stick to as simple a habitat matrix as possible by limiting it to approximately four delimiters (e.g., velocity, depth, substrate and cover, where cover is not broken down any further).
- Habitat performance measures should be scalable because while some questions about the effect of changes in fish habitat will be site specific, others will be interested in changes at the reach scale.

Table 5.2. Performance measures raised during Fish Subgroup and plenary discussions at the October 2004 workshop. Performance measures marked with an asterisk (*****) are key to the use and validation of SALMOD.

Habitat	Biological	Physical
Requires various scales of sampling for different needs, examples are: *Aerial photography* – system scale, demonstration of gross change. *Expert mapping* – What's changed at the reach scale? *Subtler measures* – site scale. Link habitat change to consequences for fish populations; get at within season changes for management purposes (e.g., PHABSIM => SALMOD). Some method using the basic components of depth, velocity, substrate and cover.	*****Number of emigrating fry and pre-smolts (size and health) – still need to define the spatial and temporal scope of this information. Fish health (condition, or "smolt quality") is related to emigrating fish, not to specific locations or sites. Thus it can't be used to evaluate the effectiveness of restoration actions such as bank rehabilitation.	Temperature – edge water temperature used for SALMOD. Probably need to extend temperature sampling beyond the 40 miles downstream of Lewiston Dam.
*****Area of rearing habitat available during the rearing season (for fry and parr of salmonid life history stages and species). This is related to the bottom bullet in the cell above.	Fish use of habitat	Flow – Required by reach, need to extend beyond the 40 miles downstream of Lewiston Dam.
	Fry growth	
	*****Number of returning and successfully spawning adults.	

5.3 Life-history vs. time diagrams

Figures 5.1–5.6 show the timing of each species' life-history stages relative to the pattern of flow for a single pre-dam water year (WY 1946). These figures clarify which life stages might be affected by flow changes in the May-July period.

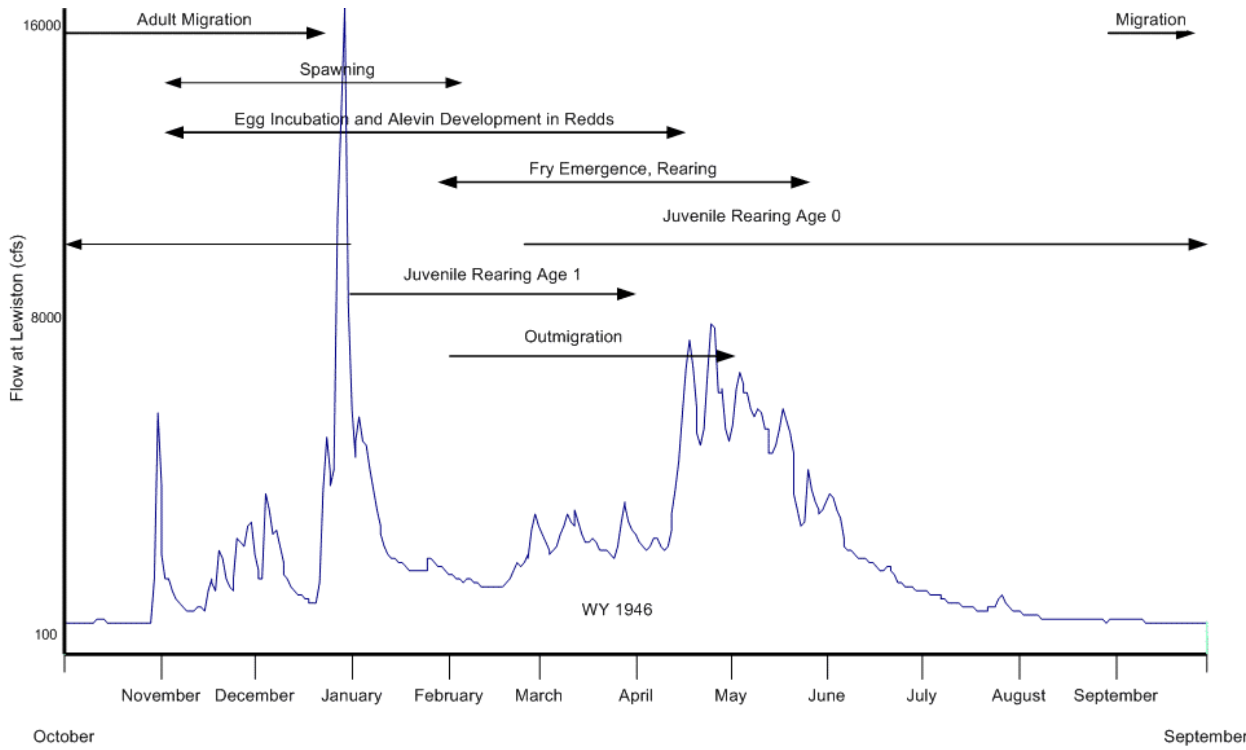


Figure 5.1. Coho life-history stages vs. time relative to pattern of historical pre-dam flow in water year 1946.

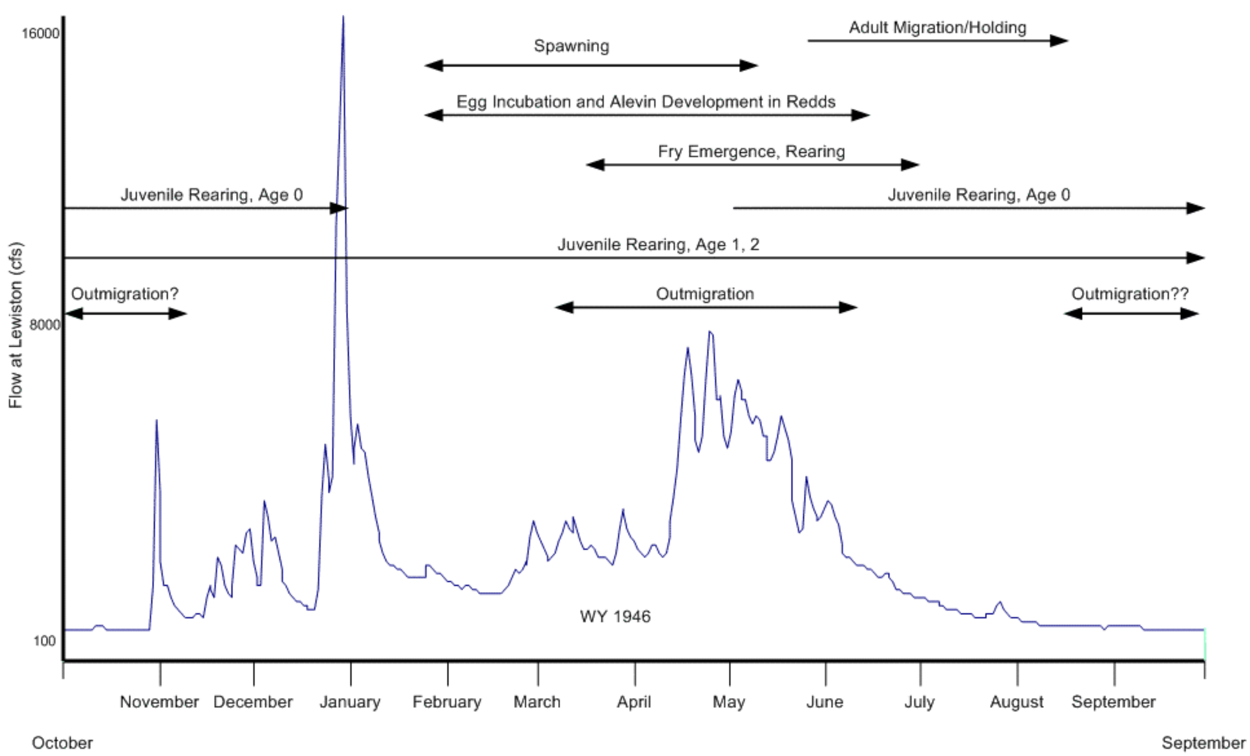


Figure 5.2. Summer steelhead life-history vs. time relative to pattern of historical pre-dam flow in water year 1946.

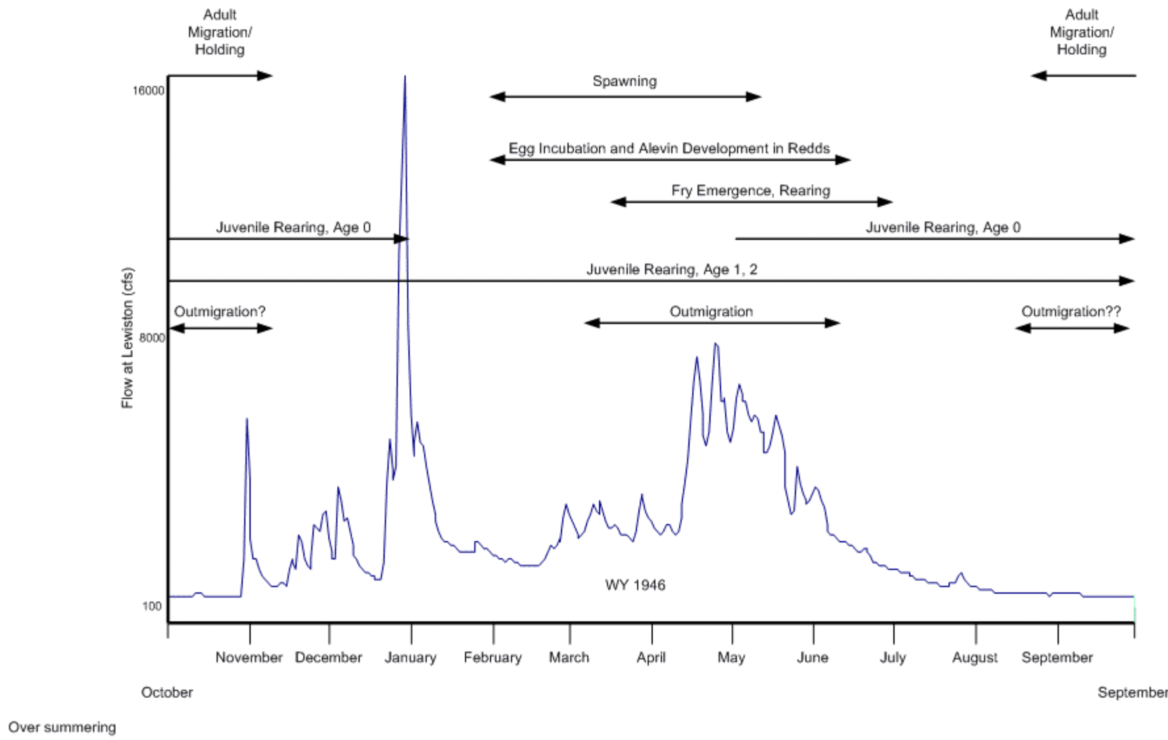


Figure 5.3. Fall steelhead life-history vs. time relative to pattern of historical pre-dam flow in water year 1946.

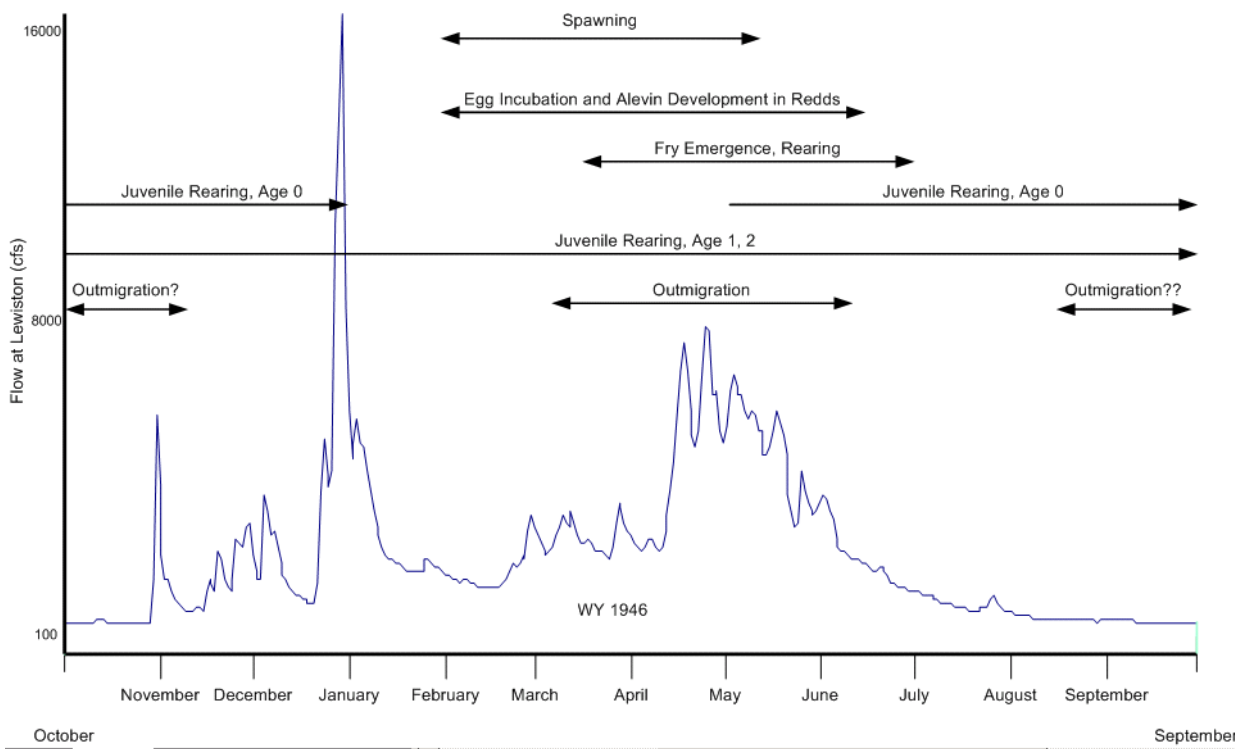


Figure 5.4. Winter steelhead life-history vs. time relative to pattern of historical pre-dam flow in water year 1946.

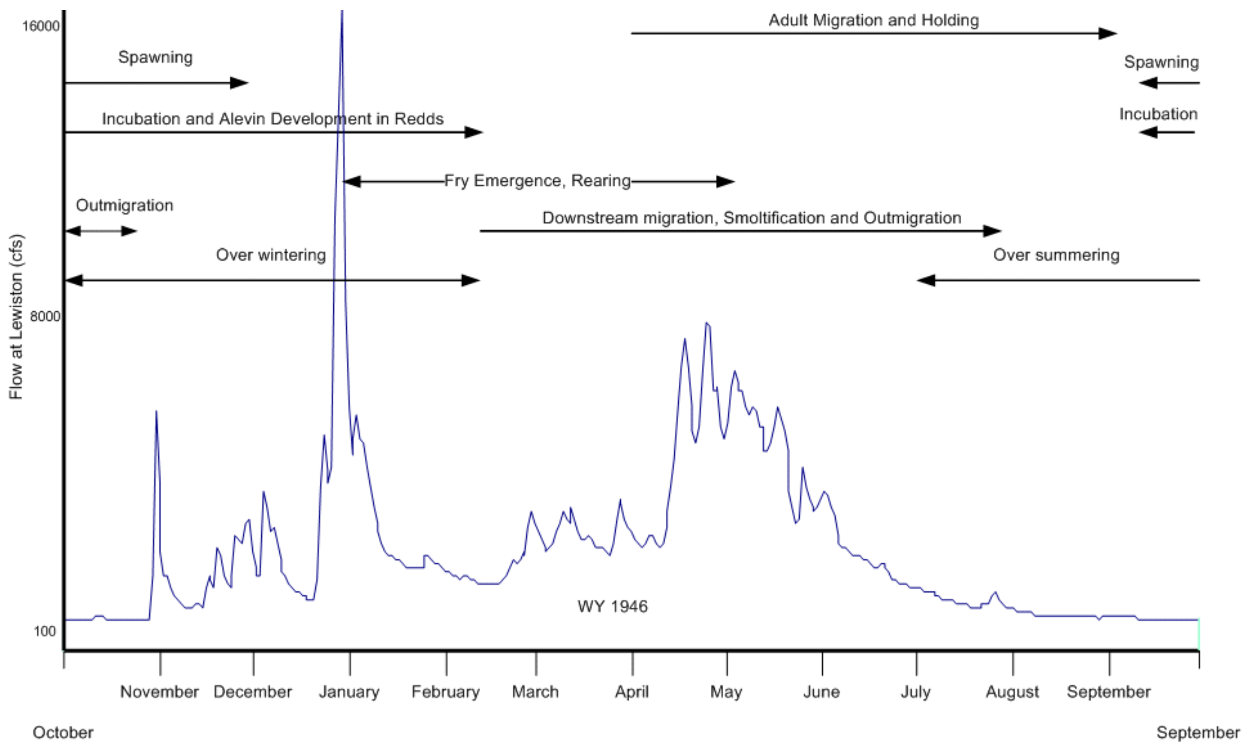


Figure 5.5. Spring chinook life-history vs. time relative to pattern of historical pre-dam flow in water year 1946.

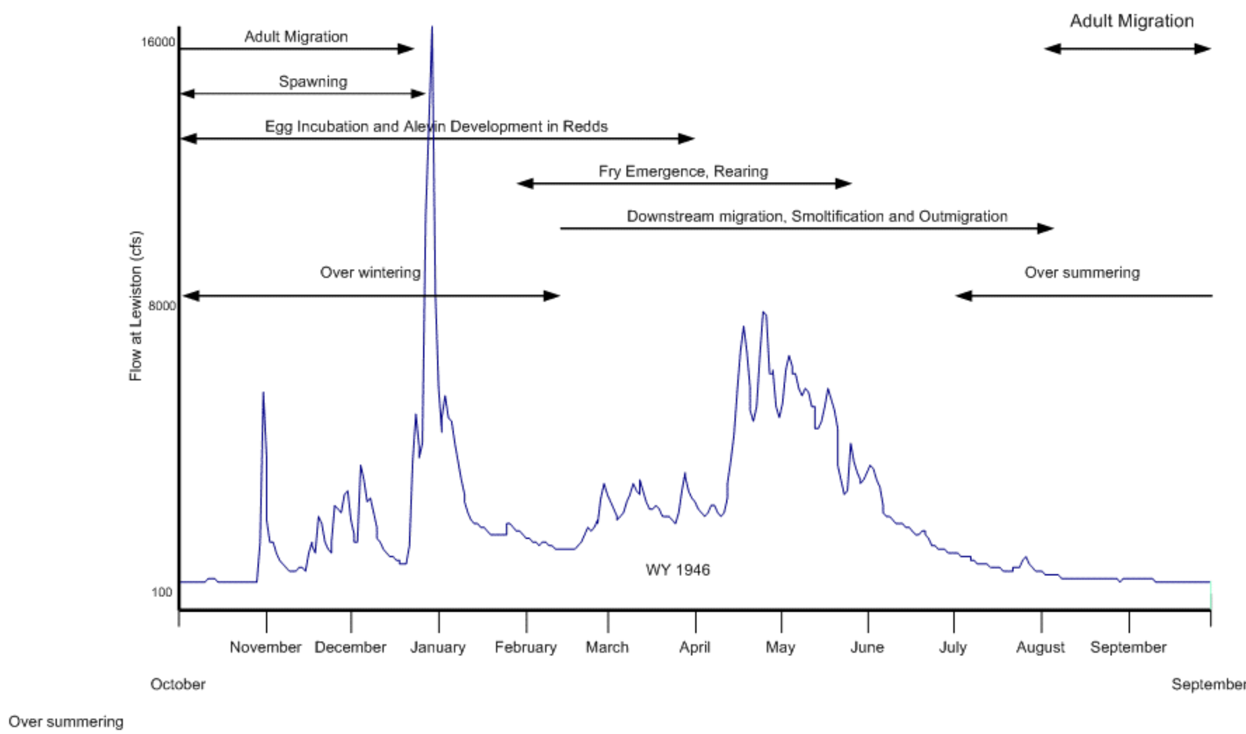


Figure 5.6. Fall chinook life-history vs. time relative to pattern of historical pre-dam flow in water year 1946.

5.4 Conceptual diagrams

The conceptual diagrams (Figures 5.7-5.10) are schematic representations of the cause-effect linkages that lead from the TRRP management actions through the hydrological, physical and biological components of the riverine ecosystem to the fish-related valued ecosystem components: production at various life stages. Production is defined here as the number of individuals at the end of a life stage period for a specified location relative to the number present at the beginning of that period, and is a function of the immigration, emigration, and survival rates the fish experience over that life stage. These rates in turn are a function of conditions in the hydrological, physical, and biological environment. The conceptual diagrams are meant to aid in the development of explicit hypotheses about these relationships, which can be tested through monitoring or direct experimentation.

For ease of presentation and discussion, the fish life cycle is split into four sub-components: Alevin Production (egg to emergence) (Figure 5.7), Natural Juvenile Production (Figure 5.8), Natural Smolt Production (successful outmigration) (Figure 5.9) and Adult Spawner Production (Figure 5.10). A further simplification is that these components are generic and not species-specific.

Each figure flows from the bottom to the top starting with the management actions (see Section 5.1) and other system inputs that may complement or confound the effects of TRRP management actions, at the bottom. The labels and thicker arrows at each diagram's left-hand side further subdivide each figure. Reading these labels from the bottom to top of each figure:

- ***System and management*** represents perturbations to the Trinity River system, either as directed TRRP management actions (e.g., flow releases), non-TRRP management actions (e.g., hatchery releases, harvest), or uncontrolled system inputs (e.g., tributary flows, or tributary sediment inputs). Note that not all management actions occur at the bottom of the figures, in some cases, management actions have been placed close to the level category they appear to affect most closely (e.g., in Figure 5.10 the "Ocean Harvest" box is positioned as a "survival factor," see below).
- ***Process*** represents the hydrological or geomorphic processes driven by these perturbations.
- ***Form*** represents the physical form imposed upon the channel by these processes.
- ***Habitat*** represents the quality and quantity of the abiotic (e.g., cobble embeddedness) and biotic (e.g., riparian cover) components of fish habitat associated with this form.
- ***Survival factors*** represent the components of fish survival affected by the quality and quantity of fish habitat.
- ***Life stage*** represents the life stage components that occur during the period captured in the diagram that the survival factors affect.
- Finally, the ***valued ecosystem component*** represents the biological result of interest (e.g., alevin production).

The levels in Figures 5.1-5.10 help to illustrate the relative distance various categories of performance measures are from the valued ecosystem components (i.e., direct vs. indirect PMs), as well as possible confounding relationships that may need to be accounted for in a monitoring design. Each box represents an important system component and the arrows joining the boxes represent hypotheses about the relationship between system components. The label, or causal link, on each arrow refers to an explicit hypothesis described in Tables 5.2 and 5.3 in Section 5.5. Arrows leading off and onto the figures indicate where particular processes or components influence or are influenced by components from other fish conceptual diagrams, or by components from other subsystems (e.g., the Riparian subsystem, Section 4).

Results for conceptual diagrams from Workshop I, October 2004

A key task for the October workshop was to review the preliminary conceptual diagrams to ensure that the boxes and linkages made sense and key linkages were not missing. Due to time constraints and participant preferences, the Fish Subgroup used the SALMOD conceptual model (Figure 5a) to guide discussions about link hypotheses (see summary of the SALMOD discussion in the Section 5 introduction, pg. 49). The following fish conceptual model diagrams have been revised to show where linkage pathways overlap with the SALMOD conceptual model (Figure 5a). This will help the fish subgroup differentiate between data and design requirements for empirical effectiveness monitoring, versus SALMOD management model updating/development/validation.

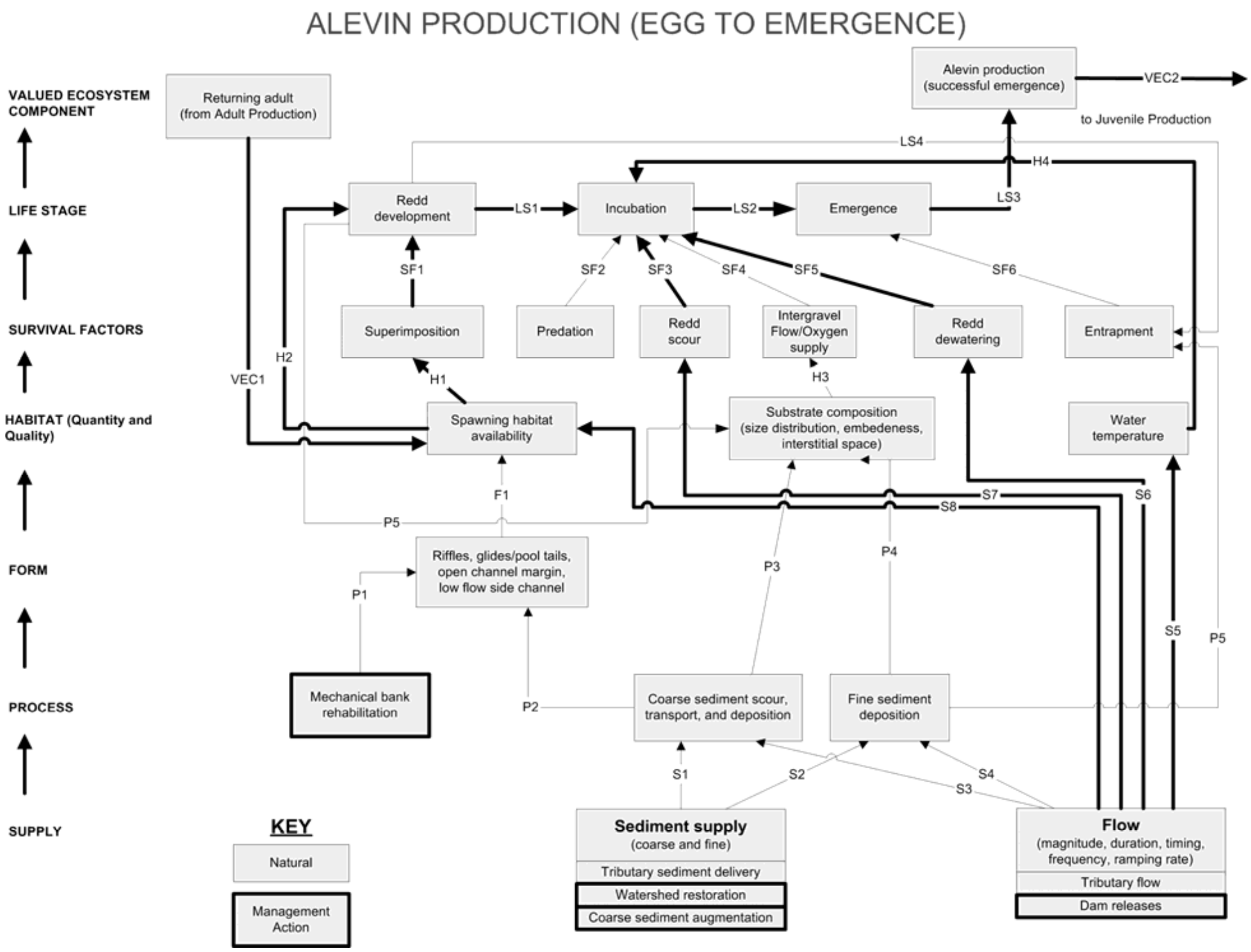


Figure 5.7. Conceptual diagram for alevin production (egg to emergence). The convention for arrow labels is a letter followed by a number where the letter designates the category [supply (s), process (p) physical form (f), habitat (h), survival factor (sf), or life stage (ls)] that linkage represents. See text for an explanation of these categories. Bolded linkages are those which also capture key SALMOD conceptual hypotheses.

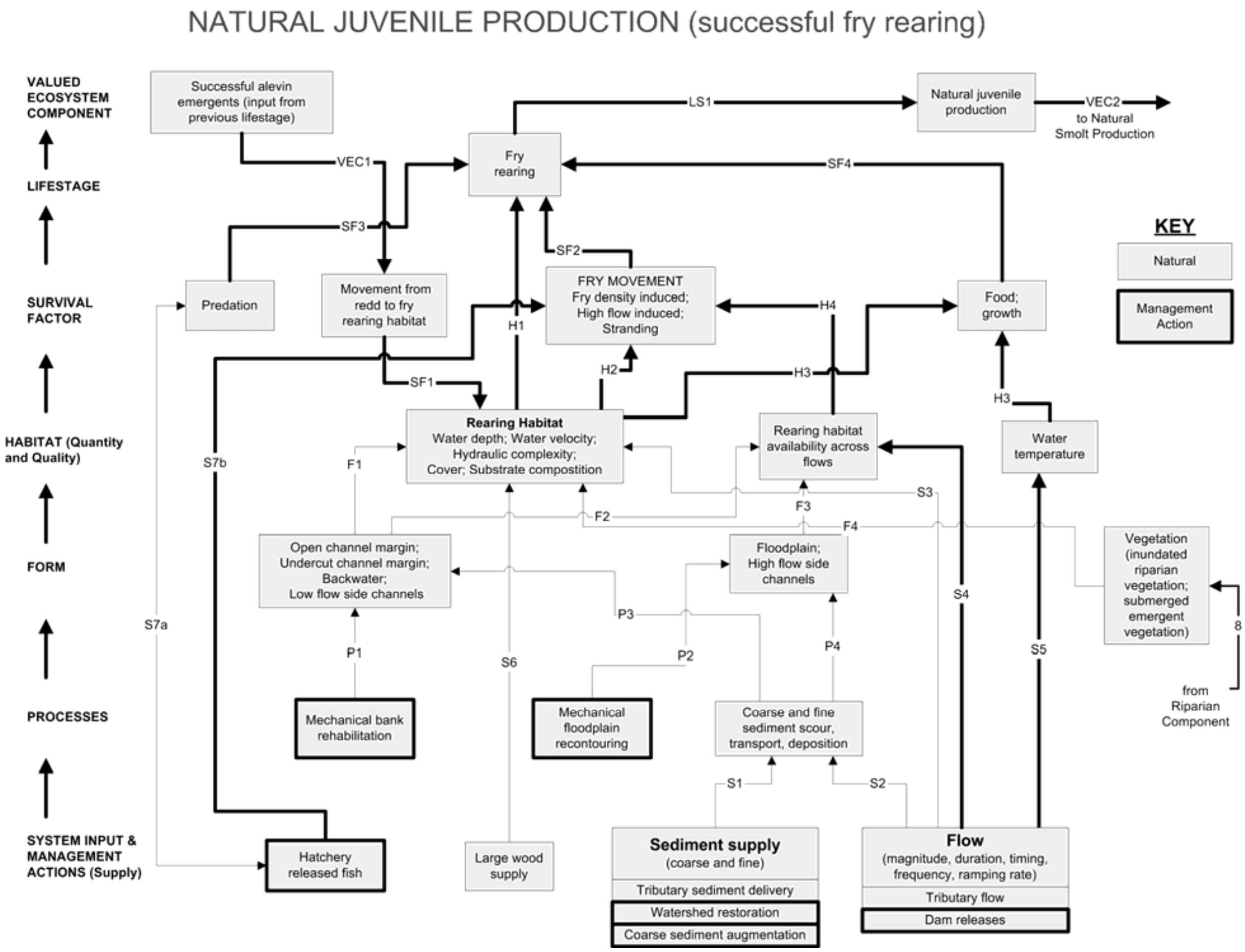


Figure 5.8. Conceptual diagram for natural juvenile production (successful fry rearing). The convention for arrow labels is a letter followed by a number where the letter designates the category [supply (s), process (p) physical form (f), habitat (h), survival factor (sf), or life stage (ls)] that linkage represents. See text for an explanation of these categories. Bolded linkages are those which also capture key SALMOD conceptual hypotheses.

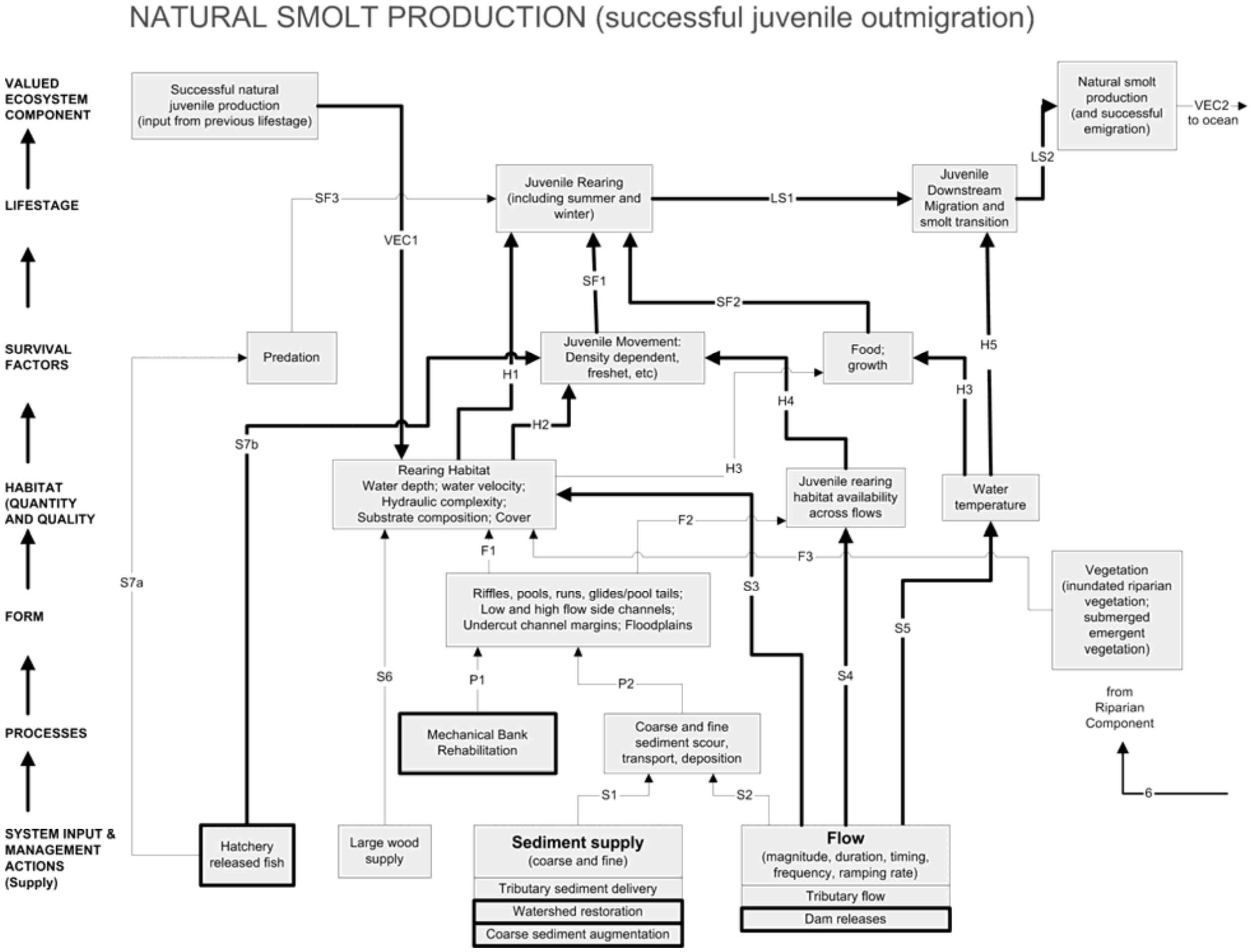


Figure 5.9. Conceptual diagram for natural smolt production (successful juvenile outmigration). The convention for arrow labels is a letter followed by a number where the letter designates the category [supply (s), process (p) physical form (f), habitat (h), survival factor (sf), or life stage (ls)] that linkage represents. See text for an explanation of these categories. Bolded linkages are those which also capture key SALMOD conceptual hypotheses.

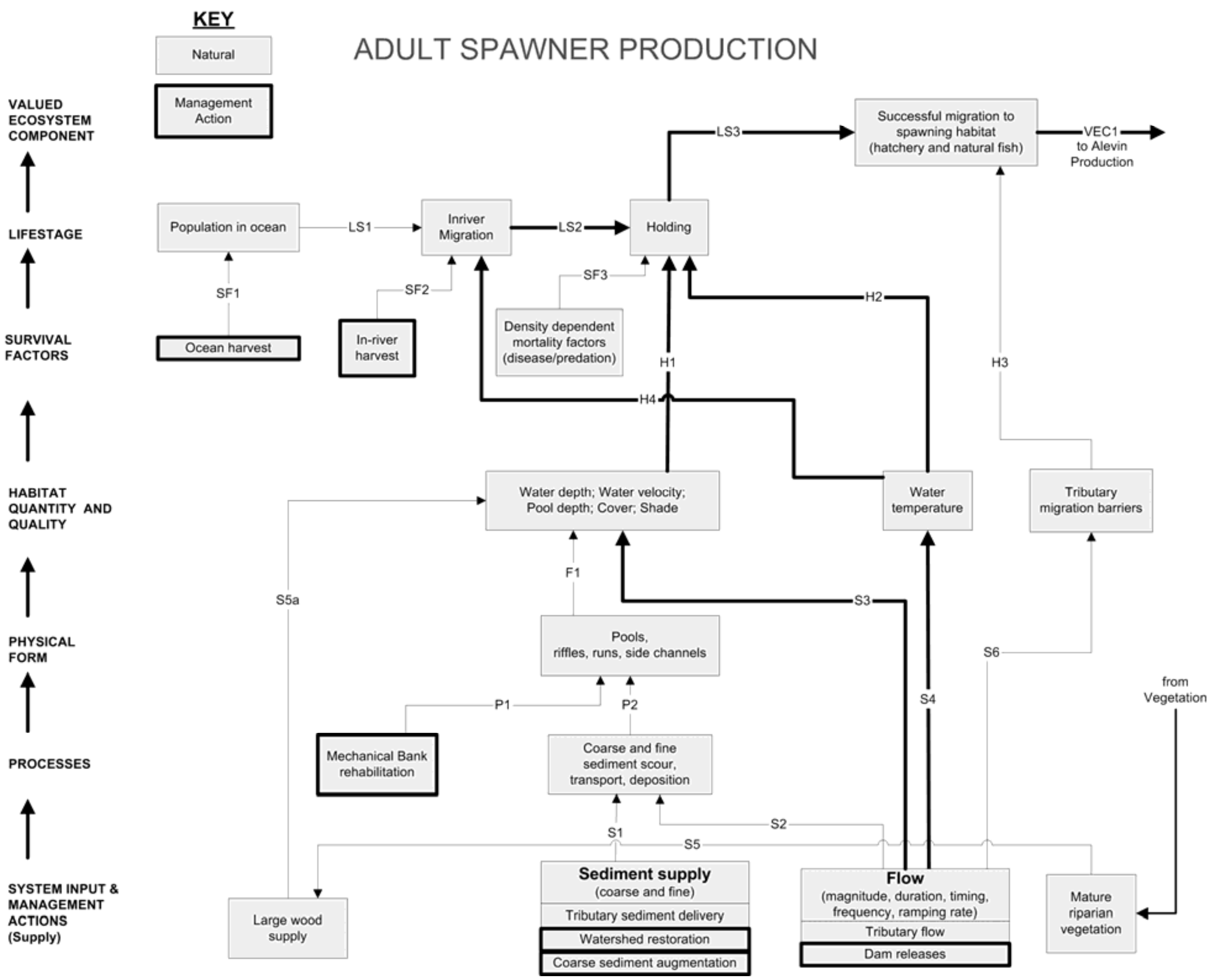


Figure 5.10. Conceptual diagram for adult spawner production. The convention for arrow labels is a letter followed by a number where the letter designates the category [supply (s), process (p) physical form (f), habitat (h), survival factor (sf), or life stage (ls)] that linkage represents. See text for an explanation of these categories. Bolded linkages are those which also capture key SALMOD conceptual hypotheses.

5.5 Statements of hypotheses/linkages and performance measures

Sections 5.5.1 to 5.5.4 provide explicit text statements of hypotheses and linkages for links and sets of links on the fish conceptual diagrams (Figures 5.7–5.10). Each section addresses a particular conceptual diagram and begins with a statement of the overall, or aggregate, impact hypothesis for that diagram, the expected impact of the TRRP management actions on that VEC. This is followed by a table that captures the key hypotheses of interest to the biologists of the Fish Subgroup, based on their understanding of the Trinity River system and the conceptual diagrams. Each table indicates the life stage to which the hypothesis applies, states the hypothesis, lists the linkages on the conceptual diagram of the hypothesis, and suggests performance measures that could be used to address the hypothesis. The hypotheses usually capture several linkages, which could be further broken down into testable sub-components in future.

5.5.1 Results for hypotheses tables from Workshop 1, October 2004

At the October workshop the Fish Subgroup reviewed, revised and prioritized the ***natural juvenile production*** and ***smolt production*** hypothesis tables in the workshop background document (Table 5b). The group worked through the hypotheses using both professional judgment and the following prioritization key, provided at the workshop:

1. Is there significant uncertainty in magnitude of cause-effect links? {If yes then 2, else low priority.}
2. Is evaluating links/hypotheses critical to either long term evaluation of TRRP effectiveness, or annual fine tuning of management decisions (directly or via a model)? {If yes then 3, else low priority.}
3. Can hypotheses be feasibly tested, or key links/model inputs feasibly tested with indicated PMs? {If yes, then high priority, else low priority.}

The hypotheses in the juvenile and smolt tables in Sections 5.5.2 and 5.5.3 have been revised according to changes suggested by the Fish Subgroup. Apart from these changes, a common concern during the discussions was that the hypotheses were either too complex (i.e., they incorporated several hypotheses) or duplicative of other hypotheses in the tables. The consensus was that more work was required by TRRP fish scientists to properly focus the key fish production and habitat hypotheses. Additionally, it would be helpful to indicate which hypotheses overlap with SALMOD key uncertainties and data needs. These comments apply to the alevin and adult spawner production hypotheses as well.

Several subgroup participants also expressed the feeling that this review exercise was merely rehashing old ground. It was noted that many hypotheses similar to those presented in this section had already been reviewed at TRRP workshops held in 2001 and 2002 (Appendix C).

Table 5b. Summary prioritization of natural juvenile production (J.x) and smolt production (S.x) hypotheses. See Tables 5.2 and 5.3 for details.

Juvenile Production Hypotheses	Priority
J.1a, J.1b	High
J.2	Low
J.3	Low
J.4	Med – High
J.5	High
J.6	Eliminated
J.7	High
J.8	Medium
J.9	High

Smolt Production Hypotheses	Priority
S.1a, S.1b	High
S.2	Low
S.3	High
S.4	Low
S.5	Med – High
S.6	High
S.7	Eliminated
S.8	High
S.9	Medium
S.10	High
S.11	High
S.12	High
S.13	High
S.14	High
S.15	High

5.5.2 Alevin production (egg to emergence)

Overall hypothesis for alevin production: Channel rehabilitation, managed flow releases from Lewiston Dam, fine sediment reduction, and coarse sediment augmentation will increase the quantity and quality of salmonid spawning habitat, improving conditions during spawning, egg incubation, and the pre-emergence period, and thus increasing alevin production in terms of the number of alevins per spawner. Uncontrolled tributary sediment input, tributary flow contribution, adult spawning abundance and distribution, and safety-of-dams releases will modify the effect of these management actions.

Table 5.3 summarizes link-specific hypotheses related to alevin production (egg to emergence). These hypotheses were not discussed at the workshop.

Table 5.3. Example set of link hypotheses for the conceptual model of alevin production (egg to emergence). Link numbers refer to arrows in the alevin production conceptual diagram (Figure 5.7)

Life Stage	Hypothesis	Linkages	Candidate Performance Measures	Prioritization / comments
Adult Spawning (Alevin production diagram)	Channel rehabilitation, high flows and coarse sediment augmentation will increase spawning habitat allowing for greater numbers of redds and potentially increasing production by increasing the number of viable eggs deposited.	(S1,S2,S3,S4, P1,P2, F1)	Amount of spawning habitat Gravel quality in spawning areas. Redd mapping	Not discussed.
	Varying flow magnitudes, rather than stable flows, throughout the spawning season will reduce the magnitude of redd superimposition, resulting in increased deposition of viable eggs.	(… F1, S8)	Distribution of redd construction across channel section/spawning areas throughout spawning season.	Not discussed.
	Channel rehabilitation, high flows and coarse sediment augmentation will increase spawning habitat, reducing superimposition.	(… F1, H1, H2, SF1)	Redd mapping to show superimposition rate	Not discussed.
Egg Incubation and Fry Emergence (Alevin production diagram)	Restoring sediment transport processes through high flow releases (>6,000 cfs), in combination with coarse sediment augmentation and fine sediment reduction activities, will reduce fine sediment composition in spawning habitats, increasing gravel permeability leading to increased egg survival and emergent fry success.	(…LS1,P3,P4 ,H3,SF4)	Permeability Apparent velocity Particle size distribution	Not discussed.
	High flow releases (>6,000) during the incubation period will result in redd scour, decreasing emergent fry production.	(…LS1, S7,SF3)	Scour depth compared to egg burial depth	Not discussed.
	Cold temperatures resulting from reservoir releases do not prolong egg development.	(…LS1, S5, H4)	Cumulative temperature unit Timing of spawning	Not discussed.
	Peak releases from later April through late May minimize the risk of redd scour, increasing of emergent fry production.	(…LS1, S7, SF3)	Pre- and post high flow surveys of redds.	Not discussed.
	Scheduled Lewiston Dam releases (300 to 450 cfs) from September through April minimize redd dewatering.	(…LS1, S6,SF5)	Redd surveys following decreases in flows.	Not discussed.
	Safety-of dam releases during the salmonid spawning period (September-March) increase redd dewatering.	(…LS1, S6,SF5)	Redd surveys following SOD releases.	Not discussed.
	High sediment input from tributary watersheds during winter storms will entomb redds, decreasing emergence success.	(…LS1, P5, SF5)	Permeability Apparent velocity Particle size distribution	Not discussed.
	Poor gravel quality in spawning areas (high fine sediment composition) will lead to redistribution of fine sediment in previously constructed redds, decreased gravel permeability and decreasing egg survival and emergence success.	(…LS1, P5, SF5)	Permeability Apparent velocity Particle size distribution Surficial mapping of sand storage	Not discussed.

5.5.3 Natural juvenile production (successful fry rearing)

Overall hypothesis for juvenile production: Channel rehabilitation, managed flow releases from Lewiston Dam, fine sediment reduction, and coarse sediment augmentation will increase the quantity and quality of salmonid fry habitat, improving conditions and increasing survival for the fry life stage, leading to increases in fish reaching the juvenile life stage. Uncontrolled tributary sediment input, tributary flow contribution, alevin abundance and distribution, and safety-of-dams releases will modify the effect of these management actions.

Table 5.4 summarizes link specific hypotheses related to natural juvenile production (successful fry rearing).

Table 5.4. Example set of link hypotheses for the conceptual model of natural juvenile production (natural fry rearing). Link numbers refer to arrows in the juvenile production conceptual diagram (Figure 5.8). The "Prioritization / comments" column states the relative priority of the hypothesis as determined by the Fish Subgroup at the October 2004 workshop as well as relevant comments provided during workshop discussions.

Life Stage	Hypothesis	Linkages	Candidate Performance Measures	Prioritization / comments
Fry Rearing (Natural Juvenile Production diagram)	**J.1a** Recreating and maintaining alternate bar channel morphology (and side channels) through mechanical restoration, coarse sediment augmentation, and high flow management will increase the amount of fry rearing habitat.	(S1,S2,S3, P1,P2,P3, P4,S6,F4)	Habitat at system, reach and site scale: Aerial photos - system Expert mapping - reach 1-D or 2-D PHABSIM analysis - site	**High**
	J.1b Increased amount of fry rearing habitat will result in increased fry production.		Site scale fish use (direct observations and electro shocking)	**High**
	J.2) Channel restoration to recreate gradually sloping banks will keep the amount of fry rearing habitat constant as river flows fluctuate.	(… F2, S4)	Area of exposed gravel bar during an index flow (e.g., 450 cfs or 300 cfs 1-D or 2-D PHABSIM analysis over a range of flows Habitat mapping over a range of flows fish use (direct observations and electro shocking) over a range of flows	**Low** Though the premise behind J.2 was tested within the TRFE using 9 sites at different flows (those findings showed that restored sites had more consistent habitat) those results are contestable and need to be confirmed.
	J.3) Mechanical channel restoration, specifically removal of riparian berms, will reduce the magnitude and incidence of fry stranding.	(P1, F2)	Post-high flow release surveys in areas of rehabilitated channel and current channel.	**Low** Stranding will remain as an issue to a lower degree despite restoration; maybe new hypothesis is required that is specific to stranding.
	J.4) Creating fry rearing habitat near spawning areas will reduce movement induced mortality of fry.	(… F1,SF1, H2)	Marked recapture between treated and untreated sites to estimate mortality. Beach seining	**Med-High** Although this hypothesis cannot be easily measured, its core dictum, "habitat close to redds is more important than habitat further from redds", is a management consideration because it is a key SALMOD uncertainty and SALMOD predictions are dependent on this assumption. Therefore it is important for annual fine-tuning and model development. "Evolution of the river will result in more habitat in the spawning areas."
	J.7) Proximity to inundated vegetation provides hydraulic complexity, increased water depth and increased cover, reducing movement-induced mortality.	(…F1, F4, S3)	Habitat mapping fish use (direct observations and electro shocking)	**High** This hypothesis essentially states that cover can be manipulated to increase fish use and that cover reduces mortality. However, there is uncertainty about the nature of this relationship. Resolving this uncertainty will provide important feedback about the effectiveness of TRRP channel rehabilitation and riparian planting actions, which are intended to dramatically change the margin cover characteristics. Additionally, this information may be used to update models used for annual decision making; for example cover could be included in SALMOD (e.g., SMET). Tim Hayden noted that the YT have been collecting habitat data that include cover components.

Life Stage	Hypothesis	Linkages	Candidate Performance Measures	Prioritization / comments
	J.8) Hatchery releases of coho and steelhead increase predation on naturally produced salmonid fry.	(… F1, F2,S7A,SF 3)	Monitor hatchery production "rearing" by mark-recapture or radiotracking. Conduct food habits survey of hatchery produced fish (gut contents). Residualization studies	**Medium** There is uncertainty about how hatchery releases affect natural production. Determining potential effects and mitigative responses is difficult. The Hoopa Valley Tribe have done two years of work on this topic and their data may be applicable here, however they did not collect predation data.
	J.9) Hatchery release practices cause hatchery produced Chinook to compete with naturally produced Chinook for habitat and food resources.	(… F1, F2,S7B,SF 2)	Monitoring emigration and/or rearing of hatchery production by mark-recapture or snorkel surveys and screw/fyke trapping.	**High** There is uncertainty about the impact of hatchery fish on natural fish. It appears that the relationship between natural and hatchery fish has changed from when SALMOD was developed; SALMOD assumed that there was no competition between hatchery and natural fish. Hatchery/ natural interactions are important for the smolt stage, not the fry stage. Hatchery release strategies (hatchery practices) can potentially lead to competition. Joel Green's 2002 RST data showed a peak in natural outmigration coinciding with a peak in hatchery outmigration. To measure these interactions it may be necessary to boost lower river RST monitoring of emigrants. This must be put into context using natural seeding rates, so spawner escapement will be required as well. It may also be important to look at hatchery natural interactions in the estuary as well. Wade Sinnen (CDFG) is doing work in the estuary).

5.5.4 Natural smolt production (successful juvenile rearing)

Overall hypothesis for natural smolt production: Channel rehabilitation, managed flow releases from Lewiston Dam, fine sediment reduction, and coarse sediment augmentation will increase the quantity and quality of juvenile salmonid habitat, improving conditions and increasing survival for the juvenile life stage, leading to increases in the number of fish reaching the smolt life stage. Uncontrolled tributary sediment input, tributary flow contribution, and juvenile abundance and distribution will modify the effect of these management actions.

Table 5.5 summarizes link-specific hypotheses related to natural smolt production (successful juvenile rearing).

Table 5.5. Example set of link hypotheses for the conceptual model of natural smolt production. Link numbers refer to arrows in the smolt production conceptual diagram (Figure 5.9). The "Prioritization / comments" column states the relative priority of the hypothesis as determined by the Fish Subgroup at the October 2004 workshop as well as relevant comments provided during workshop discussions.

Life Stage	Hypothesis	Linkages	Candidate Performance Measures	Prioritization / comments
Juvenile Rearing (spring) (Natural Smolt Production diagram)	**S.1)** Recreating and maintaining alternate bar channel morphology (and side channels) through mechanical restoration, coarse sediment augmentation, and high flow management will increase the amount of juvenile rearing habitat resulting in increased juvenile production.	(S1,S2,P1,P2S3, S6,F1,F3, H1, H2, SF1)	Area of exposed gravel bar during an index flow (e.g., 450 cfs or 300 cfs 1-D or 2-D PHABSIM analysis over a range of flows Habitat mapping over a range of flows Fish use (direct observations) over a range of flows	**High** Same as J.1a, J1.b
	S.2) Gradually sloping banks of the restored channel will maintain the amount of juvenile rearing habitat as river flows fluctuate reducing habitat bottlenecks due to fluctuating flows.	(… F2,S4)	Area of exposed gravel bar during an index flow (e.g., 450 cfs or 300 cfs 1-D or 2-D PHABSIM analysis over a range of flows Habitat mapping over a range of flows Fish use (direct observations and electro shocking) over a range of flows	**Low** Same as J.2
	S.3) Proximity to inundated vegetation provides hydraulic complexity, increased water depth and increased cover, reducing movement-induced mortality.	(…F1,F3,S3,H2)	Habitat mapping Fish use (direct observations and electro shocking)	**High** Same as J.7
	S.4) Increasing the quantity, quality and complexity of juvenile rearing habitat will minimize the impact predators (birds and fish) have on overall juvenile production.	(…H1,S7A,SF3)	Mark-recapture populations estimates Predator surveys	Low Same as J.6
	S.5) Suitable water temperatures and food supply will increase juvenile growth increasing survival.	(… H3,S5,H3,SF2)	Growth rates	**Med – High** Same as J.5
	S.6) Hatchery releases of yearlings increase density dependent mortality of naturally produced yearlings, which decreases natural production of juveniles.	(S7b, SF1, LS1)		**High** Same as J.8
Hypotheses S.8-S.11 apply only to steelhead and coho, since chinook yearlings outmigrate from the system before June 10th (SALMOD assumption). While is was agreed that SH and CO generally stay in the system longer than chinook, there was disagreement about how extensive coho are in the system and how long juvenile coho remain in the system. Andrew Hamilton suggested that coho may be gone from the Trinity by May. Joe Polos noted that he had observed stranded CO and SH, below "Cable way". Josh Korman asked how important the tributary delta areas were for rearing coho as these will be affected by TRRP flow management and restoration activities. For the remainder of the discussion about the hypotheses, the group agreed to focus on steelhead. However, given the uncertainty within the group about the extent, timing and location of habitat use by coho, it may be worth revisiting this question in future fish technical group discussions.				
Juvenile Rearing (summer) (Natural Smolt Production diagram)	**S.8)** The quantity and quality of juvenile rearing habitat for salmonids with extended freshwater rearing (primarily coho and steelhead) is increased throughout the upper forty miles of the Trinity River due to restoration activities, resulting in an increase in juvenile production.	(S1,S2,P1,P2,S3 ,S6,F1,F3, H1, H2, SF1)	Area of exposed gravel bar during an index flow (e.g., 450 cfs or 300 cfs 1-D or 2-D PHABSIM analysis over a range of flows Habitat mapping over a range of flows Fish use (direct observations) over a range of flows	**High** There is uncertainty about whether the quality and quantity of summer rearing habitat is a problem for SH.
	S.9) Current water temperatures allow for additional growth during the summer by steelhead.	(…S5,H3,SF2)	Growth rates	Medium

Life Stage	Hypothesis	Linkages	Candidate Performance Measures	Prioritization / comments
	S.10) Spring releases to provide optimal water temperature for outmigrating smolts will significantly increase total habitat for juvenile steelhead and coho salmon rearing in habitats throughout the mainstem.	(S5, H5)	Water Temperature along Trinity to confluence with Klamath River	High
Juvenile Rearing (winter) (Natural Smolt Production diagram)	**S.11)** Recreating and maintaining channel form and complexity, including vegetation/LWD and/or substrate composition, through mechanical restoration, coarse sediment augmentation, and high flow management will increase the amount of juvenile overwinter rearing habitat resulting in increased survival of overwintering juveniles.	(S1,S2,P1,P2,S3 ,S6,F1,F3, H1, H2, SF1)	Habitat mapping Embeddedness or particle size distribution in riffles	High Several participants suggested that winter habitat is a good candidate for a limiting factor in steelhead, and may be important for CO too. TRRP actions should modify substrate conditions and substrate provides cover for overwintering fish. Thus could be critical for annual fine tuning of management actions. The hypothesis is difficult to test, though lots of literature exists about the impact of substrate condition on overwinter survival and its role as a potential limiting factor. We may have to use a habitat surrogate for short-term questions, e.g., measuring lipids (condition factor) in outmigrating fish, or fish sampled at sites.
Smolt Outmigration (Natural Smolt Production diagram)	**S.12)** Temperatures and flows during the spring hydrograph in Normal or wetter water years during the salmonid smolt outmigration period will increase smolt survival.	(S5, H5)	Smolt migration timing Growth Smolt health Smolt survival from upper Trinity to the Klamath River	High Perhaps more of a limiting factor for SH and CO (but these species leave earlier) Management: potential feedback for effectiveness of TRRP flow actions Feasibility: High flows during this period may make it difficult to estimate emigration
	S.13) Temperatures and flows during the spring hydrograph in Dry and Critically Dry water years during the salmonid smolt outmigration period provide smolts environmental cues to emigrate prior to stream temperatures reaching marginal or lethal levels, increasing survival of that years production.	(S5, H5)	Smolt migration timing Growth Smolt health Smolt survival from upper Trinity to the Klamath River	High Paired with S.12
	S.14) Cumulative effect of restoration actions (channel rehabilitation, flows, coarse and fine sediment management) will increase habitat for all freshwater life stages of salmonids, and increase survival from one freshwater life stage to the next, resulting in increased smolt production.	(… LS2)	Smolt production immediately above the NF Trinity River Smolt production index at Weitchpec Smolt health at Weitchpec	High Aggregate, long-term
	S.15) Increasing smolt production will increase adult populations (after accounting for oceanic conditions), increasing ocean and in-river fisheries harvest and spawning escapement.			High Aggregate, long-term

5.5.5 Adult spawner production

Overall hypothesis for adult production: Channel rehabilitation, managed flow releases from Lewiston Dam, fine sediment reduction, and coarse sediment augmentation will increase the quantity and quality of adult holding and spawning habitat, improving conditions and increasing survival of adults successfully spawning. Uncontrolled tributary sediment input, tributary flow contribution, oceanic conditions, and ocean and in-river harvest will modify the effect of these management actions.

Table 5.6 summarizes link-specific hypotheses related to adult spawner production.

Table 5.6. Example set of link hypotheses for the conceptual model of adult spawner production. Link numbers refer to arrows in the adult production conceptual diagram (Figure 5.10).

Life Stage	Hypothesis	Linkages	Candidate Performance Measures	Prioritization / comments
Adult Immigration (Adult Spawner Production Diagram)	Temperatures provided by the descending limb of the spring hydrograph (flows >2,000 cfs) provide thermal conditions that will not inhibit migration to holding/spawning areas, increasing the number of adults reaching the holding/spawning areas.	(S4,H4, LS2, LS3)	Hourly temps (Lewiston to Terwer) Hourly Flows (Lewiston-Terwer) Adult migration/movement monitoring	Not discussed.
	August through October: Water temperatures at or above 23 C during the adult fall migration period (August-October) will impede adult migration, resulting in increased densities in or near thermal refugia, increasing density dependant mortality factors such as disease and predation.	(S4,H4, LS2, LS3)	Hourly temps (Lewiston to Terwer) Hourly Flows (Lewiston-Terwer) Fall water temps less than or equal to 23 C Adult migration/movement monitoring	Not discussed.
	At flows above 300 cfs there are no migration barriers on the mainstem Trinity River and barriers preventing migration into spawning tributaries.	(S6,H3)	Adult migration/movement monitoring, especially at tributary mouths	Not discussed.
	Harvest regulations established for Klamath/Trinity salmonids for levels for adult salmonids.	(SF1, SF2)	Stock assessment	Not discussed.
Adult Holding (Adult Spawner Production Diagram)	The quantity (number, area, location) and quality (temperature, depth, cover) of holding pools is increased due to restoration of channel form and fluvial processes to support greater numbers of adult salmonids utilizing these habitats.	(S1,S2,S5-S5a, P1,P2,S3,F1,H 1,H2)	Number and depth of pools in upper Trinity River	Not discussed.
	Increasing holding pools will decrease densities of holding adults (dependent on the magnitude of spawning escapement), leading to reductions in pre-spawning mortality and result in increased number of spawners.	SF3, LS2	Adult surveys (live counts) to determine density/pool and prespawning mortality levels	Not discussed.
	Management of summer/fall flows to provide appropriate temperatures of holding and spawning adult salmonids will decrease pre-spawning mortality by providing suitable water temperatures and reducing crowding through greater distribution of adults throughout the upper river, leading to increase in the number of spawners and an increase the viability of gametes.	S4,H2,LS3	Hourly temps (Lewiston to NF Trinity) Adult surveys to collect abundance, distribution and pre-spawning mortality data Fish health monitoring and pre-spawning mortality necropsies	Not discussed.

5.6 Identification of critical uncertainties and proposed method of testing alternative hypotheses

In the context of the TRRP, the overall, or aggregate, restoration hypothesis for fish populations is:

1. Restoration of the fluvial nature of the river through mechanical alterations, managed high flow releases, coarse sediment augmentation, and fine sediment reduction coupled with managed flow releases to provide suitable spawning/ rearing habitats and temperature regimes for salmonids will restore naturally produced salmonid populations in the Trinity River.

The aggregate overall hypothesis can be decomposed into the two main critical scientific uncertainties for the fish subsystem (*2a* and *2b* below). Each encapsulates other hypotheses, a number of which are represented in the conceptual diagrams (Section 5.4), and captured in the hypothesis tables (Section 5.5).

2a. Recreating a complex, dynamic alluvial river will increase salmonid habitat quantity and quality for all life stages and species.
2b. Increasing salmonid habitat quality and quantity will increase survival for all freshwater dependent life stages, resulting in increased salmonid smolt production and overall population increases.

Monitoring to test the effectiveness of TRRP management actions should provide data to address each of these categories of uncertainty. A direct test of the aggregate relationship (**1**) between fish production and the onset of management actions could be done on a river-wide scale by comparing the parameters of a smolt-to-spawner recruitment curve fitted to smolt abundance and spawner abundance data collected before and after implementation of the TRRP management actions. This approach would account for density-dependent effects on recruitment and the spawner-recruit model could be modified to account for other confounding factors, such as common year effects and flow. Hypothesis **2a** could be addressed by testing relationships between management actions and components of fish habitat at various spatial and temporal scales (e.g., quality of spawning habitat in rehabilitated and untreated channel locations). Hypothesis **2b** could also be tested at various scales using measures of fish habitat quality or quantity and the production or biological measures of interest for particular salmonid life stages (e.g., juvenile rearing densities vs. area/quality of rearing habitat). An adaptive monitoring program should utilize designs that will allow detection of changes in the fish VECs (the overall hypothesis statements for Sections 5.4.1-5.4.4) and help determine why these changes have occurred (link hypotheses in Tables 5.2-5.5) to improve and refine management actions.

A number of specific issues will need to be considered to move from the conceptual models and impact hypotheses towards a monitoring design. Sections 5.6.1 through 5.6.3 begin to address these issues. Section 5.6.4 lists some key points relevant to monitoring and/or experimental design when reviewing the list of candidate performance measures.

5.6.1 Alevin (egg to emergence) and fry production

For fry production, the ideal biological performance measure would be fry abundance, but the enumeration of fry with any reasonable certainty will not likely be feasible. Thus indices of fry habitat quality and quantity may need to be used as proxy measures of the success of the management actions. Temporal and spatial sampling priorities should be determined by the implementation schedule of rehabilitation efforts including channel rehabilitation sites, coarse sediment augmentation and flow management actions. Fry/Juvenile habitat will be secondary to enumeration as a performance measure, but will also be a critical measure of rehabilitation success.

Similar issues apply to juvenile, smolt and adult production, though biological measures of production become more feasible for later life stages (e.g., snorkel surveys can be used to estimate juvenile densities or abundance, rotary screw trap mark-recapture techniques can be used to estimate smolt production, and estimates of spawner escapement can be obtained using harvest data, adult weir counts and redd counts). A suitable juvenile habitat proxy may include development of annual juvenile density indices in relation to specific habitat components including indices at meso and sub-meso habitat scales, microhabitat scales and by stream margin edge type (SMET). However, confidence bounds can still be wide, especially for snorkel-based juvenile density or abundance estimates.

5.6.2 Juvenile (fry rearing success) and smolt (outmigration success) production

Juvenile production has been somewhat of a “holy grail” in the Trinity for several years with rotary trapping efforts ongoing in the upper and lower sections of the river. Previous trapping efforts have developed discharge-based indices, which may be the most achievable form of monitoring for juvenile production. Recent emigration monitoring efforts (Lower Trinity 2002-2004 and Upper Trinity 2004) have been based on mark-recapture methods to develop quantified population estimates via trapping efficiency measurements.

Discharge based indices have been the primary enumeration tool utilized by the USFWS and Hoopa Tribe for many years. This work provides a long-term dataset to identify fish production trends over a decadal time scale. Current efforts produce discharge-based indices of juveniles emigrating from the upper 40 miles (i.e., Lewiston to North Fork Trinity) and of smolts emigrating from the entire Trinity River basin.

Rotary screw trap ***efficiency-based*** population estimates are derived by counting juveniles at a designated downstream site and releasing marked fish back into the population at an upstream site for subsequent recapture. Marked fish subsequently captured at the downstream site are counted to estimate the capture probability (trap efficiency), which is used to estimate juvenile abundance for a given segment of the population.

At the end of Workshop 1, Joel Green of the Hoopa Valley Tribe Fisheries Department presented results of efficiency-based rotary screw trap estimates of chinook and steelhead outmigration from work conducted by HVT on the Trinity River in 2002 and 2003. An upcoming report will provide the details of this work and provide a strong starting point for further discussions about the scope of such work in the context of TRRP monitoring.

Spatial scale of monitoring

- Upper river monitoring should enumerate fish originating above the North Fork of the Trinity (i.e., upper 40 miles).
- Lower river monitoring should continue near Willow Creek. Trinity Basin emigration estimates should also be measured at the mouth of the Trinity River at Weitchpec to estimate smolts moving out of the basin and, if possible, mortality between upper and lower river areas.
- Estuary sampling of smolts should be implemented to determine potential productivity (estuary population estimate?, smolt condition index: fish size, health condition?) prior to entering the ocean lifestage.

Temporal scale of monitoring

- Annual, quantified efficiency-based population estimates to determine outmigrants/smolts per returning adult.

5.6.3 Juvenile habitat

Juvenile habitat has been monitored in the upper 40 miles for several years. While some of this historical data may be useful as a baseline, investigations should continue to seek the best information possible prior to implementation of large-scale rehabilitation efforts.

Pre-and post-construction assessment of habitat availability and utilization at channel rehabilitation sites is critical. Baseline work should include a comprehensive fish (fry/juvenile) habitat availability/utilization assessment to identify the reach- and river-scale habitat limitations/bottlenecks to fish production.

Spatial

- Systematic sample of bank rehabilitation and control sites throughout the upper 40 miles.

Temporal

- Baseline information for 40 miles prior to most of the rehabilitation site construction.
- Annual during initial three years of rehabilitation site construction to measure immediate change.
- Decadal, semidecadal or following high water years; following rehabilitation site completion and flow schedule implementation to monitor change from high flow events.

5.6.4 Adult spawner production

Run size for steelhead, coho and chinook, and harvest and spawner escapement for the Trinity River basin have been estimated for several years by the California Department of Fish and Game. This could be a valuable baseline dataset.

5.6.5 Some key design considerations for monitoring and evaluation

- Identify ***confounding factors*** such as common year effects that influence survival rates in the freshwater or marine environment over larger spatial scales, or density dependence (e.g., resulting from interactions between natural and hatchery juveniles). Confounding can be addressed through the judicious use of controls and/or models that explicitly account for the factors of concern.
- Specify the ***spatial and temporal scale*** at which monitoring should take place for each VEC and its associated performance measure(s). This will require explicit identification of the spatial and temporal scales of interest for making inferences. Additionally, the subgroup will need to consider whether inferences made at one spatial or temporal scale can be applied with confidence to a different scale (e.g., aggregating up from microhabitat to site to reach to river). For example, it may be useful to determine temporal and spatial sampling priorities using the implementation schedule for rehabilitation efforts (e.g., channel rehabilitation sites, coarse sediment augmentation and flow management actions). TRRP scientists should specify the temporal duration over which the performance measure is expected to respond to management actions.

- How will sample sites be selected to ensure they are ***representative*** of those types of sites/locations? This consideration may not be applicable to all types of performance measures. For example, rotary screw trap estimates of smolt abundance could be assumed to represent a census.
- Is it possible to ***replicate*** sampling in space and time (multiple treatment and control sites, repeated measures at sites)? Is it possible to ***intersperse*** treatments across space and time?
- Is it possible to specify a ***range of treatment levels*** and provide or take advantage of strong ***contrasts*** between them (e.g., active flow manipulation; or sampling at treated rehabilitation sites, untreated rehabilitation sites, and sites that are in good condition)?
- Where multiple performance measures are available to address changes in a VEC or cause-effect linkage, what is the relative ***precision and accuracy*** of each?
- What is the appropriate ***type of inference*** for a particular question? Are we interested in detecting a trend over time, or testing cause and effect relationships. This may affect which type of performance measure is required, as well as the method of measuring it.
- What ***magnitude of change***, or effect size, is important to detect? This can be either a change that is important from a management, or a biological perspective.
- What is the ***distance*** between the measured performance measure and the index of interest. Use performance measures that are closely connected to the question of interest.
- Do ***baseline data*** exist by which changes in the performance measures could be assessed, or variances estimated for *a priori* statistical power analyses?
- What type of ***statistical analysis*** would be used to assess changes in performance measures?

5.6.6 Results from the October workshop

Several examples of ways to reduce uncertainties arose during Fish Subgroup and plenary discussions at the October workshop:

SAB Plenary comments

Monitoring

- The SAB is not comfortable with the current smolt monitoring methods—the methods need to be sorted out as soon as possible.
- A “Before-After” monitoring framework does not exist; it will really be a “Before-During-After” framework since TRRP actions will be adding habitat over time, which precludes a clear “pre-post” test of action effectiveness. The TRRP may need to use a “model-based” approach, such as SALMOD, to deal with this.

Key uncertainties:

- <u>Intensity of competition between natural and hatchery fish</u>. The intensity of this competition could increase as the fish move downstream. Natural-hatchery interactions could be significant in the estuary, meriting a look at past data to explore the consequences of the overlap in timing of outmigration of natural and hatchery young-of-year (J. Green, HVT, unpublished data). The residence time in the estuary will also affect the intensity of competition.

- Mechanism of dispersal of adult spawners. This mechanism (e.g., density dependence) is important to consider when trying to understand the consequences of varying distances between redds and fry rearing habitat, and where to develop fry habitat relative to spawning habitat.
- Temperature-growth relationships for chinook, steelhead and coho. SALMOD results are very sensitive to temperature. The current temperature relationships are not parameterized with data from the Trinity River. There could be tradeoffs between species in managing temperatures. For example, using flows to create cool temperatures for chinook smolts as they move downstream may inhibit the growth of juvenile steelhead in the upper river. Experimental flows that provide some contrast in flow-temperature-growth data could be used to answer the question, "Do cooler temperatures really work?" Policy input is required on the issue of the relative importance of different species.
- Another possible tradeoff is the loss of prime coho rearing habitat near bars at the mouths of tributaries; these may be removed through TRRP habitat restoration actions.
- Tradeoffs between geomorphic vs. fish objectives. There is an apparent disconnect between what fish biologists and engineers consider to be important habitat features. For example, feathered edges do not provide the cover elements required by chinook; large woody debris (LWD) and backwater pools are important for steelhead and coho. A participant noted during the SAB presentation that there needs to be a meeting of heads about the elements of emergent vegetation that are important for fish – engineers get conflicting input. It might be possible to experimentally evaluate the relative importance of different habitat features by varying the design of rehabilitation sites and monitoring fish utilization of contrasting designs.

6.0 Birds

The ROD established that the TRRP must consider potential impacts on federal and state listed plant and wildlife species (USDOI 2000:24). Birds are a very high profile component of the ecosystem; probably second only to fish in perceived importance to various stakeholders. All environmental documentation and compliance processes (i.e., Biological Assessments [BA], Environmental Impact Statements [EIS], Environmental Impact Reports [EIR], etc.) that are required for construction activities in the Trinity (i.e., bridges, mainstem rehabilitation sites, gravel injections sites, watershed restoration, etc.) require consideration of special-status bird species and their "critical" habitats in accordance with numerous federal and state environmental laws (i.e., NEPA, ESA, Migratory Bird Treaty Act, Eagle Act, CEQA). Beyond this, TRRP agencies have a responsibility to prevent undue losses of birds and other wildlife species across the basin, and to maintain the healthy riparian corridor essential for ensuring the survival of bird species of "special concern."

6.1 Management actions directly affecting this subsystem

Management actions could have both positive and negative effects on birds at different times and locations. For example, increased flow may increase available food, while at the same time reducing the amount of critical nesting substrate. The long term, overall effects are, however, expected to be positive. Examining the cumulative impacts on birds throughout the Trinity watershed will provide the most reliable measure of overall system-level effects. While this requires a more comprehensive and larger scale monitoring program than would be mandated by NEPA/CEQA licensing processes, it also ensures that inferences on restoration action impacts are not biased by site-specific observations.

Bank rehabilitation

- Removal of riparian berms will dramatically reduce the amount of foraging and nesting habitat for many species of special concern, at least in the short-term. Buffering effects should be examined for: 1) unmanipulated sites; and 2) lower sections of tributaries.
- The effect of succession and vegetation restoration of critical habitat for various birds can be predicted with models using surveys taken during the rehabilitation process, and methods that result in improved bird habitat can be accelerated.
- Minor adjustments in restoration site selection, design, and timing could greatly decrease the birds' risk of predation, and maintain or improve nest success, survival, and persistence of individuals and species.

Channel and pond development

- This will increase available nest site habitat for some important birds. For instance, gravel surfaces adjacent to water provide foraging for Spotted Sandpipers, nest substrate for Killdeer, and protection from predators for mergansers. Developing riparian vegetation near new watercourses will increase habitat for migrant and resident landbirds, as well as for aquatic birds.

Flow

- Timing and magnitude of flow releases can markedly affect nest success of various birds, as nests are often on or near the ground and very close to water where they are subject to inundation.

General Restoration Activities

- Restoration activities could increase merganser populations. Mergansers are important predators of young fish; in some areas they have been documented taking as much as half of the fish population. A critical element of the program will be to monitor the merganser population and its potential impacts on fish. Management actions that increase availability of small fish, macro-invertebrates, and other prey items, could greatly benefit productivity and survival of aquatic and riparian birds.

6.2 Key performance measures

The effects of management actions on birds will be evaluated for adaptive management decisions through monitoring and predictive models. The performance measures selected are crucial to the success of this approach. Bird metrics will be sensitive to changes in the quality or quantity of important components of the habitat, including food, cover, nest substrate, and predators. Criteria for evaluating the efficacy of performance measures include: responsiveness to management actions; efficiency of measurement; value at varied temporal and spatial scales; and extent of natural year-year variation[9]. To test the hypotheses for birds, we propose the following metrics:

Population Metrics:

- **Abundance** is a measure of bird survival and persistence at a location and indicates the ability of a habitat to provide food, nest sites, and protective cover. Both historical (estimated abundances) and current (measured abundances) can be used for developing abundance targets for aquatic/riparian birds under TRRP flow/channel actions. This information (in conjunction with regional scale comparisons) can also be used for determining the lower thresholds of species abundances that would cause management concern.The **Juvenile to Adult Ratio** is a measure of nest productivity and survival and is site-specific. It is directly affected by predation risk, and by the quantity and quality of food and nest sites, and allows separation of local effects from the confounding effects of migratory behavior.

- By recording changes in bird behavior across the breeding season and noting the timing and number of juveniles, a **Reproductive Index** can be calculated to measure reproductive success.

Behavioral/Ecological Metrics

- The abundance of various **Food Resources** is key to bird survival and productivity. Birds that forage in the river rely on fish and macro-invertebrates, while riparian birds depend on insects and plants. We are using a variety of methods to directly measure these resources and relate their abundance to river and riparian habitat conditions. A supporting literature review of the food preferences of Trinity upland birds is currently being undertaken (by John Alexander).

- Amount and configuration of **Riparian Habitat,** measured and tracked by remote sensing and field methods, are important for relating habitat changes to changes in bird abundance and will

[9] Natural year-year variation could be filtered out with the use of a good control site, but the control will have to be in fairly close proximity to the Trinity as birds respond to local conditions. Within 40 miles of the Trinity watershed it will be difficult to find a control site that does not have some level of human disturbance (e.g., camping, land use, etc.). The South Fork of the Trinity (relatively undisturbed) and Clear Creek (identical monitoring methods) could represent good controls to consider, as might the Klamath River (although this is more problematic due to disturbances and distance from the Trinity). The Trinity River above Lewiston Dam could be another possible control, though the topography is different upstream (no longer in a canyon) and there are more mining impacts. It may be necessary to look at various datasets across different sites and assess correlation in abundance and productivity (3 years of data exist in the Trinity study area for comparison). Power analyses have already been developed that can be applied to estimate the number of monitoring sites required to account for year-year variation in age ratios (juvenile:adult) and abundance.

provide valuable information on effects of restoration actions on birds. Categorical Regression Tree (CART) models developed by the Redwood Sciences Laboratory for riparian birds will permit both retrospective and prospective predictions of changes in bird abundance as a function of historical and future estimates (respectively) of habitat conditions. Using historical air photos it will be possible to evaluate pre-dam (1940s) riparian conditions and generate model-based estimates of historical abundances for approximately 15 bird species. Future riparian habitat scenarios can be used to model possible population trajectories of these bird species (e.g., expected short-term decrease in riparian birds, then recovery). The California Riparian Conservation Plan additionally provides targets for habitat conditions for focal bird species, and indicates maximum densities under optimal habitat conditions for four of the riparian bird species of concern in the Trinity. These established benchmarks can be used to further judge the changing status of riparian vegetation/bird interactions in the Trinity.

- **Activity Budgets** record the time birds spend searching for food, defending territories, building nests, and feeding young. This measure of energy expenditure provides information on habitat use and quality, and can be used to anticipate how bird species will react to habitat change. Activity budgets are, however, less important than population metrics, which integrate all impact pathways.
- **Predator Abundance** is an important index for assessing predation risk for birds and is related to nest success and overall survival.

6.3 Life-history vs. time diagrams

Life-history vs. time diagrams (Figure 6.1a,b,c) are intended to determine which life-history stages for birds are most likely to be directly affected by environmental change caused by management actions.

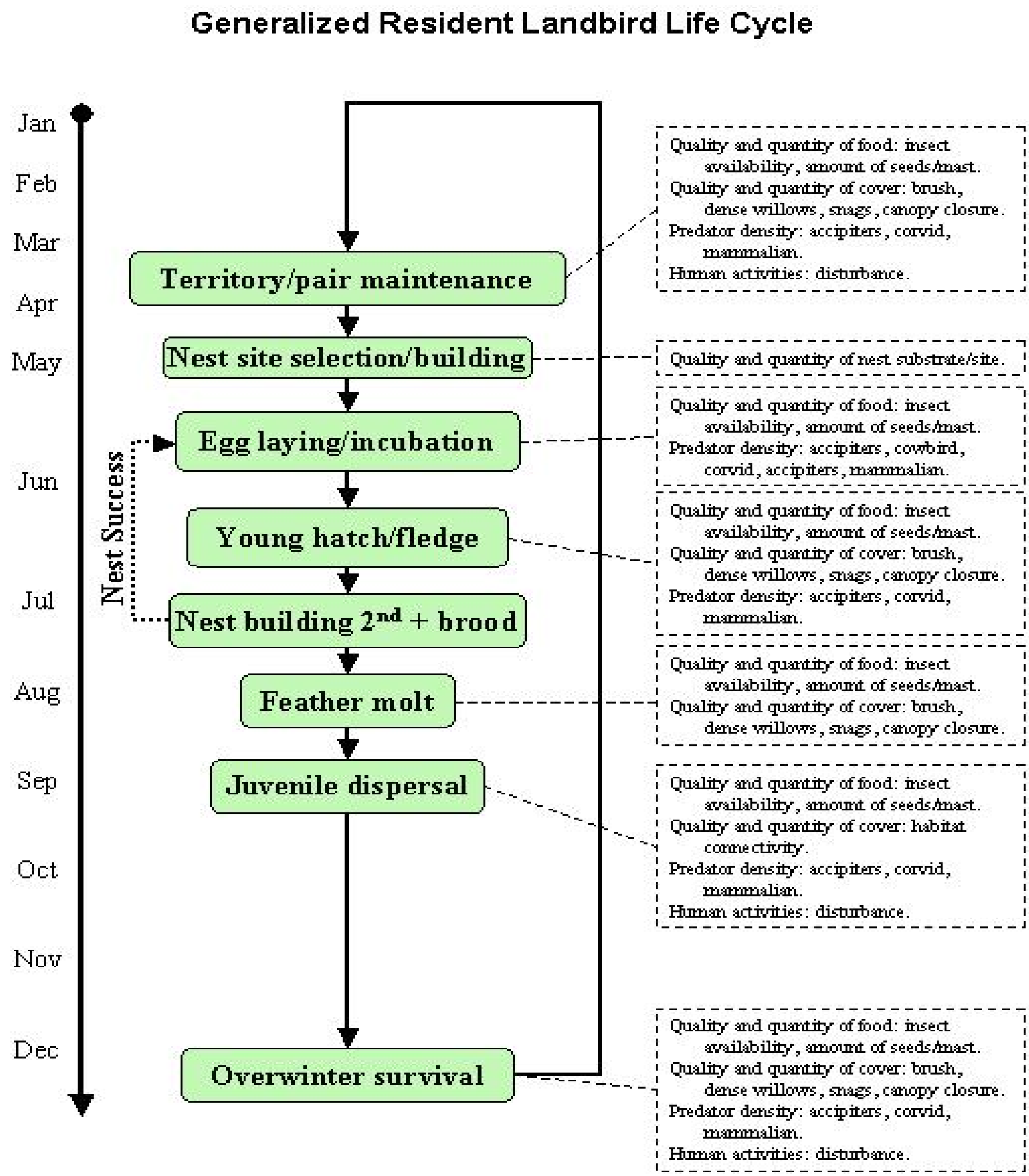


Figure 6.1a. Generalized resident landbird life cycle.

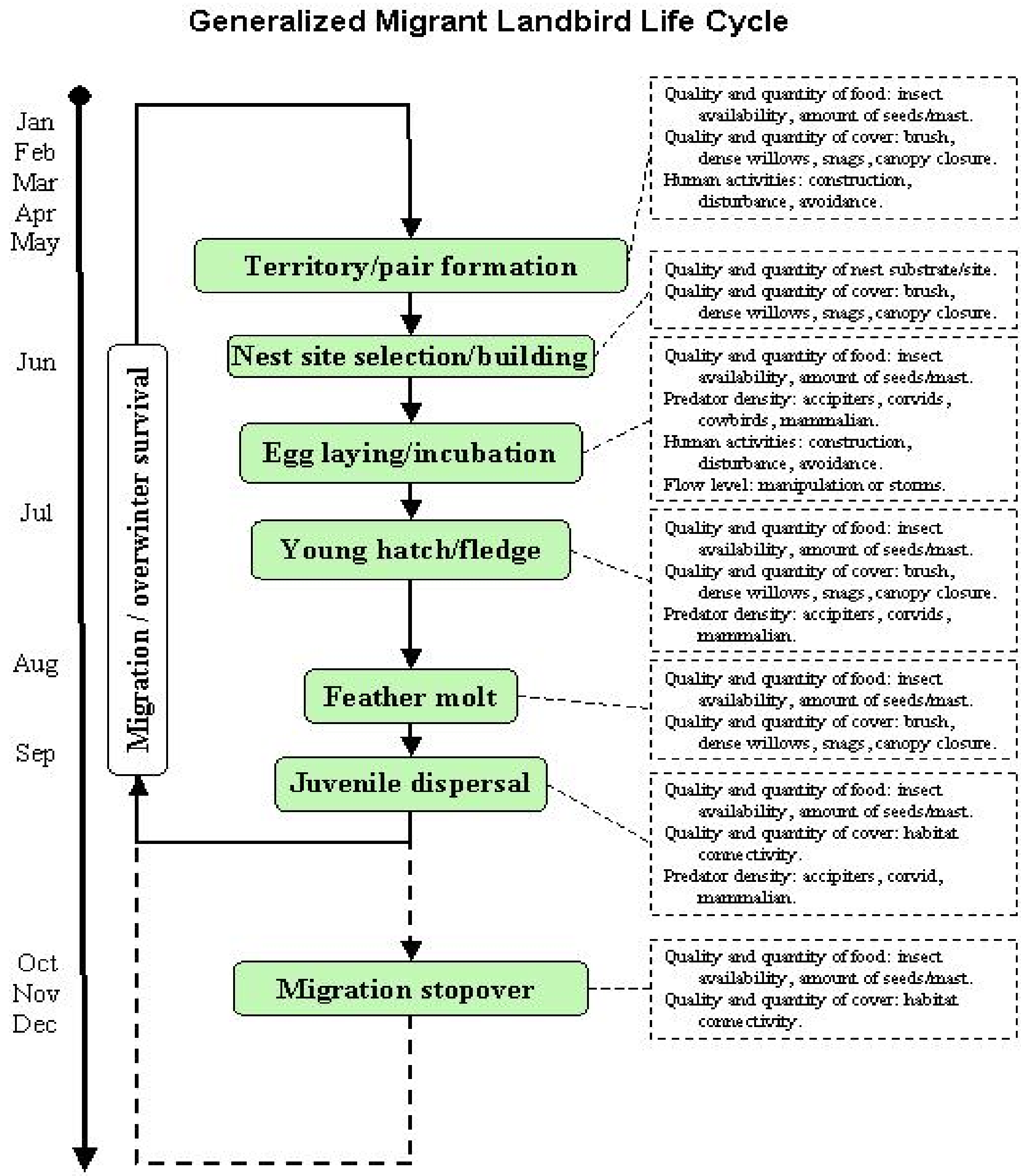


Figure 6.1b. Generalized migrant landbird life cycle.

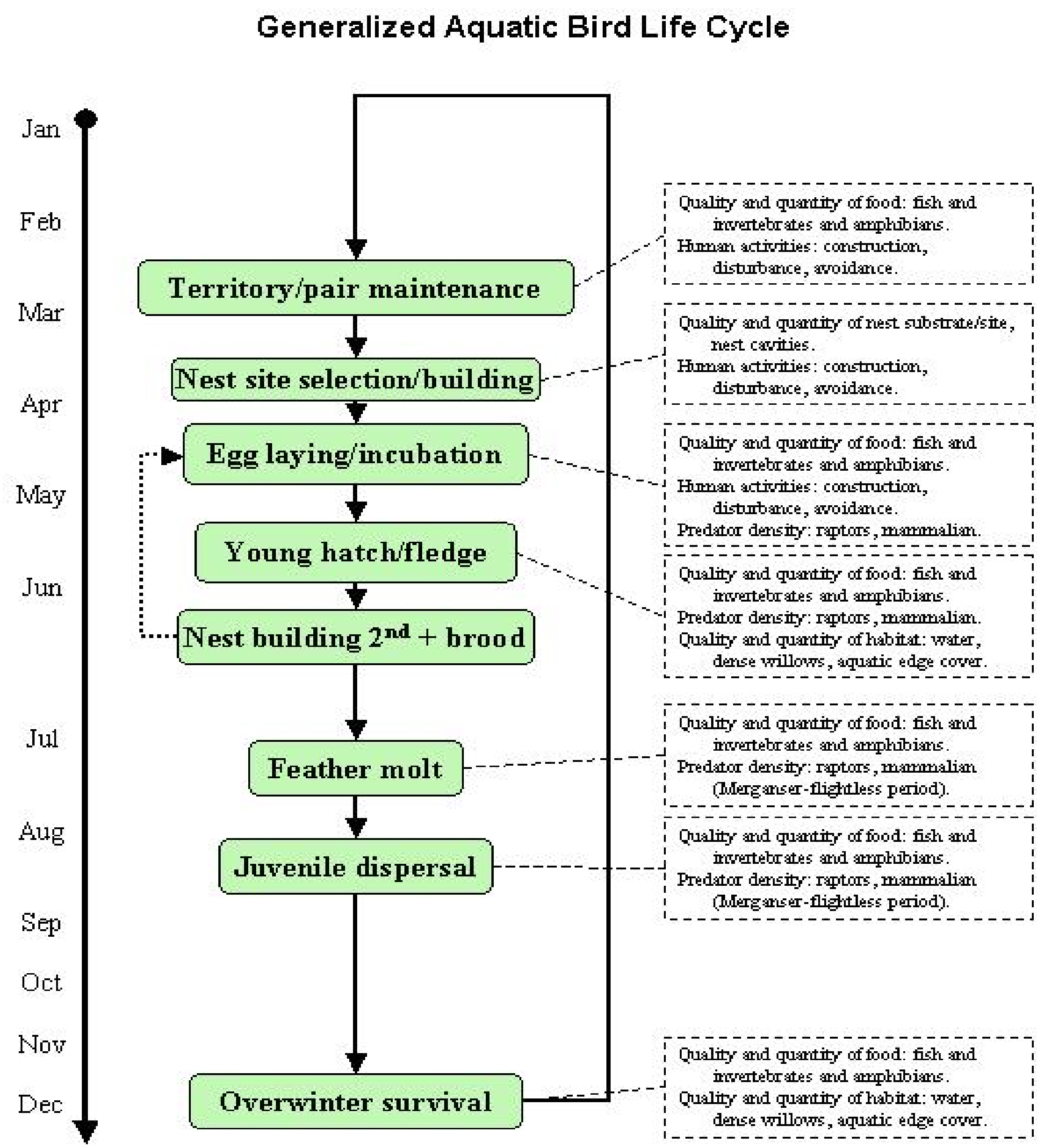


Figure 6.1c. Generalized aquatic bird life cycle.

6.4 Conceptual diagrams

A box and arrow diagram (Figure 6.2) is used to illustrate the varied assumptions about how management actions are expected to generate habitat changes that will ultimately change population metrics and valued ecosystem components for both riparian and aquatic birds.

Impact Hypothesis: Response of Bird Populations to Trinity River Restoration Activities

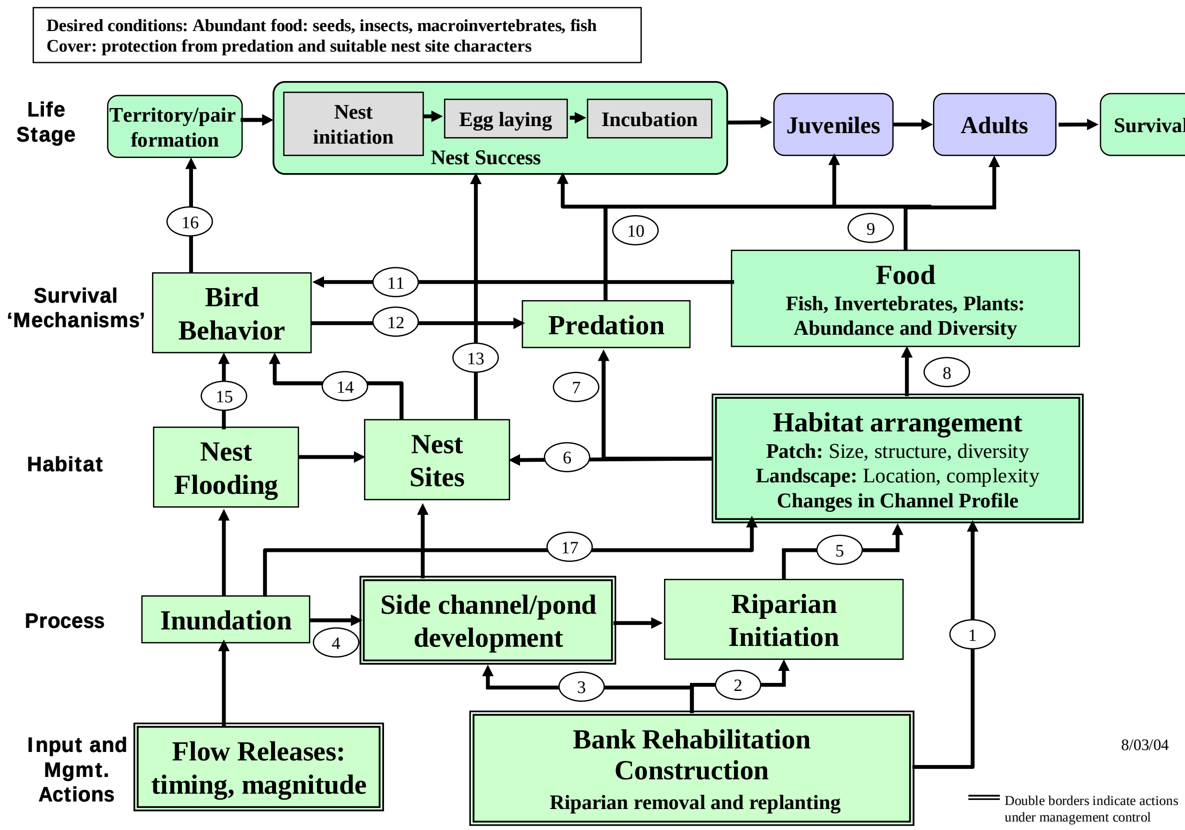


Figure 6.2. Overall conceptual model for riparian and aquatic fledging success and survival.

6.5 Statements of hypotheses / linkages and performance measures

Table 6.1 provides detailed descriptions of mechanistic linkages within the conceptual model (section 6.4) developed for riparian and aquatic birds.

Table 6.1. Mechanistic linkage descriptions for the overall riparian and aquatic bird conceptual model (as illustrated in Figure 6.2).

Link	Description	Linked to Subsystem:
1a	Removal of riparian berms at bank rehabilitation sites will affect the size, structure (inc. vertical diversity and cover), and plant species diversity of riparian habitat patches.	Riparian
1b	Removal of riparian berms at bank rehabilitation sites will change the landscape configuration of riparian habitat, including the landscape complexity and juxtapositions of habitat types.	Riparian, Physical
1c	Riparian berm removal and feather edge construction at bank rehabilitation sites will increase the amount of shallow, slow-water habitat in the channel.	Physical
2	Bank rehabilitation construction will create habitat for riparian plant initiation on the restored floodplain.	Riparian, Physical
3	Bank rehabilitation construction will create the potential for side channel and pond development resulting in additional nest sites and food resources.	Riparian, Physical
4	Increased flow levels will inundate natural and constructed side channels and ponds, prompting riparian initiation and increasing the number of nest sites.	Riparian, Physical
5a	Riparian initiation and replanting after bank rehabilitation construction will increase the amount of foraging and nesting cover.	Riparian, Physical
5b	Riparian removal will decrease cover and increase effects of weather (wind, rain, high and low temperatures) on nest success.	Riparian
5c	Riparian initiation and replanting after bank rehabilitation construction will change habitat patch and landscape characteristics.	Riparian, Physical
6	Changes in riparian patch size and patch type configuration will affect nest site quantity and quality.	Riparian
7a	Changes in habitat arrangement may affect predator abundance or prey vulnerability.	Riparian
7b	Increased riparian cover will increase survival by reducing predation risk for nests, juveniles, and adults.	Riparian
7c	Changes in landscape configuration that increase juxtaposition of urban and riparian habitats may increase abundance of predators causing increased predation risk for birds.	Riparian, Physical
8a	The arrangement of riparian habitat (patch and landscape characteristics) may increase or decrease food abundance and diversity.	Riparian, Physical
8b	Changes in the channel profile that create shallow, slow water habitat at bank rehabilitation sites and general diversity of channel types, will result in higher abundance, diversity, and availability of food for aquatic birds, including macro-invertebrates and small fish.	Physical, Fish
8c	Changes in amount of cover (vegetation and cobble) will affect the abundance and diversity of food.	Riparian, Physical
9	Changes in food abundance and diversity will affect nest success, and survival of juveniles and adults.	Riparian, Physical, Fish
10	Changes in predation rates will affect juvenile and adult survival rates.	
11	Changes in food abundance and diversity of food will affect the time birds spend foraging.	Riparian, Fish
12	The amount of time spent foraging may affect predation risk.	
13	Amount and quality of nesting sites will affect nest success rates.	
14a	The creation of nest sites through development of new habitat and cover will stimulate birds to form pair bonds and establish territories.	Riparian, Physical
14b	Birds may change breeding behavior, immigrate, or emigrate in response to abundance and quality of nest sites.	Riparian, Physical
15	Nest flooding caused by increased flows after nest initiation may cause birds to abandon nesting efforts or expend additional energy to reinitiate nesting.	Physical

Link	Description	Linked to Subsystem:
16	Bird behaviors that reduce the number of breeding pairs will decrease the number of juveniles.	
17	Inundation may change the habitat arrangement by reducing the amount of wetland and riparian vegetation.	Physical, Riparian

Tables 6.2a and 6.2b describe the hypotheses relating to the impacts of TRRP restoration activities on riparian and aquatic birds respectively, and identify the key performance measures that will be monitored to evaluate response.

Table 6.2a. Aggregate hypothesis statements describing the conceptual model of bank rehabilitation effects on fledgling success and survival for **riparian** birds. Linkage numbers refer to those illustrated in the hypothesis diagram (Figure 6.2) and described in Table 6.1. **Bolded** hypotheses (i.e., Hypotheses 1, 6 and 7) are those considered to be both important and highly feasible to evaluate.

Links	Hypothesis	Performance Measures	Class
Nest success (H1) **Linkages: 1, 7, 5b, 6, 7a, 7c, 8a, 8c, 9, 10, 12, 13, 14b**	**Removal of 50% of riparian habitat at bank rehabilitation sites will reduce the total number of breeding adults and juveniles.**	**1) Number of juveniles and ratio of juveniles to adults measured at banding stations.** **2) Nest success evaluated using reproductive index rankings.** **3) Number of adults and number of breeding adults.**	**Mgmt**
Nest success (H2) Linkages: 7a, 7c, 10	Riparian removal will reduce cover and increase risk of nest predation.	1) Reduced production of juveniles, decreased juvenile to adult ratio. 2) Increased rate of predation of observed nests.	Mgmt
Nest success (H3) Linkages: 1a, 7a, 8a, 8c, 11, 12, 10	The amount of food available to birds will be reduced by removal of riparian habitat, causing increased foraging times for adults and increased exposure of nests to predators.	1) Length of foraging periods will increase from activity budgets. 2) Increased rate of predation of observed nests. 3) Number of birds surviving until breeding season from census and demographic study.	Mgmt
Nest success (H4) Linkages: 2, 3, 5a	Replanting, channel and pond development, and riparian initiation increases vegetation cover, plant species diversity, and food availability, and will increase nest success.	1) Fledging rate: increased juvenile/adult ratio from demographic study. 2) Nest success evaluated using reproductive index rankings.	Mgmt
Survival (H5) Linkages: 1b, 5c, 7a, 7c	Changes in juxtaposition of urban and wild lands may increase predator abundance and reduce survival of nests, juveniles and adults.	1) Predator abundance from point counts at site, reach, and 40 miles. 2) Landscape configuration measured by habitat mapping and monitoring.	Mgmt
Survival (H6) **Linkages: 1, 2, 3, 5a, 5c, 6, 8, 9, 13 (later effect than H1)**	**Habitat changes following bank rehabilitation construction and riparian initiation will increase food resulting in increased total number of breeding adults and juveniles.**	**1) Number of juveniles and ratio of juveniles to adults measured at banding stations.** **2) Nest success evaluated using reproductive index rankings.** **3) Number of adults and number of breeding adults.**	**Mgmt, Natural**
Survival (H7) **Linkages: same as H6 (but later effect than H6)**	**Habitat changes following bank rehabilitation construction and riparian initiation will increase plant and food diversity resulting in a diverse bird community.**	**1) Species composition (number of species and diversity indices).**	**Mgmt, Natural**

Table 6.2b. Aggregate hypothesis statements describing the conceptual model of bank rehabilitation effects on fledgling success and survival for **aquatic** birds. Linkage numbers refer to those illustrated in the hypothesis diagram (Figure 6.2) and described in Table 6.1. **Bolded** hypotheses (i.e., Hypotheses 1 and 6) are those considered to be both important and highly feasible to evaluate.

Links	Hypothesis	Performance Measures	Class
Nest success (H1) **Linkages: 1, 8b, 8c, 9**	**Physical restoration will create a heterogeneous channel profile providing higher prey abundance, greater prey species diversity, and increased prey availability, resulting in higher nest success rates.**	**1) Abundance index (adult and/or juvenile) from float surveys (mergansers, dippers, herons).** **2) Prey abundance: small fish and macro-invertebrate indices at both rehab and control sites (finest spatial resolution possible, ideally monthly), and overall index for 40 miles.**	Mgmt
Nest success (H2) Linkages: 6, 13, 17	Changes in flow levels and timing may reduce the amount of vegetation cover and nesting substrate.	1) Juveniles/adult ratio and juvenile abundance index from float surveys. 2) Reduced cover at bank rehabilitation sites or over 40 miles, measured by riparian vegetation mapping and monitoring.	Mgmt
Nest success (H3) Linkages: 1, 2, 3, 4, 5, 7, 10, 17	Flow changes, replanting and channel and pond development increase vegetation cover and species diversity, decreasing predation risk and increasing nest success.	1) Juvenile/adult ratio and juvenile abundance index from float surveys. 2) Reduced cover at bank rehabilitation sites and over 40 miles, measured by riparian vegetation mapping and monitoring.	Mgmt
Survival (H4) Linkages: 15, 16	Flooding of nests after initiation may reduce the number and success of nests.	1) Number of territories at site and reach scales from point counts, spot mapping, and float surveys. 2) Juvenile/adult ratio and juvenile abundance index from float surveys.	Mgmt
Survival (H5) Linkages: 1c, 8b, 9, 10a, 10b, 17	Physical restoration will create a heterogeneous channel profile providing higher prey abundance, greater prey species diversity, and increased prey availability, resulting in higher abundance of aquatic foraging birds.	1) Abundance evaluated through float surveys and river point counts.	Mgmt
Survival (H6) **Linkage: 1c, 2, 3, 4, 8b, 9, 17**	**Bank rehabilitation construction and changes in flow releases will increase the number of juvenile fish (prey) in the river and improve survivorship for aquatic bird species.**	**1) Abundance of aquatic birds by reach, in the 40 miles, and to the confluence.** **2) Abundance of small fish by reach, in the 40 miles, and to the confluence.**	**Mgmt**
Survival (H7) Linkages: 1b, 5c, 7a, 7c	Changes in juxtaposition of urban and wild lands may increase predator abundance and reduce survival of nests, juveniles and adults.	1) Predator abundance from point counts at site, reach, and 40 miles. 2) Landscape configuration measured by habitat mapping and monitoring.	

6.6 Identification of critical uncertainties and proposed method of testing alternative hypotheses

- Wildfires in riparian habitat or adjacent uplands would directly affect the amount and configuration of habitat. Additionally, landslide sediment from wildfires in the watershed could affect riparian initiation, fish and macro-invertebrate abundance.
- Timing and quantity of fish released from the hatchery would affect abundance of small fish in the system and could affect the distribution, survival and productivity of birds that feed on fish, i.e. herons, Belted Kingfishers, and Common Mergansers.

- Predator abundance could change in response to human interference. For example, feeding of some wildlife, such as ravens, jays, or raccoons, could increase predator numbers near feeding areas.
- Tree removal or the planting of exotic species on private lands adjacent to restoration sites may affect bird abundance and/or species composition.
- Natural changes in flow levels due to large flood events could influence the rate or level of restoration effectiveness.
- Mosquito control programs (insecticide spraying) by Trinity County could affect bird survival.

It will be important to monitor these covariates relating to confounding effects, in order to tease out the signal of TRRP actions over time.

6.6.1 Monitoring design to assist with testing of hypotheses

Redwood Sciences Laboratory's bird monitoring protocols, survey designs (300-350 sample points) and habitat-population models (i.e., CART regression models) will allow statistically powerful inferences about the effects of TRRP restoration actions on various focal bird species, at multiple spatial scales. Compliance monitoring of birds is in place at channel rehabilitation sites, but it is focused only on identifying direct localized effects. The proposed comprehensive bird monitoring and modeling program will permit evaluation of cumulative *direct* and *indirect* effects of TRRP actions on birds across the entire Trinity system, relative to historical conditions, current conditions and California habitat/population targets. The program will also provide useful feedback on the design of channel rehabilitation sites.

Tables 6.3a and 6.3b (for riparian and aquatic birds respectively) describe elements of the monitoring design (i.e., measurement scale, response time, monitoring frequency and duration) that will dictate the ability to effectively evaluate performance measure response at different spatial and temporal scales.

Table 6.3a. **Riparian** birds performance measures for monitoring, adaptive management evaluation, and modeling.

Performance Measure	Spatial extent	Hypotheses Tested	Measurement Scale	Expected Response Time [1]	Monitoring Frequency and Duration
Bird Abundance (by species) and Species Composition	(1) Rehabilitation Site	H1, H3, H5, H6, H7	Point Count Station (Point count, Area search)	1 year and 5-10 years	1-2 years pre-rehab, 5 and 10 years post rehab
	(2) Index Reach [2]			1-5 years	5 years baseline, 5 year interval
	(3) Reach [3]			5-10 years	5 years baseline, 5 year interval
	(4) Dam to N. Fork			10 years	Annually
Juvenile to Adult Ratio[4]	(1) Rehabilitation Site	H1, H2, H4, H6, H7	Demographic Capture Station	1 year and 5-10 years	2 years pre-rehab, 5 years post-rehab, 2 consecutive years at 5 year intervals, or annually
	(2) Index Reach			1-5 years	5 years baseline, 2 consecutive years at 5 year intervals, or annually
	(3) Dam to N. Fork			10 years	Annually for 10 years, then 2 consecutive years at 5 year intervals
Reproductive Index	(1) Rehabilitation Site	H1, H4, H6, H7	100 m x 100 m Study Plot	1 year and 5-10 years	1-2 years pre-rehab 5 and 10 years post rehab
	(2) Index Reach			5 years	5 years baseline, 2 consecutive years at 5 year intervals, or annually
Amount and Configuration of Riparian Habitat	(1) Reach	H1, H5, H6, H7	Varied scales using GIS	5 years, post-rehab	5 years
	(2) Dam to N. Fork			10 years	10 years
Predator abundance	(1) Rehabilitation Site	H2, H3, H5, as covariate for H1, H6, H7	Point Count Station (Point counts, Area search)	1 year and 5-10 years	1-2 years pre-rehab, 5 and 10 years post rehab
	(2) Index Reach			5 years	
	(3) Dam to N. Fork			5-10 years	

1 Dependent on riparian response times (models)
2 Index Reach = A portion of a Reach to serve as a reference sampling area for the Reach. Scale (length and width) will be determined later and will vary by taxa or objective.
3 Reach = One of 4 physiographic reaches from the Dam to N. Fork, boundaries to be determined later
4 allows separation of local effects from confounding effects of migratory habitat

Table 6.3b. **Aquatic** birds performance measures for monitoring, adaptive management evaluation, and modeling.

Performance Measure	Spatial extent	Hypotheses Tested	Measurement Scale	Expected Response Time [1]	Monitoring Frequency and Duration
Bird Abundance (by species) and Species Composition	(1) Rehabilitation Site (Spotted Sandpiper)	H5, H6	Area search plot, and for Float Surveys: Index Reach, Reach, and Dam to N. Fork	1-3 years	1 year pre-rehab, 2 and 3 years post-rehab, then 5 year interval
	(2) Index Reach [2]			1-3 years	5 years baseline, 5 year interval
	(3) Reach [3]			3-5 years	5 years baseline, 5 year interval
	(4) Dam to N. Fork			5 years	Annually
Juvenile to Adult Ratio	(1) Rehabilitation Site (Kingfisher) (2) Index Reach	H1, H2, H3, H4, H6	Area search plot, and for Float Surveys: Index Reach, Reach, and Dam to N. Fork	1 year and 3-5 years	1 year pre-rehab, 2 and 3 years post-rehab, then 5 year interval
	(3) Reach			3-5 years	5 years baseline, 2 consecutive years at 5 year intervals, or annually
	(4) Dam to N. Fork			10 years	Annually for 5 years, then 2 consecutive years at 5 year intervals
Amount and Configuration of Riparian Habitat	(1) Reach	H2, H3, H6	Varied scales using GIS	5 years, post-rehab	5 years
	(2) Dam to N. Fork			10 years	10 years
Prey Abundance	(1) Index Reach	H1, H6	Varies depending on Fish count and macro-invertebrate techniques	1-5 years	5 years baseline, then 5 year intervals
	(2) Reach				
	(3) Dam to N. Fork				
Predator abundance	(1) Index Reach	H7 (covariate for H6)	Point Count Station (Point counts, Area search)	1 year and 5-10 years	1-2 years pre-rehab, 5 and 10 years post rehab
	(2) Dam to N. Fork			5 years	
				5-10 years	

[1] Dependent on riparian response times (models)
[2] Index Reach = A portion of a Reach to serve as a reference sampling area for the Reach. Scale (length and width) will be determined later and will vary by taxa or objective.
[3] Reach = One of 4 physiographic reaches from the Dam to N. Fork, boundaries to be determined later.

6.7 Summary of Workshop 1 discussions (Bird Subgroup)

The Birds Subgroup spent time reviewing the compliance requirements that necessitate monitoring of bird populations as part of the TRRP.

The ROD has established that the TRRP must consider potential impacts on federal and state listed plant and wildlife species, while NEPA/CEQA requirements, state and federal environmental laws and international commitments under the Migratory Bird Treaty Act require that bird impacts must be considered. The subgroup and external reviewer confirmed that the Redwood Sciences Lab’s bird monitoring protocols, survey designs (300–350 sample points) and habitat-population models (CART regression trees) will allow statistically powerful inferences on the effects of TRRP restoration actions on various focal bird species, at multiple spatial scales. Compliance monitoring of birds is currently intended for channel rehabilitation sites, but is focused only on identifying direct localized effects. A broader bird monitoring and modeling program will permit evaluation of cumulative *direct* and *indirect* effects of TRRP actions on birds across the entire Trinity system, relative to historical conditions, current conditions, and California habitat/population targets. The program will also provide useful feedback on the design of channel rehabilitation sites.

The subgroup identified both TRRP actions of importance for birds (i.e., channel rehabilitation, pond development, flow), as well as potential confounding actions that need to be monitored as potential alternative causal mechanisms (e.g., wildfires, floods, hatchery releases, tree removal, mosquito control). Subgroup participants agreed that habitat features (boxes in the conceptual model) most strongly dictating the population responses of aquatic birds to TRRP actions are ‘Habitat Arrangement’ and ‘Food’ (especially juvenile fish and invertebrates—a component that would be expected to increase with TRRP management actions). For riparian birds, the key habitat feature in the conceptual model was considered to be ‘Habitat Arrangement.’

The subgroup then prioritized the Backgrounder Document’s impact hypotheses based on perceived importance and feasibility. The 7 hypotheses originally proposed for **riparian** birds were filtered down to a smaller set of the 3 highest priority management hypotheses, which center on the effects of riparian habitat removal, channel rehabilitation, and riparian initiation on numbers of breeding adults and juveniles, and species diversity. These effects are expected to be initially negative, and then become positive over time. The Categorical Regression Tree (CART) model developed for riparian birds will permit both retrospective and prospective predictions of changes in bird abundance as a function of historical and future estimates (respectively) of habitat conditions. Similarly the 7 management hypotheses originally proposed for **aquatic** birds were filtered down to 2 key hypotheses, centered on the expected positive effects of bank rehabilitation and flow increases on bird prey abundance and diversity, leading to higher abundances of aquatic birds. The remaining hypotheses were considered low priority because either they were likely to be difficult to evaluate or the responses they predict were unlikely to occur, or both. Subgroup participants also identified the specific linkages in the conceptual models for riparian and aquatic birds that relate to these key management hypotheses.

The primary performance measures used to evaluate these key causal pathways were identified as: abundances of juveniles, adults and breeding adults; bird species diversity; nest success for riparian birds; prey abundance (especially fish for aquatic birds); and predator abundance.

Finally, the Birds Subgroup updated the information they would like to receive from the Physical, Riparian and Fish Subgroups. The participants found the workshop to be a very worthwhile experience.

7.0 Reptiles and Amphibians

Trinity management actions directly affect several species of reptiles and amphibians, in addition to causing indirect effects via other subsystems. The western pond turtle and foothill yellow-legged frog provide prime examples of sensitive species in this regard and have been focal species of study on the Trinity River for many years. Negative impacts to both species documented since construction of the Trinity and Lewiston dams have been attributed to changes in channel morphology and flow dynamics (Reese and Welsh 1998, Lind et al. 1996). Reptiles and amphibians represent a diverse group of animals with a wide variety of habitat needs, but restoring pre-dam function to the river system should benefit most native species.

7.1 Management actions directly affecting this subsystem

In this report, we directly examine only the affects on species identified in the ROD (USDOI 2000) as focal species of concern. Management actions directly affecting these focal species are listed below.

7.1.1 Reptiles (western pond turtle)

- Modification of flow timing, duration, magnitude and velocity
- Removal of riparian vegetation during bank rehabilitation
- Management of water temperatures through operations at Trinity and Lewiston Dam and diversion through Carr Tunnel
- Gravel/cobble augmentation
- Fine sediment removal (catchment ponds)
- Development on 100 year flood plain
- Creation / restoration of wetlands

7.1.2 Amphibians (foothill yellow-legged frog)

- Modification of flow timing, duration, magnitude and velocity
- Removal of riparian vegetation during bank rehabilitation
- Management of water temperatures through operations at Trinity and Lewiston Dam and diversion through Carr Tunnel
- Gravel/cobble augmentation
- Fine sediment removal (catchment ponds)

7.2. Key performance measures

7.2.1 Reptiles

Potential performance measures to be evaluated for western pond turtles include direct population metrics and habitat metrics.

Population metrics:

- Body size/given age
- Age of reproductive maturity
- Clutch size
- Age structure
- Population distribution
- Population density
- Nest fate

Habitat metrics:

- Macro-invertebrate production
- Number of basking sites
- Area of slack water refuge and pools
- Area of available nesting habitat
- Area of available rearing habitat at various inundation levels

7.2.2 Amphibians (foothill yellow-legged frog)

Potential performance measures to be evaluated for foothill yellow-legged frogs include direct population metrics and habitat metrics.

Population metrics:

- Distribution of adults and subadults
- Relative abundance of adults and subadults
- Adult population density
- Egg mass distribution
- Egg mass count
- Timing of oviposition
- Hatching rates
- Hatching success (% hatched per egg mass)
- Tadpole survival rates (difficult to assess in situ)
- Time and size at metamorphosis
- Over-winter survival of recent metamorphs

Habitat metrics:

- Area of overwintering habitat
- Area of oviposition habitat
- Availability of food resources

7.3 Life-history vs. time diagrams

7.3.1 Reptiles (western pond turtle)

Figure 7.1 gives a generalized view of the timing of western pond turtle activity. There is, however, a great deal of individual plasticity regarding habitat use, so not all turtles comply strictly with these generalized activity descriptions. Western pond turtles have high site philopatry, often returning to the same sites each year for overwintering, nesting, and foraging. These animals are primarily aquatic in the summer and terrestrial in winter. Generally, the summer home range includes a 200-500 meter length of river channel, where feeding and mating occur in water. Terrestrial activities, including nesting (in summer) and overwintering, have been documented from 25-400 meters from the river. Reproductive output is low, with an average clutch size of 7 eggs and most mature females reproducing only once in two years. Nest success and hatchling survival are generally low, but once animals reach adulthood they tend to be long-lived. Many turtles alive in the system today pre-date the dam.

Generalized Life History **Western Pond Turtle**

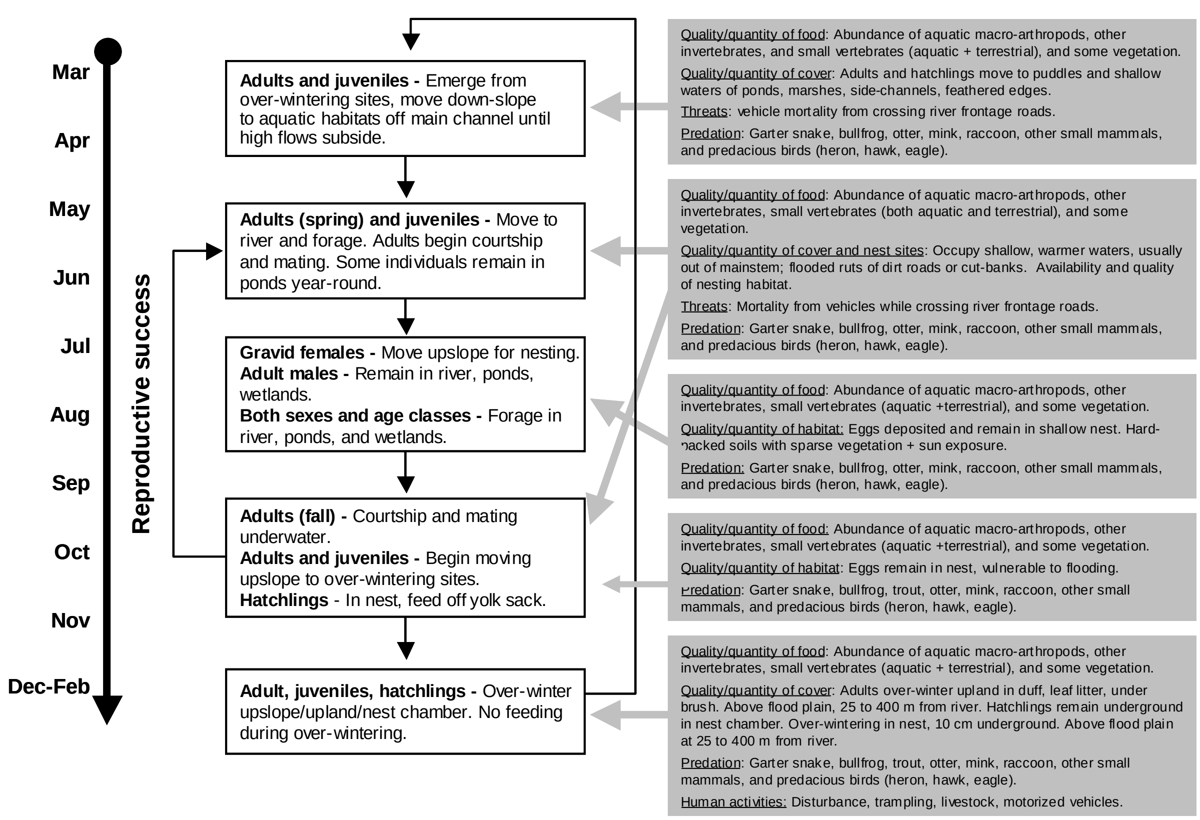


Figure 7.1. Life-history timeline for western pond turtle in Trinity River Basin.

7.3.2 Amphibians

Figure 7.2 gives a generalized view of the timing of Foothill Yellow-legged frog activity.

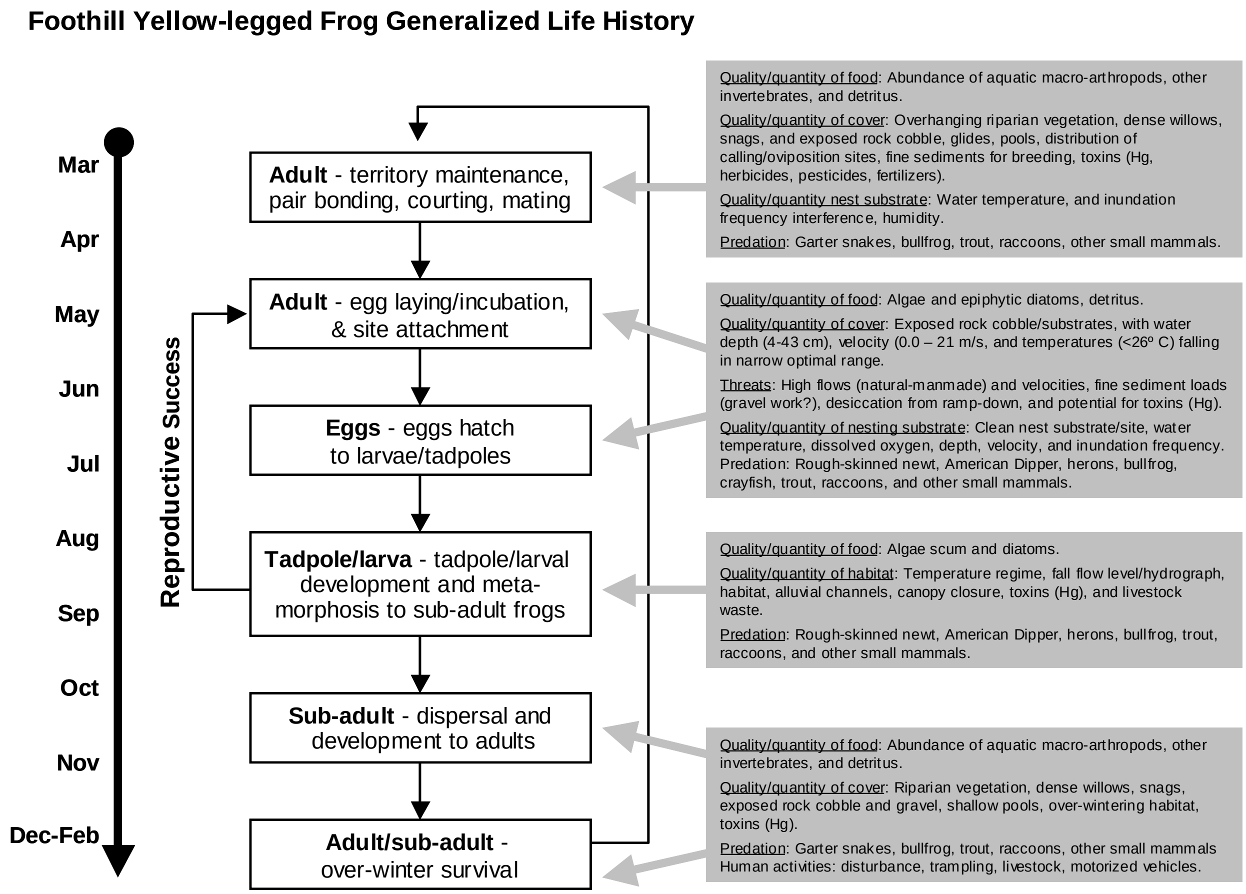


Figure 7.2. Generalized life-history timeline for yellow-legged frog.

7.4 Conceptual diagrams

Box and arrow diagrams (Figures 7.3 and 7.4) are used to illustrate the varied assumptions about how management actions are expected to create habitat change and ultimately change population metrics and valued ecosystem components for western pond turtle and foothill yellow-legged frogs.

7.4.1 Reptiles

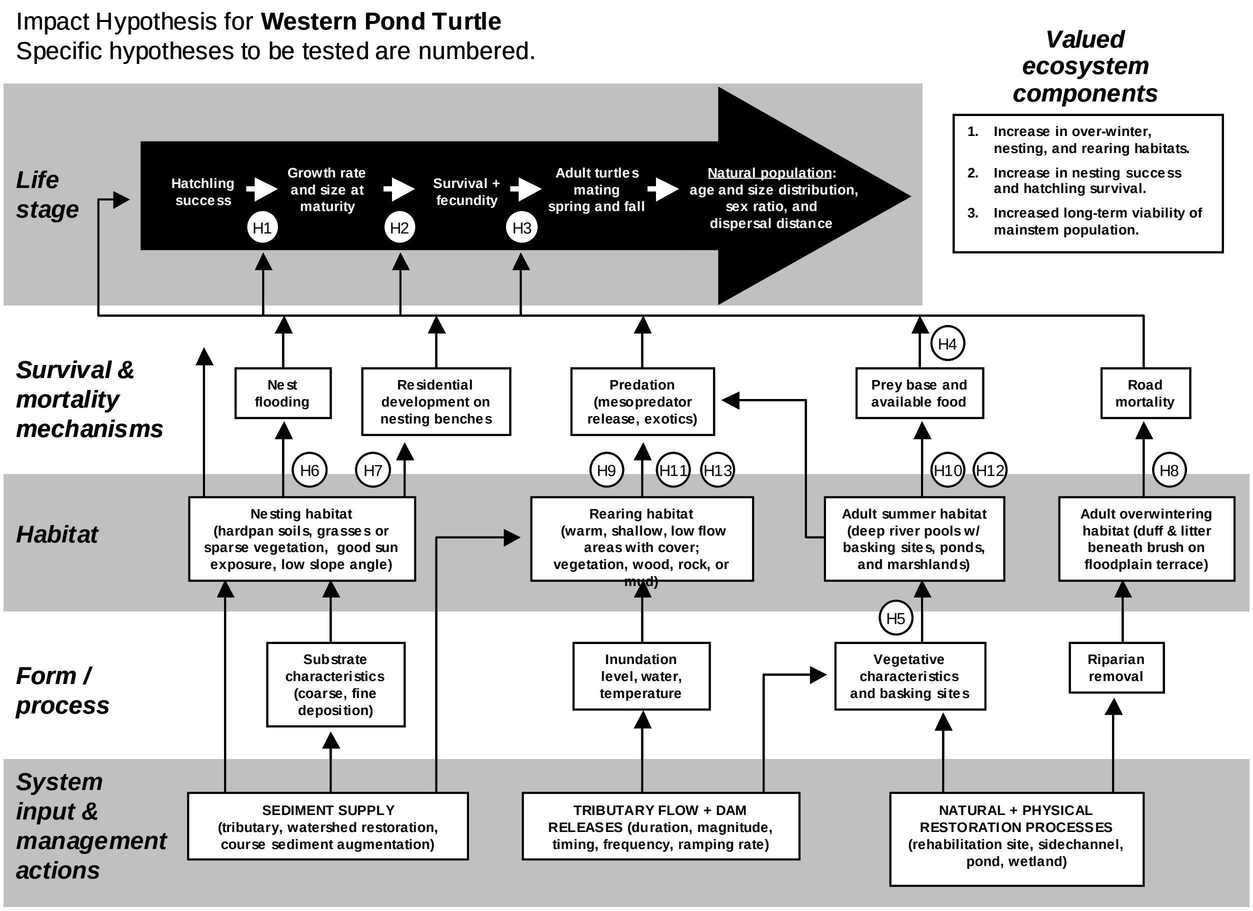


Figure 7.3. Western pond turtle conceptual model. Specific hypotheses to be tested are numbered (see Table 7.1).

7.4.2 Amphibians

Impact Hypothesis for **Foothill Yellow-legged Frog** Egg-Mass Assessment – Specific Hypotheses to be Tested are Numbered

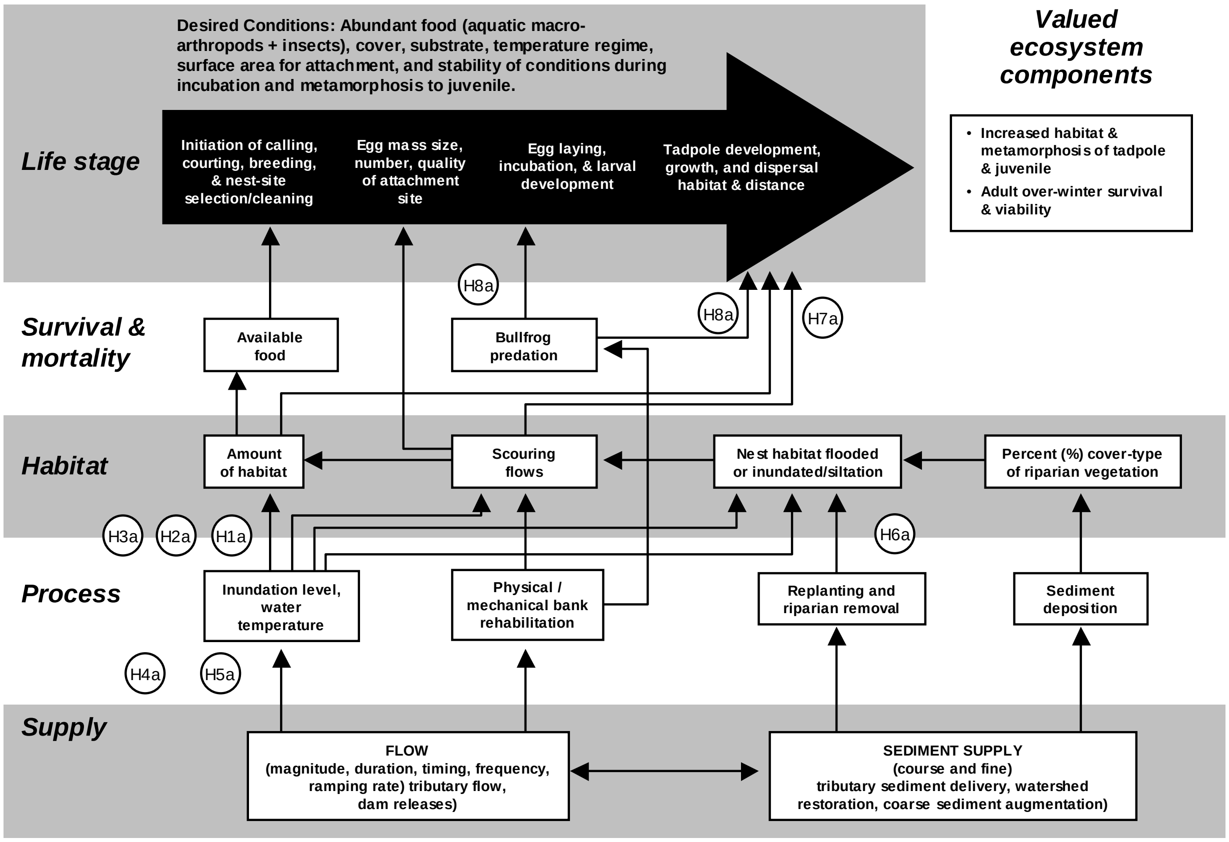


Figure 7.4. Major pathway: conceptual model for yellow-legged frog egg-mass assessment. Specific hypotheses to be tested are numbered (see Table 7.2).

7.5 Statements of hypotheses / linkages and performance measures

Text statements of selected cause and effect linkages illustrated in Figures 7.3 and 7.4 are presented in Tables 7.1a, 7.1b, 7.1c and 7.2 in the form of testable hypotheses (including alternative hypotheses), with associated performance measures (Tables 7.1b, 7.1c and 7.2) to be monitored for testing of these hypotheses. The key hypotheses presented in Tables 7.1b and 7.2 relate to the measurable affects of management actions. Alternative hypotheses (i.e., bullfrog/exotic fish predation/competition, small mammal predation, road mortality, and urban development) potentially affecting survival and demographics of the focal reptile and amphibian species are also presented here, and should be evaluated/quantified as covariates in any overall assessment of population response. These additional factors are, however, generally considered to be outside the direct control of management/restoration actions planned for the Trinity system and therefore cannot be fully evaluated within the constraints of the TRRP's AEAM framework.

7.5.1 Reptiles

Table 7.1a. Western pond turtle statement of hypothesis linkages.

Key hypotheses under the control of TRRP management decisions:

Link	Description
1	Water temperature affects growth rate of turtles.
2	Overwinter survival and clutch size are related to body size. Body size is related to water temperature.
3	Shallow, warm water habitat with low flow favors hatchlings and young turtles.
4	Growth rate is influenced by availability of prey (macro-invertebrates). Production of macro-invertebrates is influenced by characteristics of flow, vegetation, and substrate.
5	Removal of riparian vegetation will reduce cover for adults. Large woody debris and overhanging willow branches are used for basking. Removal of vegetation may reduce the amount of emergent willow branches available for basking. Removal of riparian vegetation may decrease recruitment of woody debris, or it may increase recruitment of woody debris by initiating bank failure.
6	Nesting occurs above the flood plain in hard-packed soils with sparse vegetation (often on benches on the 100 year flood plain). Large flood events can deposit sediment for future nesting.

Alternative hypotheses *outside* direct TRRP management control:

Link	Description
7	Areas favored for nesting by western pond turtles also make good building sites. Development in these areas may exclude use by nesting turtles.
8	Road mortality may play an important role in reducing turtle populations where major roads parallel the river (e.g., Hwy 299).
9	Residential activity can drive away larger predators allowing increase of mesopredators, such as foxes, skunks, and raccoons, which prey on turtle nests and young turtles.
10	Bullfrogs were introduced to the Trinity River Basin over a century ago. Their impact on native herpetofauna is unknown, but is currently under investigation.
11	Exotic fish (e.g., bass, bluegills, shiners, etc.) have been introduced to the Trinity River Basin. Their impact on native herpetofauna is unknown.

Table 7.1b. Western pond turtle statements of testable TRRP **management** hypotheses. **Bolded** hypotheses (i.e., Hypotheses 1, 2, 3 and 4) are those considered to be both important and highly feasible to evaluate.

Linkages	Hypothesis	Performance Measures
(H1) Linkages: 1, 2	**H1o: Water temperature or river flow has no significant effect on growing season or turtle growth. H1a: Colder water temperatures or high flows affects growing season and retards growth.**	**Compare size per given age relative to turtles on the unregulated South Fork Trinity River (carapace length and total weight). Sampling should occur on at least two spatial scales. Spatial Scale 1. The entire 39-mile study area of the Mainstem from Lewiston Dam down to the confluence with the North Fork and the South fork Trinity from Surprise Creek down to the confluence with the Mainstem. Size and age estimates will be recorded for each turtle captured and released by any method. Spatial Scale 2. Intensive sampling will occur at a subset of the area covered by Spatial Scale 1. The Mainstem will be stratified into three sections based on distance from the dam. From each section, three 1-kilometer reaches will be randomly selected for snorkel surveys. The South Fork will be stratified into two sections based on accessibility. From each section, three 1-kilometer reaches will be randomly selected for snorkel surveys. Compare growing seasons by evaluation of temperature recorders, flow velocities and turtle movement patterns.**
(H2) Linkages: 1, 2	**H2o: Water temperature has no significant effect on age to maturation. H2a: Age at maturation is delayed by lower water temperatures.**	**Compare age at reproductive maturity relative to turtles on the unregulated South Fork Trinity River (by counting annuli or through skeletochronology). Spatial scale same as above (H1).**

Linkages	Hypothesis	Performance Measures
(H3) Linkage: 3	**H3o: Body size is not related to fecundity (clutch size). H3a: Smaller body size equates to lower fecundity.**	**Compare clutch sizes between the Mainstem and South Fork Trinity River (x-ray gravid females in spring and early summer). Spatial scale same as above (H1).**
(H4) Linkage: 4*	**H4o: Availability of food resources does not significantly influence growth and fecundity. H4a: Scarcity of food resources reduces growth and fecundity.** ***NOTE: Indirect linkage.**	**Monitor macro-invertebrate production. Compare food resources between the Mainstem and South Fork Trinity River; relate to H1, H2, and H3. Stomach lavage of adult turtles and compare to available aquatic macro-invertebrate community sampled during the same day. Spatial scale same as above (H1).**
(H5) Linkage: 5	H5o: Removal of riparian vegetation will not affect recruitment of large woody debris to the channel. H5a: Removal of riparian vegetation will promote recruitment of large woody debris to the channel.	Compare amount of basking sites before and after vegetation removal. The "after" sample should be collected following large flow events that initiate localized bank failure and after high flows have receded. Initially the spatial scale will be limited to areas near project sites. Basking sites will be quantified at, and downstream of, project sites prior to project implementation and again after the river has had a chance to respond to bank manipulations. Quantity (density) of basking sites within randomly selected reaches along the South Fork Trinity River could be used for additional comparison.
(H6) Linkage: 6	H6o: The lack of periodic large flood events has not changed the quantity and quality of nesting habitat. H6a: The lack of periodic large flood events has reduced the quantity and quality of nesting habitat.	Assess vegetative encroachment and substrate condition of potential nesting areas relative to pre-dam conditions. Also compare Mainstem nesting conditions to those on the South Fork Trinity River. Locating nest areas can be extremely difficult (best assessed by radio-tracking gravid females in the late spring and early summer). Nesting habitat parameters would include: soil condition, soil porosity, soil temperature, soil cover, herbaceous layer, grass layer, brush layer, slope, aspect, and distance to river.

Table 7.1c. Western pond turtle statements of **alternative** hypotheses.

Linkages	Hypothesis	Performance Measures
(H7) Linkage: 7	H7o: Residential and recreational development does not change the amount of available nesting habitat for western pond turtles. H7a: Residential and recreational development reduces amount of available nesting habitat for western pond turtles.	Compare age structure between population in developed areas and remote areas. (Turtle nests are extremely difficult to locate, direct testing of this hypothesis may be cost prohibitive.) Same as above (H6).
(H8) Linkage: 8	H8o: River side motor vehicle traffic has no impact on turtle population size through direct mortality. H8a: River side motor vehicle traffic reduces population size through direct mortality. (Turtles move upland in the fall to overwinter and move back down to the river in the spring. In mid-summer, gravid females move upslope for nesting then return to the river. Roads paralleling the river pose a risk.)	Compare population densities for areas of comparable habitat arrangement and different road activity/positioning. Populations on the Mainstem Trinity River will be randomly selected based on proximity to major and minor roads. Reaches for population surveys will be stratified based on road proximity with a target of 3 populations from areas with major roads parallel to the river and 3 populations from areas without major roads.
(H9) Linkage: 9	H9o: Mesopredator release around residential areas does not affect turtle nest predation rates. H9a: Mesopredator release around residential areas increases turtle nest predation rate.	Track gravid females to nest areas. Monitor fate of nests in residential and remote areas. Survey of nesting benches for predated nests. Trap, track-plate, or photo-trap mesopredators at nest areas to compare relative impact between residential areas and non-residential areas.
(H10) Linkage: 10	H10o: Bullfrogs do not compete with young turtles for food resources. H10a: Bullfrogs compete with young turtles for food resources.	Assess habitat associations and ecology of bullfrogs in the Trinity River Basin. Assessment would occur on a small spatial scale, and should initially focus on areas where bullfrogs and young turtles are known to co-occur.

Linkages	Hypothesis	Performance Measures
(H11) Linkage: 10	H11o: Bullfrogs do not prey upon young turtles. H11a: Bullfrogs prey upon young turtles.	Conduct gut content analysis of bullfrogs during spring, summer, and fall. Collect bullfrogs from areas known to have nesting populations of western pond turtles. Assessment would occur on a small spatial scale, and should initially focus on areas where bullfrogs and young turtles are known to co-occur (same spatial scale as H10).
(H12) Linkage: 11	H12o: Exotic fishes (sticklebacks, bluegills, shiners, etc.) do not compete with young turtles for food resources. H12a: Exotic fishes compete with young turtles for food resources.	Assess habitat associations of sticklebacks in the Trinity River Basin. Conduct gut content analysis of exotic fishes during spring, summer, and fall. Assessment would occur on a small spatial scale, and should initially focus on areas where exotic fishes and young turtles are known to co-occur (similar spatial scale as H10).
(H13) Linkage: 11	H13o: Exotic fish (e.g., Largemouth bass) do not prey upon young turtles. H13a: Exotic fish (e.g., Largemouth bass) prey upon young turtles.	Conduct gut analysis on larger exotic fishes that occur in habitats utilized by hatchling and young turtles. Choose a randomly stratified sample based on where turtle nesting is known to occur and/or where hatchlings and young turtles have been found sympatric with exotic fishes. Sample in spring when hatchling turtles are moving from nesting locations to lentic habitats where exotic fishes are to occur.

7.5.2 Amphibians

Table 7.2. Foothill yellow-legged frog statements of testable TRRP **management** hypotheses. **Bolded** hypotheses (i.e., Hypotheses 1-6) are those considered to be both important and highly feasible to evaluate.

Links	Description of Hypothesis	Impact (+, m, -) and Potential Monitoring Metrics	Overall Spatial Extent (Scale)	Performance Measures
H1, H2, H3 (Linkages: 1, 2, 3)	**H1o: There are no biological impacts to YLF habitat from managed rapid up-ramping rates at Lewiston.** **H1a: There are negative biological impacts to YLF habitat from managed rapid up-ramping rates at Lewiston.** **H2o: There are no biological impacts to YLF habitat associated with timing of annual peak releases.** **H2a: There are negative biological impacts to YLF habitat associated with timing of annual peak releases.** **H3o: Staggering of peak releases will not afford advantages to YLF egg masses in dry years and may have > hatching success than in wetter years.** **H3a: Staggering of peak releases will afford advantages to YLF egg masses in dry years and will > hatching success relative to wetter years.**	**Flow Timing, Duration, Magnitude, Velocity** **(+) creation/maintenance of habitat.** **(-) threat of scour/desiccation of eggs.** **Water temperature** **(m) 12- 26 degrees C.** **(-) Colder water increases incubation time, slow tadpole growth, smaller juveniles, and reduced over-winter survival.** **Sediments - Wash-load (<0.5mm) – silt + fine sand** **(-) Fills interstitial spaces, suppresses macro-invertebrates, covers egg mass.** **(+) Fines (0.5-8.0 mm) coarse sand and fine gravel provides habitat for prey base and refuge for tadpoles.** **(+) Coarse (>8.0-256 mm) "pebble, cobble, boulder" provides attachment site for egg masses.**	**Main-stem Wide** **(Lewiston Dam to North Fork)**	**Stratified random or representative set of locations along mainstem where breeding, nest sites, and egg masses are known to exist.** **No significant ($P > 0.05$) decrease in:** **(1) Area of critical habitat for adults and egg mass attachment;** **(2) Total number of egg masses/adults; or** **(3) Geographic or ecologic distribution of egg masses and adults.**

Links	Description of Hypothesis	Impact (+, m, -) and Potential Monitoring Metrics	Overall Spatial Extent (Scale)	Performance Measures
H4, H5	**H4o: Gradually increasing water temperatures during spring flow releases will have no affect on YLF's egg laying or increase growth rates of tadpoles.** **H4a: Gradually increasing water temperatures during spring flow releases will encourage YLF's to lay eggs or increase growth rates of tadpoles.** **H5o: Recommended ramping rates will have no affect on desiccation mortality of YLF egg masses during spring snowmelt runoff.** **H5a: Recommended ramping rates will minimize desiccation mortality to YLF egg masses during spring snowmelt runoff.**	**Flow Timing, Duration, Magnitude, Velocity** **(+) Creation/maintenance of habitat.** **(-) Threat of scour/desiccation of eggs.** **Sediments - Wash-load (<0.5mm) – silt + fine sand** **(-) Fills interstitial spaces, suppresses macro-invertebrates, covers egg mass.** **(+) Fines (0.5-8.0 mm) coarse sand and fine gravel provides habitat for prey base and refuge for tadpoles.** **(+) Coarse (>8.0-256 mm) "pebble, cobble, boulder" provides attachment site for egg masses.**	**Main-stem Wide** **(Lewiston dam to North Fork)**	**Stratified random or representative set of known breeding locations.** **(1) No significant increase ($P > 0.05$) in number of adult YLF courting, breeding, or engaged in nest construction.** **(2) No significant decrease ($P > 0.05$) in number and density of egg masses and attachment sites.** **(3) No significant increase ($P > 0.05$) in number of desiccated egg masses or tadpoles swept away by increased flows associated with manipulated spring hydrographs.**
H6 (Linkage 6)	**H6o: Removal of 50% of riparian vegetation during bank rehabilitation and creation of associated gravel habitats will not increase the size and distribution of populations of Foothill Yellow-legged Frogs.** **H6a: Removal of 50% of riparian vegetation during bank rehabilitation and creation of associated gravel habitats to increase juvenile survival of salmonid fry will increase the size and geographic distribution of populations of YLFs.**	**Riparian Vegetation** **(+) Open bars with little or no vegetation preferred.** **(+) Sparse willow (<3 yrs since initiation).** **(-) dense encroached vegetation along shoreline**	**Reach Wide or Cluster of Rehabilitation sites**	**Stratified/representative set of locations within a cluster of rehabilitation sites where breeding, nest sites, and egg masses are known to exist.** **(1) Significant ($P < 0.05$) increase in area of critical habitat for adults and egg mass attachment.** **(2) Significant ($P < 0.05$) increase in number of egg masses and adults.**
H7 (Linkage: 7)	H7o: Oviposition habitat selection and microhabitat specificity will not affect population stability of YLFs subjected to substantial temporal and spatial variability in river environments. H7a: Oviposition habitat selection and microhabitat specificity will affect population stability for YLF subjected to substantial temporal and spatial variability in river environments.	Breeding Habitat - Point bars variable size (30 to >1000 m) (m) Length of shoreline. (m) Area of aquatic (<0.5 m deep, <3 m from shore). (+) Shallow (<0.5 m), Low flow (<0.2 m/sec), aquatic habitat. (+) Substrate for oviposition (part. size >5 mm). (+) Low slope angle into water	Reach Wide or Cluster of Rehabilitation sites	Stratified/representative set of locations within a cluster of rehabilitation sites where breeding, nest sites, and egg masses are known to exist. (1) Significant increase ($P < 0.5$) in expanse of geographic and ecologic distribution of egg masses and adults. (2) Significant increase ($P < 0.5$) in density of egg masses and adults.
H8 (Linkage: 8)	H8o: Exotic populations of predatory bullfrogs in the Trinity River mainstem will have no impact on native populations of tadpole, subadult, and adult YLF at rehabilitation sites or designated side-channel construction sites H8a: Exotic populations of predatory bullfrogs in the Trinity River mainstem will have a negative impact on native populations of tadpole, subadult, and adult YLF at rehabilitation sites or designated side-channel construction areas.	Breeding Habitat - Point bars variable size (30 to >1000 m) (m) Length of shoreline. (m) Area of aquatic (<0.5 m deep, <3 m from shore). (+) Shallow (<0.5 m), Low flow (<0.2 m/sec), aquatic habitat. (+) Substrate for oviposition (part. size >5 mm). (+) Low slope angle into water	Reach Wide or Cluster of Rehabilitation sites	Stratified/representative set of locations within a cluster of rehabilitation sites where breeding, nest sites, and egg masses are known to exist. (1) Significant ($P < 0.5$) decrease in the number of tadpole, subadult, and adult YLF at proposed restoration sites and newly constructed side-channels.

7.6 Identification of critical uncertainties and proposed method of testing alternative hypotheses

Reptiles

- Loss of individuals to human collectors for food or as pets.
- Threat of disease or parasites from exotics.
- Loss of individuals to road mortality.

Amphibians

- Threat of increased exposure to disease or parasites from exotics. Bullfrog tadpoles captured in the mainstem near Bucktail this spring tested positive for chytridiomycosis. The chytrid fungus has been implicated in amphibian declines across the globe and the non-native bullfrog may serve as an over-wintering reservoir for this disease organism.

7.6.1 Monitoring design to assist with testing of hypotheses

Note: Monitoring designs for FYLF and WPT are will be completed as part of later steps in the AEAM Framework process.

7.7 Summary of Workshop 1 discussions (Reptiles/Amphibians Subgroup)

The subgroup leads provided an overview of the biology of key reptile/amphibian species found in the Trinity Basin. Subgroup participants then discussed the overall rationale for including a monitoring/ evaluation program for reptiles and amphibians within the TRRP. Subgroup participants recognized that the management actions of the TRRP will be focused on benefiting fish, but the ROD also indicates concern for wildlife within the Trinity watershed. This can be evaluated only through development of a monitoring program for the river's varied wildlife biota. Beyond this goal, monitoring assemblages of reptiles and amphibian species can provide integrative indicators of habitat conditions both in-river and within the larger floodplain, as the composite of aquatic/terrestrial life-histories require a full range of properly functioning riverine conditions for population persistence.

The subgroup identified 4 principal reasons for including a monitoring/evaluation program for reptiles and amphibian species within the TRRP program:

- Proposed management actions in the Trinity are hypothesized to have numerous direct and indirect affects on these animals (both positive and negative).
- One reptile species (western pond turtle) and one amphibian species (foothill yellow-legged frog) have already been identified as focal species of concern in the ROD.
- There is a suite of readily measurable performance measures (PMs) that could be used to evaluate the impacts of management actions on these animals at multiple spatial scales.
- The USFS's Redwood Sciences Lab already has in place amphibian/reptile monitoring protocols for the Trinity; these long-term baseline datasets (including control sites existing in the South Fork Trinity) could be easily expanded to encompass any proposed TRRP monitoring design.

Subgroup discussions concentrated on refining and prioritizing the impact hypotheses proposed for western pond turtle and yellow-legged frog (the two focal species), based on tighter linkage with direct management actions planned for the Trinity. The 13 hypotheses originally proposed for western pond turtle were filtered down to a more workable set of 6 management hypotheses. The remaining 7 hypotheses were considered of interest as alternative hypotheses (and should be evaluated/quantified as potential confounding factors) but are outside TRRP management control and therefore not directly testable within the Trinity AEAM framework. The 8 hypotheses proposed for yellow-legged frog were filtered down to a smaller set of 6 primary management hypotheses. There was discussion among the participants about how to prioritize amongst these management hypotheses and how to better identify/evaluate the key linkages in the conceptual models. Further work in this regard should continue.

The Reptiles/Amphibians Subgroup felt that working towards development of a more comprehensive monitoring program for assemblages of reptile and amphibian species (beyond just the two focal species identified in the ROD) would be a worthwhile undertaking. Information about these other species could provide data for a suite of habitat/water quality conditions in the Trinity, would be highly feasible given the protocols required, and would be relatively inexpensive compared to the effort required for monitoring of fish and other biota in the system. As reptiles and amphibians represent good indicators of habitat conditions both in-river and within the floodplain, they could serve as general surrogates of conditions for fish, when direct fish data are not available. Candidate reptile species to monitor for this purpose include garter snakes (which hunt primarily in aquatic fringe habitat—increases in garter snake abundance could indicate increases in salmon fry numbers) and whiptail lizard and/or sagebrush lizard (both of these lizards are indicators of extensive sandy floodplain habitat and are currently rare in Trinity—marked increases would indicate a return to natural river structuring processes).

8.0 Aquatic Macro-invertebrates

The Trinity River Flow Evaluation study (USFWS and HVT 1999) seeks to enhance smolt/juvenile salmonid rearing density by providing "a favorable range of baseflows for maintaining high-quality juvenile salmonid rearing and macro-invertebrate habitat in an alternate bar" morphology. The TFRES recognized that crucial attributes of restoration success include "increasing macrobenthic invertebrate productivity," "greater substrate complexity in riffle and run habitats for improved macro-invertebrate production," and "greater habitat complexity." These attributes collectively recognize the importance of macro-invertebrate diversity and productivity to enhancing salmonid juvenile success. Benthic macro-invertebrates within the Trinity River ecosystem are thus intrinsic components of habitat and fisheries restoration efforts.

Benthic macro-invertebrates have emerged as excellent integrative proximal indicators of lotic habitat integrity, ecosystem disturbance, and recovery. Their life histories and benthic habitat associations integrate information about ecological condition at spatial and temporal scales that are directly relevant to habitat management, whether basin wide or in response to point source disturbances. Protocols for ecosystem condition monitoring with benthic invertebrates are well established, but have not yet been applied extensively within the major salmonid bearing streams of the Trinity River basin. Therefore, to determine baseline benthic macro-invertebrate communities within the mainstem and major tributaries of the Trinity River, assess the response of those communities to natural and anthropogenic habitat changes, and evaluate the expected annual variation in benthic macro-invertebrate community organization, the following information is needed:

- Establish and test standard baseline protocols for surveying benthic macro-invertebrates in the lower mainstem Trinity River basin and in the upper basin above Lewiston, the North Fork Trinity River, and the South Fork Trinity River, including monitoring sites for long-term ecological condition assessments.
- Measure habitat and water quality variables in conjunction with macro-invertebrate samples to quantify biotic community organization relationships with environmental gradients that determine overall habitat integrity.
- Sample benthic macro-invertebrate communities in the Trinity River system for 3 consecutive years to estimate the expected range of normal variation in community organization and associated environmental gradients in response to natural flow variation, and to recommended spring and fall flow.
- Test individual elements of combined multi-metric ecological condition indices that best reflect the status of the selected sites and develop a standard ecological condition index for comparison with future monitoring results.
- Coordinate our efforts with other research to yield data suitable for inclusion in multi-organism habitat suitability and ecosystem response trajectory models.

8.1 Management actions directly affecting this subsystem

8.1.1 Aquatic macro-invertebrates

- Local density of aquatic macro-invertebrates will likely increase in subsurface portions of the rehabilitation sites but the overall effect of such actions in the mainstem is unknown. Any management action that increases structural diversity associated with the subsurface and associated vegetation should increase diversity and density of aquatic macro-invertebrates.
- Hydrologic discharge, substrate enhancement, channel change/formation—side channel, pond development, high flow scour channels, backwater alcoves, addition of gravel, cobble, and sand surfaces, and any additional subsurface topographic diversity will increase habitat (hidey holes) for aquatic invertebrates.
- Removal of riparian vegetation during bank rehabilitation in association with any increase in the overall diversity of riparian plant species, which develop within the floodplain and at the waters' edge, will add to the plant structure and species composition in wet areas and facilitate an increase in the area and quality of habitat for aquatic invertebrates.
- Management of water temperatures through operations at Trinity and Lewiston dams and diversion through the Carr Tunnel.
- Gravel/cobble/sediment augmentation.
- Fine sediment removal (catchment ponds).
- Diversification of substrate complexity in riffle and run habitats.

8.2. Key performance measures

Monitoring of various population and habitat performance measures for aquatic macro-invertebrates will be used to construct predictive models and evaluate the impact of specific bank rehabilitation site designs. Selection of performance measures will be critical to the success of the adaptive management process. For example, population diversity and abundance of aquatic macro-invertebrates are largely dependent upon the quality of both aquatic and subsurface habitat structure and complexity. Species distribution and abundance (population density/biomass) of aquatic macro-invertebrates are known indicators of the productivity of riverine and riparian systems.

Distribution and abundance measures for macro-invertebrates will also allow estimates of production, survival, and persistence of fish populations in riverine and riparian systems (site-to-reach-specific scales), because aquatic macro-invertebrates provide the critical food base for growth and reproduction of populations of native salmonids and wildlife.

Potential performance measures used to test various hypotheses for aquatic macro-invertebrates include population metrics and habitat metrics.

Population metrics:

- Species/taxonomic group abundance (population density at multiple geographic scales)
- Species/ taxonomic group distribution
- Species diversity
- Species/ taxonomic group reproductive effort or index

- Species/ taxonomic group production (biomass)
- Relative use and importance as a prey item by populations of fish and wildlife

Habitat metrics:

- Production and availability of food (i.e., smaller invertebrate prey species, algae, detritus, etc.)
- Topographic diversity and complexity of subsurface
- Instantaneous discharge
- Channel alterations
- Reach length
- Water surface gradient
- Geomorphic unit frequency
- Proportion of channel filled
- Pool variability
- Amount/total area of available habitat

8.3 Life-history vs. time diagrams

Aquatic macro-invertebrate life-history vs. time diagrams for detritivores, grazers, and predators are still being considered. They are intended to determine which life-history stages of selected macro-invertebrate species are most likely to be important to salmonids (both juveniles and adults), and therefore most directly affected by environmental perturbations caused by various management actions.

Note: There is a need for further input from the fish and other wildlife subsystems as to the specific taxa of invertebrates that should be assessed (or the specific suites of taxa within the 3 major categories listed above (i.e., detritivores, grazers, and predators)) before final development of life-history vs. time diagrams will be undertaken. Figure 8.1 provides a general representation of the time periods when macro-invertebrate prey could be most important in the life-histories of fish.

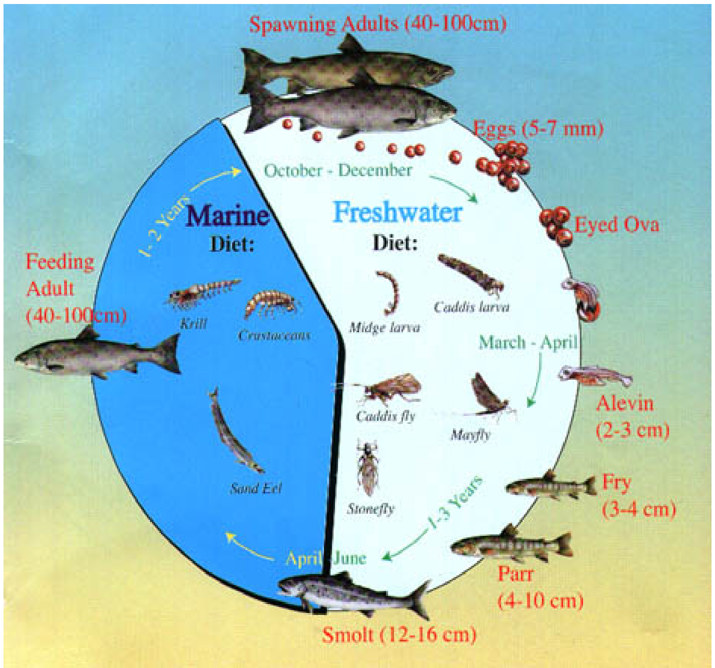


Figure 8.1. Yearly periods of fish utilization of macro-invertebrate prey.

8.4 Conceptual diagrams

The box and arrow diagram (Figure 8.2) illustrates assumptions about how management actions are expected to generate habitat changes that will ultimately affect population metrics and valued ecosystem components for aquatic macro-invertebrates.

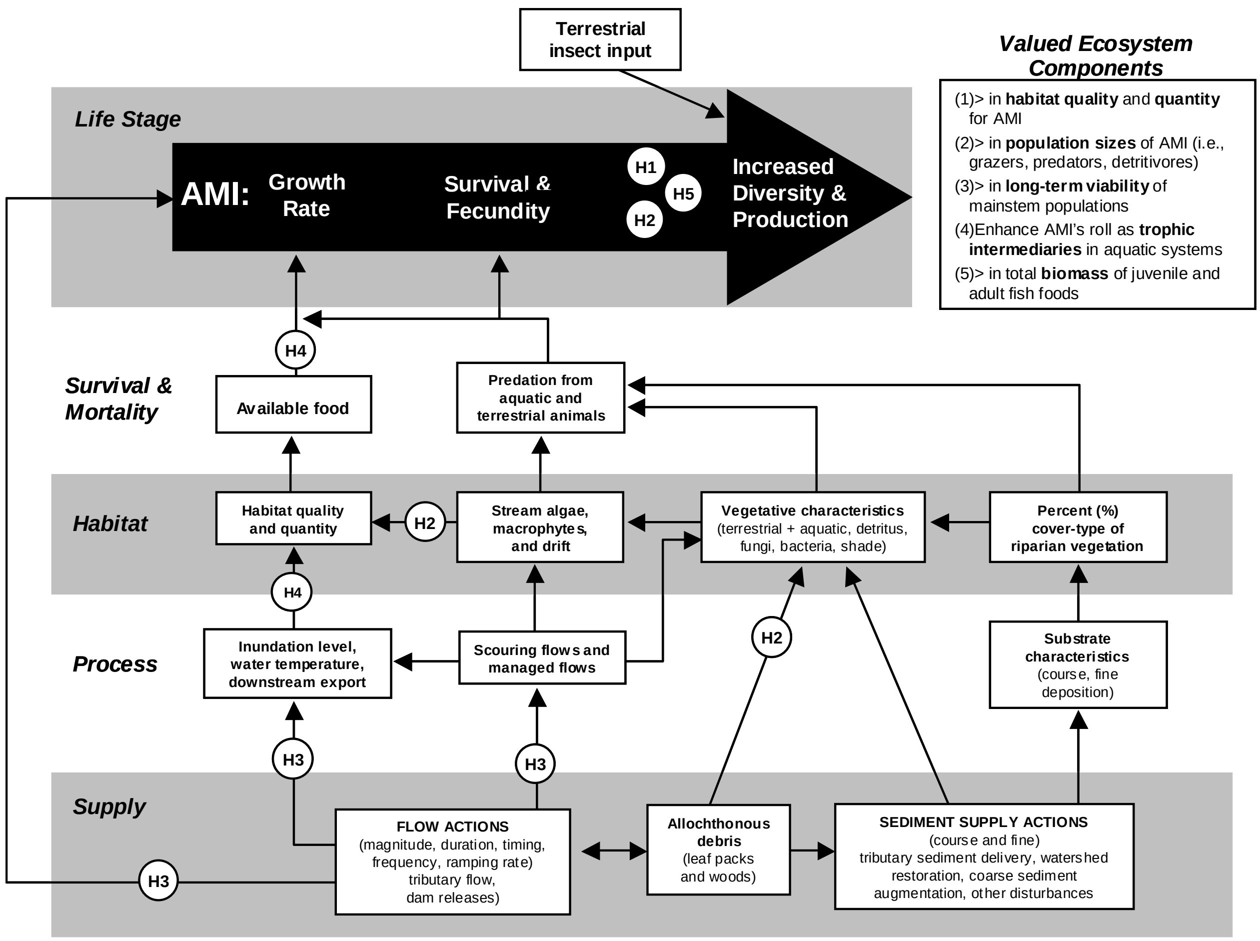


Figure 8.2. Draft conceptual model for aquatic macro-invertebrates.

8.5 Statement of hypotheses / linkages, and performance measures

Text statements of selected cause and effect linkages as illustrated in Figure 8.2 are presented in Table 8.1 in the form of testable hypotheses (including alternative hypotheses), with associated performance measures to be monitored for testing of these hypotheses. Hypotheses 1 and 2 represent research hypotheses required for understanding responses to management manipulations in the Trinity. Hypotheses 3-5 are direct management hypotheses that will likely only become testable after the initiation of a program to evaluate the first two hypotheses.

Table 8.1. Aquatic macro-invertebrate statements of testable hypotheses.

Links	Potential Hypotheses
H1 (Linkage 1)	H1: Diversity of benthic macro-invertebrates and drift biomass are significant indicators of lotic ecosystem condition within tributaries of the Trinity River drainage that support anadromous salmonid fisheries.
H2 (Linkage 2)	H2: Diversity of benthic macro-invertebrates and drift biomass are significant indicators of proximal ecological conditions among Trinity River sub-basins that are physiographically similar (e.g., stream order, gradient, base/peak flow).
H3 (Linkage 3)	H3: Increased higher ROD flows will result in an increase in downstream invertebrate habitat quality and a shift in taxonomic composition toward organisms with high food value for fish. Increased occurrence of stoneflies (*Plecoptera*) and mayflies (*Ephemeroptera*) should signal improved conditions for resident fish species in the lower mainstem and in association with rehabilitation sites when pre- vs. post-construction conditions are compared.
H4 (Linkage 4)	H4: Aquatic macro-invertebrate communities and drift biomass are respond to annual variation in ecological and managed mainstem conditions. Benthic macro-invertebrate biomass (major taxa) and diversity will be positively affected by TRRP manipulations of physical variables (i.e., flow, sediment, vegetation).
H5 (Linkage 5)	H5: Increased aquatic macro-invertebrate diversity and productivity, and drift biomass in association with increased substrate complexity in riffle and run habitats will enhance salmonid juvenile production. Increases in biomass of benthos due to TRRP actions will lead to increased growth of juvenile salmon and steelhead at a given density of fish.

8.6 Identification of critical uncertainties & proposed method of testing alternative hypotheses

The primary hypothesis to be tested is that increased macrobenthic invertebrate diversity and productivity (biomass) in association with increased substrate complexity due to site restorations and more natural flows will increase food availability for juvenile salmonids. Over time, there should be a significant increase in total production of juvenile fish along the mainstem. Uncertainties in this regard are still being defined. For example, the degree of substrate complexity and total functional high-quality habitat (i.e., flood plain) resulting from different extent (area) and types of various rehabilitation site designs are unknown. Geomorphic engineering designs that are linked to fish use need to be finalized before a more refined substrate-benthic invertebrate-fish production hypothesis can be tested. Additionally, patterns of food selection by salmonids in association with food availability in the Trinity mainstem need to be examined and tested. It is also unclear whether current fish production in the Trinity system is food limited, and whether increased macro-invertebrate production will result in a significant fish population response.

One approach to monitoring and determining the success of the TRRP at designing rehabilitation sites (perturbed sites) for benthic macro-invertebrates would be to assess whether topographic complexity and subsurface area is significantly correlated with aquatic macro-invertebrate production; then, test whether this production translates into significant juvenile fish production (i.e., size and number of individuals) relative to "natural" and "control" sites where modification of the subsurface has not occurred.

The primary hypothesis could be evaluated by monitoring: 1) the rate of colonization and relative biomass of macro-invertebrates before and after construction of a site; and 2) the population density, consumption rates of benthic macro-invertebrates, and growth rates of juvenile salmonids before and immediately following construction of each site and over a predetermined period of time.

8.6.1 Monitoring designs to assist with testing of hypotheses

Potential monitoring designs that could be used to evaluate predicted macro-invertebrate response to TRRP restoration actions are described in Table 8.2. Variation in designs relates to the scale of interpretation, expected response time, monitoring duration/frequency, and the required analyses to evaluate performance measure response.

Table 8.2. Aquatic macro-invertebrate monitoring designs to test hypotheses and evaluate ecosystem response.

Links	Scale	Response Time	Monitoring Duration / Frequency	Baseline Data Holdings	Sampling and Statistical Analyses
H1 (Linkage 1)	1. Basin-wide	3 – 5 yrs	1. Develop baseline information in 2 to 3 yrs. 2. Follow with monitoring (3, 5, 10, 15, 20 yrs) in coordination with biodiversity, biomass, habitat, and fisheries production goals and objectives.	1. Very limited in extent and scope. 2. Very limited - USFS, Redwood Science Laboratory reference samples on the Mainstem Trinity River. 3. Limited – Department of Biological Sciences, Humboldt State University, Invertebrate Museum/collection reference samples for Mainstem Trinity River.	Standardized reference sampling Statistical Tests 1. Species richness by use of Jack-knife 2. Niche overlap indices 3. Association and binary similarity coefficients, and diversity indices 4. Ordination and cluster analyses 5. No-metric multidimensional scaling 6. Principal Components Analysis + ANOVA on Factor loadings.
H2 (Linkage 2)	1. Stream segment 2. Sample reach	3 – 4 yrs	3, 5, 10, 15, and 20 yr intervals in coordination with biodiversity, biomass, habitat, and fisheries production goals.	4. Very limited or not useful? – USGS reference samples associated with biological assays of methyl-mercury on the Mainstem Trinity River.	Standardized reference sampling, stratified sampling, or randomized sampling delineated by geomorphic or geologic criteria, etc. Statistical Tests 1. No-metric multidimensional scaling 2. Principal components Analysis + ANOVA on Factor loadings 3. ANOVA + multiple comparisons tests 4. Multi-group MANOVA, and canonical correlation analysis 5. Correlation + multiple-regression analysis
H3 (Linkage 3)	1. Rehabilitation site 2. Gravel Injection site 3. Stream segment 4. Sample reach	2 – 3 yrs	As above		
H4 (Linkage 4)	1. Rehabilitation site 2. Gravel Injection site	2 – 3 yrs	Selected pre- and post-construction baselines followed by monitoring at 3, 5, 10, 15, and 20 yr intervals in coordination with biodiversity, biomass, habitat, and fisheries production goals.		
H5 (Linkage 5)	1. Sample reach 2. Stream segment3. Basin-wide	3 – 5 yrs	As above		

8.7 Summary of Workshop 1 discussions (Macro-invertebrates Subgroup)

The subgroup participants discussed the overall rationale for including a monitoring/evaluation program for aquatic macro-invertebrates within the TRRP. It is expected that the abundance of macro-invertebrates should increase with the more diverse flow regimes and habitat configurations created by TRRP restoration efforts. However, no level of monitoring for macro-invertebrates is currently in place to evaluate this, nor are there any real baseline datasets with which to make comparisons. Previous flow studies (although limited) and general consensus among participants is that Trinity fish populations are likely not food limited, given the current size of the fish population. However, it is uncertain how fish consumer/food ratios might change as the system is enhanced. Any future food limitations in the systems could only be tracked and fully evaluated with a comprehensive macro-invertebrate monitoring program in place.

The subgroup proposed 3 principal reasons for monitoring aquatic macro-invertebrates:

1. Although TRRP actions may be expected to increase macro-invertebrate abundance, the increase could be in taxa of macro-invertebrates unavailable to fish as food. As such the system could become food limiting to fish despite an overall increase in invertebrate biomass. This could only be evaluated through a program designed to monitor changes in macro-invertebrate abundance and community composition.
2. Macro-invertebrates represent the best integrative metric for quick and localized detection of major habitat/water quality changes, much faster and more tightly delineated than fish responses. This species group has great utility as an aid to examining the effects of localized restoration activities (positive or negative) within operational time frames.
3. Knowledge of baseline and changing macro-invertebrate abundance and community structure will likely provide a basis for understanding and predicting not only the potential population trajectories of fish but also of monitored wildlife biota (birds, reptiles and amphibians).

The subgroup recognized that macro-invertebrates would only be a useful monitoring tool if techniques are developed that can be employed/analyzed within relevant time frames (e.g., Rapid BioAssessment Protocols). To achieve this would require some period of focused strategic sampling within the Trinity to establish key benchmarks/indicators, which would then provide the basis for more rapid assessment methods for continued monitoring of the system. The level of information generated (i.e., taxonomic detail, sampling effort) would have to be tightly linked to the data needs of other TRRP subsystems, and would have to recognize the realities of TRRP budgetary constraints.

The subgroup distilled the 5 hypotheses originally proposed for this subsystem into a smaller set of 4 hypotheses. One of these hypotheses related to a general assessment of the value of using macro-invertebrates as significant indicators of lotic conditions in the Trinity, requiring a focused effort to define key benchmarks and taxonomic indictors for the Trinity. This hypothesis could be evaluated at two separate scales, dependent on whether assessments are limited to a subbasin scale or focused at finer scales (e.g., tributary level). The other 3 management hypotheses link intended management actions (principally related to changes in flow and substrate condition) in the Trinity, to predicted changes in macro-invertebrate productivity and community structure, and concomitant changes in juvenile salmonid production.

9.0 Considerations for Monitoring and Evaluation Plans

This first AEAM Framework Workshop did not focus on monitoring plans. However, it did provide a foundation for the development of future monitoring designs.

To achieve system-level scientific understanding of the relationships between proposed restoration activities, resources of the Trinity River, and related dam operations, we will need to integrate monitoring among physical and biological components as well as management actions. Monitoring plans should include nested multi-scale designs to allow regional, site specific and agency specific issues to be addressed, as well as cross-system comparisons to address those variables that are most uncertain and most sensitive to independent variables.

Monitoring is done to: 1) evaluate whether objectives are being achieved; and 2) to improve our scientific understanding via the AEAM process. The first step in developing the monitoring strategy is identifying the objectives for collecting data. The objectives guide the development of the monitoring program and help determine: 1) which attributes will be measured; 2) where, how often, and for how long they will be measured; and 3) what analyses will be done on the resulting data.

Several types of monitoring are necessary in a well managed program, such as trend and process monitoring. Process monitoring involves choosing a process-based independent variable (e.g., flow, shear stress) rather than time, as in trend monitoring. Process monitoring is less common than trend monitoring because it is difficult (both mentally and field-wise), yet it has several advantages. For example, process monitoring helps establish strong causal linkages, while trend monitoring often does not relate treatment (or lumps treatments) to the dependent variable of interest. This forces the researcher to speculate on what caused the response, and requires significant time to establish (e.g., 10-12 years may be required to establish a trend in biological monitoring data), whereas process monitoring can often establish relationships in a year or so.

It can be difficult to detect population responses to habitat restoration, as illustrated in Figure 9.1. The *actual* post-treatment condition of an ecosystem component is a function of three things: its pre-treatment condition; the restoration actions undertaken; and the confounding natural and human disturbances which occurred concurrently with the restoration actions. The *observed* post-treatment condition and inferred benefits of the restoration action are a function of the actual post-treatment condition in combination with the experimental design and monitoring effort. Hence, failure to observe any benefit from restoration actions (i.e., unable to reject a no effect (null) hypothesis) could be a function of severe pre-treatment conditions, inadequate restoration actions, confounding natural or human disturbances that undermine the restoration action, or inadequate experimental design and monitoring. In the absence of monitored control or reference systems for a given treatment, positive confounding factors (e.g., good climate) could imply that an ineffective restoration action actually had some benefit. Conversely, negative confounding factors could mask an otherwise effective action. Traditional monitoring programs that focus on before-after comparisons within single watersheds (without any reference systems) are often insufficient for separating the real effects of habitat restoration actions from these confounding factors. Reference or control systems are best found reasonably close to treated systems to minimize landscape and climatic differences.

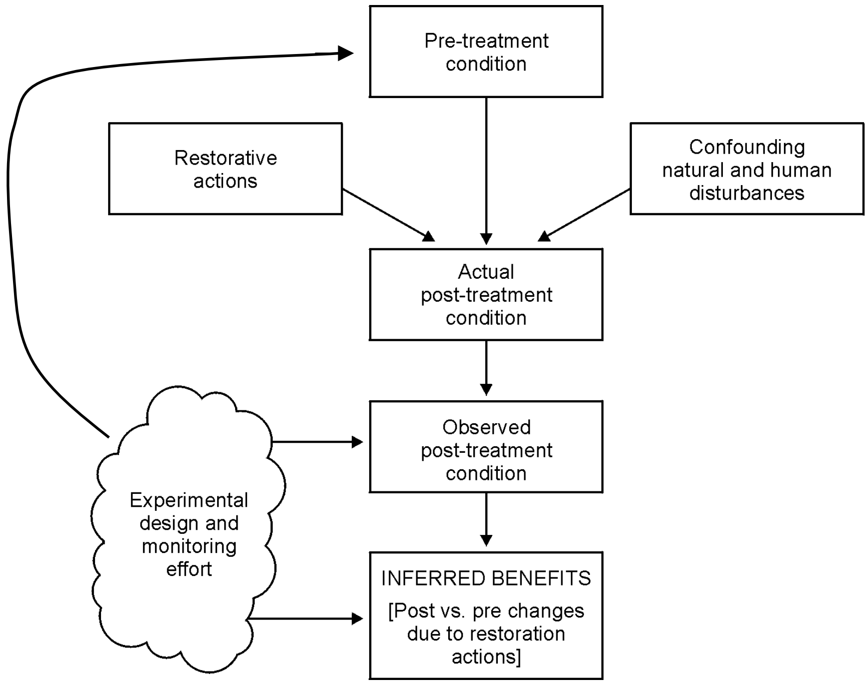


Figure 9.1. Framework for testing restoration hypotheses.

Monitoring and Evaluation plans to be developed after this first workshop will include:

- Descriptions of **indicators to be monitored** (*what*) and field sampling protocols (*how*) that will be used, including justification for why these were selected. The plans should also list and describe the indicators that were considered but not selected for monitoring, and the reasons why they were not selected.
- Summary of **baseline** ("before") **data holdings** as they apply to the indicators chosen for measurement. Against what baseline will TRRP changes be assessed? This is a key issue for all subgroups, and needs to be addressed in the monitoring plan. In particular, what is the baseline that is to be used to assess whether or not smolt abundance has doubled?
- Testing hypotheses of habitat-biota responses requires **spatial and temporal contrasts**. What spatial / temporal contrasts can, or ought to be designed into the 24 channel rehabilitation sites that are currently being implemented?
- The overall **statistical sampling design** (sampling units, where and at what scale, specific index sites, what kind of randomization procedures—stratified random subdivisions at various locations, fully random or clustered?, when & how often—number of replicate measurements, what reference sites are to be used, expected statistical power, basis for sample size) within which field sampling data are to be collected, e.g., Before-After-Control-Impact, Before-After, etc. Samples are often a source of error, and a key question is often whether a sample was selected in a manner which is representative of the measured variable for the whole population of interest.
- What **specific statistical analyses for testing hypothesis** will be done on the results (*how evidence will be generated ,what test statistics, criterion for rejecting hypotheses*), e.g., randomization tests, regression analysis, ANOVA, CART, parametric vs. nonparametric methods, etc.

- Explicit and clear statements of **how monitoring information will feed back into decision-making** (*management rules*), e.g., "if parameter A < X, then increase flows by…".
- Specification of appropriate **entity/people to accomplish task(s)** (*who*).
- **Data management plan**, including how often reports will be generated and who will be responsible for ensuring that results are provided to TRRP in a timely manner.

On the final day of the workshop, David Marmorek presented a process for moving towards definition of a monitoring plan for all subsystems, which was well received by workshop participants. The process is modified from EPA's Data Quality Objectives (DQO) process, which has been used to develop hundreds of monitoring plans. The DQO process is a 7-step template that helps to: clarify program objectives, define the appropriate types of data to collect/analyze, and specify tolerable limits on potential decision errors. The steps in the DQO process are outlined in Figure 9.2.

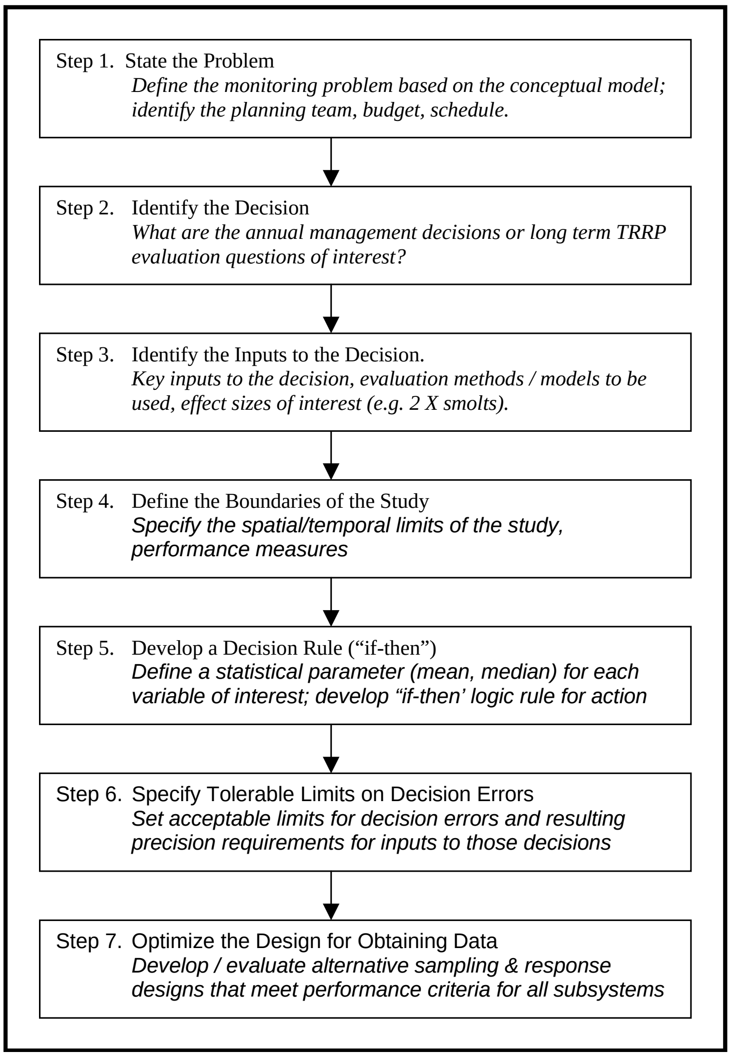


Figure 9.2. The EPA's Data Quality Objectives process (modified from EPA 2000).

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Appendix A: AEAM Framework Workshop 1 Agenda

Trinity River Restoration Program AEAM Framework Workshop 1
Review and Improve TRRP Conceptual Models

October 13th to 15th 2004
Red Lion Hotel, 1929 4th Street, Eureka CA

The AEAM Framework process focuses on development of an integrated conceptual model of the Trinity River system as the foundation for developing quantitative performance measures and monitoring plans. TRRP scientists and partners have made good progress on individual subsystem conceptual models over the last several months, as described in the Workshop Backgrounder. The Backgrounder is a working draft. The primary goal of this workshop is to improve both individual conceptual models and their integration, setting the stage for development of well-focused monitoring plans.

Workshop Objectives

1. Intensively review and revise working drafts of the conceptual models developed by TRRP leads, improving their policy relevance, scientific defensibility and integration. All participants will work together constructively to advance the draft conceptual models.
2. Bring together scientists and water/resource managers so that scientists better understand the critical information needs of decision makers and the roles of the AEAM framework in supporting management decisions, and decision makers have a better grasp of the current state of scientific understanding.
3. Develop a priority set of quantitative performance measures to assess overall ecosystem responses to restoration actions and inform decision making on both annual and longer time scales.
4. Stimulate thinking on an integrated monitoring plan centered on these quantitative performance measures.

Day 1: Orientation, subsystem overview presentations, general plenary discussions

This first day will focus on providing an overview of the draft conceptual models, and getting feedback from policy makers and managers on critical information needs. The second and third days of the meeting will have a technical focus.

Wednesday, October 13th 2004

8:30a.m.	Introductions; review context of this workshop in the overall process of development of an AEAM Framework; clarify workshop objectives, agenda and structure.	David Marmorek, ESSA Technologies
8:50a.m.	**The BIG Management Picture**: Background / foundation of TRRP; AEAM underpinnings and importance of science in decision making. Importance of clear input from policy makers and managers. What types of information do they need? How can scientists best serve these needs?	Doug Schleusner, TRRP
9:15a.m.	**The Big Scientific Picture**: "The AEAM Framework Process" How the process builds on Trinity River Flow Evaluation study & ROD, makes uncertainties explicit, sets the stage for rigorous monitoring and evaluation, improves decision making	Andreas Krause, TRRP
9:45a.m.	*Discussion/Questions: TMC, others*	
10:00a.m.	Conceptual model components and roles in AEAM Framework: • Overall System and definition of subsystems • Subsystem integration; Looking Outward Matrix • Issues of scale: spatial and temporal extent/resolution • Components: - Management actions - Key performance measures - Life-history vs. time diagrams - Conceptual model diagrams - Statements of hypotheses/linkages and performance measures - Identification of critical uncertainties & proposed method of testing alternative hypotheses (monitoring strategy)	David Marmorek, ESSA Technologies
10:35a.m.	*Discussion/Questions: TMC, others*	
10:45a.m.	Physical Subsystem Overview	Andreas Krause, TRRP Scott McBain, McBain & Trush
11:15a.m.	*Discussion/Questions: TMC, others*	
11:30a.m.	Riparian Vegetation Subsystem Overview	John Bair, McBain & Trush
12:00noon	*Discussion/Questions: TMC, others*	
12:15p.m.	**LUNCH**	
1:15p.m.	Fish Subsystem Overview	Joe Polos, USFWS Tim Hayden, Yurok Tribal Fisheries Robert Franklin, Hoopa Valley Tribe

2:00p.m.	*Discussion/Questions: TMC, others*	
2:20p.m.	Bird Subsystem Overview	Sherri Miller, USFS Redwood Science Lab CJ Ralph, USFS Redwood Science Lab
2:50p.m.	*Discussion/Questions: TMC, others*	
3:05p.m.	**BREAK** (15 minutes)	
3:20p.m.	Reptiles and Amphibians Subsystem Overview Aquatic Invertebrates Subsystem Overview	Don Ashton, USFS Redwood Science Lab Bob Sullivan, Bureau of Reclamation
4:00p.m.	*Discussion/Questions: TMC, others*	
4:20p.m.	Guidance from TMC Panel to TRRP, partner and external scientists on critical policy / management priorities. Questions from scientists to panel on priorities. *{Some of these questions should be prepared beforehand and provided to TMC}*	Moderated by David Marmorek, ESSA Technologies
5:00 pm	Wrap-up; Review of plan for Thursday	David Marmorek, ESSA Technologies
5:10p.m.	**ADJOURN**	
6:15p.m.	Meet for dinner and informal discussions	
7:45p.m.	Progress Report on Integrated Information Management System (IIMS)	Colin Daniel, ESSA Technologies

Day 2: Detailed subsystem review, focused subgroup discussions

Thursday, October 14th 2004

8:30a.m. — Key focus areas for different subsystems (based on summary of Day 1 discussions); — David Marmorek

Thinking ahead: considerations for monitoring and evaluation plans

Process check (format for the day, subgroup composition and expected outputs)

9:00a.m. — *Discussion/Questions*

Split into four subgroups for detailed subsystem discussions

9:20a.m. to 12:15p.m. — **ALL**

- Detailed subsystem reviews by subject matter experts
- Appoint note taker
- ESSA technical facilitators lead and "coach," as needed
  - Starting with Workshop Backgrounder, review and revise:
  - Specific management actions to be evaluated
  - Key performance measures (PMs)
  - Life-history vs. time diagrams
  - Conceptual model diagrams {
  - Statements of hypotheses/linkages and performance measures {Main focus: consider alternative hypotheses, prioritize hypotheses and PMs according to importance and feasibility}
  - Information required from other subsystems {Specify variables, spatial / temporal scale, units for Looking Outward Matrix, Section 2 of Backgrounder; List issues to be discussed at 3:15 session}
  - Identification of critical uncertainties & proposed method of testing alternative hypotheses (monitoring strategy)
- Groups to report back on in closing plenary on Friday, noting areas of consensus and disagreement

12:15p.m. — **LUNCH**

1:15p.m. — …Continue subsystem reviews in break-out rooms — **ALL**

3:00p.m. — **BREAK** <sign up and specify schedule/location for inter-group meetings; see wall of flip charts in plenary session room>

3:15p.m. — **Inter-subgroup dialogue** to refine Looking Outward linkages and improve integration, consistency of spatial / temporal scales at which measurements will occur. — Subsystem leads; other subgroup members

Process check; parking-lot/table issues bogging groups down; make 'pleas for help' to facilitators. — David Marmorek and ESSA coaches

4:15p.m. — ….Wrap-up subsystem reviews — **ALL**

Identify key changes, uncertainties, strategy for testing alternative hypotheses

Tidy-up notes/documentation for closing plenary on Friday

5:15p.m. — **ADJOURN**

6:15p.m. — Meet for dinner and informal discussions

7:45p.m. — Facilitators and submodel leads meet to summarize subgroup discussions, next steps

SAB and invited external scientists meet to consolidate their recommendations

Day 3: Detailed subsystem review (continued) and closing plenary presentations

Friday, October 15th 2004

8:15a.m.	Physical & Riparian Vegetation Summary (15 min)	Clint Alexander ESSA
	SAB/External Scientist Recommendations (15 min)	SAB Members (Ned Andrews, Clair Stalnaker, Riparian Expert)
8:45a.m.	*Discussion/Questions (Submodel Leads, others)*	
8:55a.m.	Fish Subsystem Summary (15 min)	Ian Parnell ESSA
	SAB/External Scientist Recommendations (15 min)	SAB Members (Josh Korman, Mike Sale, others…)
9:25a.m.	*Discussion/Questions (Submodel Leads, others)*	
9:35a.m.	Bird Subsystem Summary (10 min)	David Marmorek ESSA
	SAB/External Scientist Recommendations (10 min)	SAB/External Scientists
9:55a.m.	*Discussion/Questions (Submodel Leads, others)*	
10:05a.m.	Reptiles, Amphibians & Aquatic Invertebrates Subsystem Summary (15 min)	Marc Porter ESSA
	SAB/External Scientist Recommendations (10 min)	SAB/External Scientists
10:30a.m.	*Discussion/Questions (Submodel Leads, others)*	
11:15a.m.	SAB / External Scientists Panel Overall Recommendations (5 minutes / panelist)	
12:05p.m.	*Discussion/Questions (Submodel Leads, others)*	
12:20 p.m.	**LUNCH** {in hotel}	
1:20p.m.	**Where to go from here?**	
	Next steps to finalize conceptual models and performance measures	
	Action items	
	Schedule: looking ahead to Workshop 2	
2:20p.m.	**Closing Statement**	
2:30p.m.	**ADJOURN**	

Appendix B: AEAM Framework Workshop 1 Participants List

Last Name	First Name	E-mail Address	Telephone	Subgroup
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Krause	Andreas	akrause@mp.usbr.gov	530.623.1807	Physical/Riparian
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Manji	Neil	N/A	N/A	Fish
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Merigliano	Mike	mmerly@forestry.umt.edu	208.354.8289	Physical/Riparian
Miller	Sherri	sherri_miller@fs.fed.us	707.825.2949	Birds
Munroe	Bill			Fish

Last Name	First Name	E-mail Address	Telephone	Subgroup
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Whitridge	Arnold	awhitridge@snowcrest.net	530.623.6688	
Williamson	Sam	sam_williamson@usgs.gov	970.226.9362	Fish
Wittler	Rod	rjwittler@mp.usbr.gov	530.623.1801	Physical/Riparian
Yoshioka	Glenn	N/A	N/A	

Appendix C: Fish Habitat and Physiology Hypotheses from TRRP 2001 and 2002 Workshops

Fish Habitat (pg 11 of 2002 AEAM background document):

Restoring and maintaining an alternate bar morphology will greatly increase fry rearing habitat, thereby increasing smolt production.

Channel complexity will provide habitat for all life stages at a greater range of flows.

Increased gravel storage through gravel introduction efforts will increase the quantity and quality of spawning habitat, thereby increasing fry and smolt production.

Reduction in fine sediment supply via fluvial and mechanical means will increase spawning gravel quality, thereby increasing fry and smolt production.

Lower water temperatures during smolt outmigration period will increase smolt health and outmigration success.

Lower water temperatures in the upper river may decrease growth rates.

Temperature differences between Trinity River and Klamath River may cause thermal shock-induced stress or mortality.

Hypothesis Testing (product from July 28-30 2001 Adaptive Management Workshop)

The following Fish Habitat and Fish Physiology Hypotheses were extracted from a spreadsheet. The information is organized as follows: 1) Foundation Hypotheses, a) Subhypotheses, and I) Information (I), or Modeling (M) needs. These were columns in the spreadsheet, subsequent columns were: Subtasks, Priority, Rationale, and Notes. These hypotheses overlap significantly with the impact hypotheses presented in this document.

I Fish Habitat Subgroup:

1. Foundational Hypothesis – Recreating a complex dynamic alluvial river will increase salmonid habitat quantity and quality.
    a. Sub hypothesis – Complex fish habitats will have greater fish numbers/density per river mile than simple habitats.
        i. Conduct workshop and peer review to 1) develop habitat complexity metric, and 2) fish response to that metric incorporating fish numbers/density for all life stages of steelhead, coho salmon, and chinook salmon.
    b. Sub-hypotheses – Recreating a complex dynamic alluvial river will increase salmonid smolt production from the Trinity River.
        i. Continue using SALMOD as predictive tool for salmonid smolt production, develop habitat characterizations for input to SALMOD.

c. Sub-hypothesis – Increased smolt production from river will result in increased adult returns to river

i. Install weirs and monitor adult harvest to estimate total adult production, with better separation of natural vs. hatchery produced component (harvest and in-river escapement).

2. Foundation Hypothesis – Increased salmonid habitat quantity and quality will result in increased smolt production.

a. Sub Hypothesis - increased smolt production from upper 40 miles of Trinity River is a result of increased habitat quantity and quality.

i. Monitor and compare adult escapement and subsequent emigrants (juveniles and smolts) from the upper 40 miles of Trinity River (at a point slightly upstream of the North Fork of the Trinity River) with a representative tributary and regional index watershed. Also monitor the entire basin if possible to separate contribution of upper/lower basin and provide physiological (growth?) information.

3. Foundational Hypothesis – Restoration of alternate bar sequences and the spawning habitats that they provide will disperse the spawning activity throughout a greater area of the river.

a. Sub-hypothesis – Distribution of spawners longitudinally and laterally will reduce risk of catastrophic egg scour during high flow release or tributary derived flow.{Alternative statement from spreadsheet printout – Distribution of spawners locally is likely influenced by restoration actions (gravel intro., channel migration, etc.)}

i. Quantify the spawning fish distribution, and also their timing and abundance.

4. Foundational Hypothesis – Restoration of a functioning alluvial river will recreate and maintain pool habitats that provide adult spring chinook holding habitat.

a. Sub-hypothesis – Increasing pool depth and providing adequate water temperatures will increase spring chinook survival, increasing spring chinook smolt production.

i. Identify and quantify adult spring chinook salmon holding locations, compare water temperature monitoring data.

5. Foundational Hypothesis – Piggybacking dam releases on tributary floods will create and maintain complex channel morphology.

a. Sub-hypotheses –Scouring redds during egg incubation will decrease smolt production from Trinity River.

i. Relate peak flow magnitude to redd scour depth and associated egg mortality to evaluate potential impacts of piggybacking dam releases on tributary floods.

II Fish Physiology Subgroup:

1. Foundational Hypothesis – Recommended (and delivered) flows meet temperature targets specified in TRFE (e.g., smoltification at Weitchpec).

a. Determine if temperature targets are met with specified flow regimes.

i. (I) – Monitor hourly temperatures at specified locations.

ii. (M) – Confirm the existing temperature model (SNTMEP)

2. Foundation Hypothesis – Temperature targets specified in TRFE/ROD are appropriate for each species/lifestage. Specifically, to reduce uncertainty, perform lab study to evaluate/confirm smoltification requirements of all 3 species of salmonid smolts.

a. Trinity River specific salmonid thermal physiological response characterization.
    i. (I) – Measure physiological response (smoltification readiness) to range of thermal conditions that include both above and below existing targets.
    ii. (M) – Incorporate results into SALMOD production model for each species.

3. Foundational Hypothesis – Mainstem spring thermal regime achieved by TRFE flow regimes will improve juvenile salmonid growth compared to “baseline” conditions. Growth achieved when optimal targets are met is measurably better than growth achieved during years when marginal targets are met
    a. (I) – a) Monitor timing of peak fry emergence and size of emergents. b) Monitor length/weight of outmigrants. c) Monitor spring growth of resident coho, steelhead, chinook parr
        i. Establish timing of fey emergence (coho, chinook, steelhead) at longitudinal sites (thermally variable) in the Trinity River and measure growth of age-0 fish throughout the year. Establish relative density estimates of age-0 throughout the river for development of hypotheses about important areas/reaches of growth and production, coordinate with emigration trap in mainstem near Junction City or North Fork..
        ii. (M) – a) Use results to improve the SALMOD production model. B) Evaluate results with a bioenergetics model.
4. Foundational Hypothesis – Thermal regime resulting from TRFE flows extend the temporal duration and spatial extent of successful smoltification, resulting in higher smolt survival and adult returns.
    a. (I) – a) Abundance and timing of smolts measured and marked at Weitchpec (NOTE: Significant improvement needed in the approach used to monitor and estimate abundance of emigrating smolts.) b) Escapement estimates of individually marked fish
        i. i. Emigration monitoring in the lower Trinity River. Mark-recapture for quantifiable estimation.
    b. (M) – Use results to improve the SALMOD production models. C) Development of a “healthy smolt metric or index” would be tremendously useful in determining the quality (likelihood of return) of emigrating smolts.
        i. i. Incorporate results into SALMOD production model for each species.
5. Foundational Hypothesis – In a critically dry year the recommended thermal regime meets smoltification requirements for all three species.
    a. (I) – “Healthy Smolt Index”, document health and water temperatures at Weitchpec and other specified locations along the river.
        i. Develop a “healthy smolt index” based on literature review and evaluation of Trinity River smolts. Evaluate smolt health during critically dry year using measures of “smoltability” and general length-weight information collected from the emigrants (steelhead, coho, chinook salmon).
6. Foundational Hypothesis – Temperature targets provide for thermal needs of holding, spawning, and incubating eggs for spring chinook salmon in all water year types.
    a. Trinity River specific salmonid thermal physiological response characterization.
        i. Laboratory measure of physiological response of Trinity River origin spring chinook adults to range of thermal conditions that include both above and below existing temperature targets.

7. Foundational Hypothesis - Reduced travel time (associated with high flow rates) results in higher smolt survival.
    a. Transit times of various emigrating species.
        i. (I) – rates of timing and emigration: Mark fish upriver for capture in lower river traps by using a statistically rigorous design to estimate the transit times of emigrating smolts by marking fish in multiple locations upstream of the screw traps and documenting their recapture in the traps.
8. Foundational Hypothesis – Target thermal regime during the summer supports increased growth for parr (e.g., thermal habitat is increased for salmonid parr with 450 cfs).
    a. (M) - Production models to predict the increased growth to test with observations in the field.
        i. Measure absolute growth of uniquely marked parr (pit-tagged) for predicting 1+ and 2+ growth rates in production models.
9. Foundational Hypothesis – Current temperature targets in the Trinity River will have no deleterious effects (residualization, mortality) on smolts/adults migrating to or from the Trinity River.
    a. (I) “Healthy Smolt Index”.
        i. Workshop participants at end of year to synthesize several of the above projects investigating temperature, growth, mortality.
10. Foundational Hypothesis – Altered channel form (point bars, decreased bank slopes, etc.) provide greater thermal diversity for juvenile salmonid rearing habitat.
    a. (I) – a) Information needed on emergence and fry growth, b) need to monitor water temperature diversity in complex channel morphology, c) measures of thermal diversity between a control site and a desired habitat feature.
        i. Microhabitat temperature investigation in simplified (riparian berm) and complex (alluvial) channel reaches (Stowaways).

IV Long-term response/baseline monitoring.

a. Adult anadromous salmonid escapement estimation
    i) Harvest monitoring
    ii) Weirs
    iii) Hatchery return
    iv) Carcass surveys
    v) Age/scale analysis
b. Smolt production estimation
c. Etc.

Adult holding

A. Are there adequate adult holding areas for spring chinook, fall chinook, coho? (e.g., density dependence?)

Spawning

A. Does more/better spawning habitat = greater numbers of emergent fry?
   1. Success of emergence for redds in "quality" reach is greater than in sediment impacted reaches.
   2. Superimposition is relieved by flow manipulation during spawning period.
   3. Superimposition is relieved by gravel introduction.

B. Do fish respond by spawning on alternating bars? More than trapezoidal channel?
   1. Redds/mile is higher in alternating bars than trapezoid.

Fry rearing

A. Does better fry rearing habitat – faster growth and better fry survival to juvenile or smolt stage?
   1. fish exhibit faster growth in high quality habitat.
   2. Fish exhibit longer residence time in higher quality habitat.
   3. Fish exhibit faster growth as they transit through reaches with a continuum of high quality habitat than in reaches with low diversity, low quality habitat.
   4. Fish exhibit higher survival as they migrate through reaches with a continuum of high quality diverse habitat than in reaches with low diversity, trapezoidal channel.
   5. Feeding stations in high quality dynamic reaches are more numerous and bioenergetically superior to those in trapezoidal reaches.

B. Does better fry rearing habitat support more fish?
   1. Is there more fish per linear distance in naturalized reach than trapezoidal reach? Is there more after naturalization than pre-naturalization?

Smoltification

A. Does higher quantity and quality juvenile rearing habitat = better juvenile survival to smoltification and = larger size at smoltification?
   1. Smolts leaving a restored or naturally dynamic alternating bar river reach are healthier/larger than those emigrating from a trapezoid.
   2. Survival from fry to smolt is higher in alternating bar than trapezoid.

B. Does higher quantity and quality of juvenile rearing habitat = faster growth to smoltification and emigration from the rearing habitat earlier.
   1. Growth is faster in alternating bar than trapezoid.
   2. Fish reach emigration/smoltification size sooner in alternating bar than trapezoid.

C. Does better juvenile rearing habitat support more fish?
   3. Is there more fish per linear distance in naturalized reach than trapezoidal reach? Is there more after naturalization than pre-naturalization?

Over Wintering

Does higher quantity and quality over-wintering habitat = better winter survival?