Mainstem Methow habitat effectiveness monitoring of stream restoration

Pre-treatment phase: October 2008—May 2012
Post-treatment phase: June 2012--September 2014

Background, Questions, Assumptions, Hypotheses, Objectives, and Tasks

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Prepared by: Patrick J. Connolly, Ph.D.
Lead Research Fish Biologist
Project Leader--Watershed Restoration Ecology
USGS-Western Fisheries Research Center, Columbia River Research Laboratory
5501A Cook-Underwood Rd.; Cook, WA 98605
phone: 509-538-2299 ext 269; FAX: 509-538-2843; email: pconnolly@usgs.gov

Background

River restoration projects are becoming widely implemented throughout the Pacific Northwest and other regions in the U.S. (Bernhardt et al. 2007); however, project monitoring has rarely been conducted in scientifically valid experimental designs and timeframes (Katz et al. 2007). Monitoring is of critical importance to inform future restoration efforts and project designs, and it is in need of more practice and research. In their survey of restoration projects in the Pacific Northwest representing expenditure of hundreds of millions of dollars, Rumps et al. (2007) concluded that we know little about the effectiveness of restoration projects for fish because of inadequate investment in monitoring. While many projects are being conducted with the goal of improving riverine habitat for fish, Katz et al. (2007) show that most of these projects lack designs to link restoration actions with the response of the targeted species.

Without incorporation of an appropriate spatial and temporal context to assess the potential fish response, the real effectiveness of the restoration efforts could be under or over estimated (Cooper and Mangel 1999, Isaak and Thurow 2006). Due to fish behavior and the linear dependence of riverine communities, the effects of restoration projects should be expected to extend beyond the limits of the restoration project. The connectivity between spawning and rearing life stages of anadromous salmonids can link widely dispersed habitat areas (Kocik and Ferreri 1998, Mangel et al. 2006). Focusing entirely on the reach level can yield little or misleading information about the scale that fish populations are affected (Fausch et al. 2002).

What constitutes effective restoration for salmonids needs to be assessed by how it improves existing habitat and biotic linkages (Jansson et al. 2007, Lake et al. 2007), but this needs to be considered within the historical capacity for habitat linkage within a system (McKean et al. 2008). As a word of caution, Rahel (2007) explains how efforts to connect habitats can go wrong if the habitats reconnected were separated by true biogeographical barriers that preceded human intervention, or when a renewed linkage allows access by a subsequently established invasive species. With the depletion of target species over several decades, other native fish and aquatic species may have become more prominent. It is possible that the subsequently established community could offer a degree of biotic resistance (Ward et al. 2008) and limit the reintroduction or enhancement of formerly prominent target species.

Our primary goal is to measure the response of target fish species (steelhead, Chinook salmon) to an intensive stream restoration project planned by Reclamation in 2012. Because we wish to measure the response of highly mobile fish populations, fish sampling will need to extend beyond the bounds of the restoration project. We have identified reasonable bounds for initial sampling based on the geomorphic characteristics of the Methow system (Reclamation, unpublished data) and on recent literature regarding the extent of spatial relationships for fish species important to the restoration efforts in the Methow watershed: Chinook (Isaak and Thurow 2006, Neville et al. 2006, McKean et al. 2008), steelhead (Hendry et al. 2002), and bull trout (Baxter and Hauer 2000, Rieman and Dunham 2000). Sampling of fish in similar unconstrained reaches upstream and downstream of the project area, and constrained areas between these reaches, will allow an assessment of the role of habitat size and connectivity. In recognition of the potential scale needed to assess the fish response (Fausch et al. 2002, Schick and Lindley 2007, McKean et al. 2008), the project reach will be surrounded with fish monitoring devices (e.g., smolt traps, PIT tag interrogation systems) to detect movement in and out of the project area. We will collaborate with existing fish monitoring efforts within the Methow. With funding from Douglas County PUD and NMFS, biologists from the Washington Department of Fish and Wildlife (WDFW) will be simultaneously conducting smolt trapping, PIT tagging, and detecting PIT tagged fish with PIT tag interrogation systems in the mainstem Methow and lower Twisp River. We plan to collaborate with biologists from Yakama Nation, who are planning to conduct nutrient enhancement studies to test effect on fish production. These activities will benefit data collection and result in cost efficiencies for both projects.

Study design protocols developed by the action agencies for effectiveness monitoring research (Hillman and Giorgi 2002, Hillman 2003) require that studies adhere to statistically valid study designs that implement treatment and control sites and/or a pre- and post-treatment design. This project incorporates the statistical rigor called for by Isaak and Thurow (2006), and it uses a set of validated methods of evaluation and reporting called for by Palmer et al. (2005). Information gained from this intensive and extensive project will help ensure that the millions of dollars planned to implement riverine restoration in the Methow watershed and the greater Pacific Northwest will be available for adaptive learning. A key question for the region that will be addressed is: Can large river restoration efforts be effective enough to meet Reclamation's fisheries enhancement goals as required by the NMFS's Federal Columbia River Power System Biological Opinion?

The degree of retention of natal fish and amount of movement from and into a stream reach are important indicators of the value of the reach to fish production (Harvey 1998). Longitudinal differences in habitat availability, food availability, stream temperature, and predation risk within a stream present habitat and bioenergetic heterogeneity for fish survival and growth. These differences can also exist between tributary habitats and downstream mainstem river habitat. This heterogeneity promotes differential potential for survival and growth between those fish that remain in natal areas and those that move upstream or downstream to new habitat. Van Horne (1983) showed that abundance and density can be misleading indicators of habitat quality, especially for fish that are territorial, such as steelhead, Chinook, and bull trout. Increase in abundance and density may not be the primary response to improved habitat conditions. To measure the effects of restoration efforts on habitat quality and productivity, we will use retention (Harvey 1998) and movement (Winker et al. 1995) data in conjunction with abundance and density data. To assess differential biological performance, we will compare age structure, growth, and age at smolting between those fish that stay in natal areas versus those fish that move. To assess retention in, and movement from or into, the restoration reach, we will use a combination of within reach and out-of-reach sampling. We will use PIT tags, a network of instream PIT tag interrogation systems, and smolt traps to assess differences in biological performance and the magnitude of retention in, and movement from and into, the restoration reach.

Below we present key questions, assumptions, and hypotheses for this study.

Questions (Q)

The pre-treatment phase of the project is designed so that specific questions about the response of target fish species (Chinook, steelhead, and bull trout) to the restoration actions can be addressed. During the pretreatment phase, we will conduct modeling to predict response to treatment, and we will update the model with empirically-derived data as these data become available. This modeling effort is expected to inform us about data gaps, sensitivity of key variables, and ability to detect response based on variability of data. The primary questions we intend to address are:

Q1) What is the difference in habitat availability and suitability between the restoration reach and geomorphically similar reaches upstream and downstream?

Q2) What is the difference in fish productivity between the restoration reach and geomorphically similar reaches upstream and downstream?

Q3) Will and did the implementation of the project in the restoration reach increase stage-specific survival of target fish species?

Q4) Will and did the implementation of the project in the restoration reach increase parr and/or smolt production?

Q5) Was the response of the target species large enough to make a difference in the probability of their persistence in the Methow watershed?

As a part of this study, we will collaborate with a graduate student, Ryan Bellmore of Dr. Colden Baxter's laboratory at Idaho State University, to address key components of the food web dynamics in the restoration reach prior to restoration. Three of the important questions that he will address are:

Q6) How much food is currently available to fuel fish production?

Q7) How does food availability compare to the demand by fish for those resources?

Q8) How much additional fish production could be supported in the restoration segment of the Methow River via the restoration of off-channel habitats?

Assumptions (A)

Several assumptions are inherent in our approach to ensure that these questions can be answered after implementation of the restoration actions:

A1) Current fish productivity in the restoration reach is limited by reach-specific habitat conditions. [Limiting factors concept]

A2) The primary factors contributing to pattern and magnitude of growth of fish are stream temperature, food quantity, and food quality. [Bioenergetics concept]

A3) Growth of juvenile fish is a determinant of age at smolting and degree of residualism. [Bioenergetics concept]

A4) Degraded longitudinal and lateral habitat connectivity and life-stage connectivity are currently limiting fish production. [Connectivity concept]

A5) The restoration reach does or could provide an important rearing capacity for juvenile fish spawned within the reach ("natal") and for fish spawned elsewhere in the Methow watershed ("non-natal"). [Connectivity concept]

A6) Production of target fish species relies on longitudinal connectivity with other spawning and rearing areas. [Connectivity concept]

A7) The restoration effort will substantially increase the habitat quality and degree of lateral connectivity with the floodplain. [Implementation success]

A8) Past and current hatchery management practices for production of steelhead and Chinook may limit response to restoration efforts depending on the remaining genetic diversity in the Methow system. [Biotic resistance concept: wild and hatchery fish interactions]

A9) Presence and response of existing non-target fish and aquatic species could limit the response of the targeted fish species to the restoration actions. [Biotic resistance concept: aquatic community interactions]

Hypothesis (H)

Our "working hypotheses" are present below in roughly the chronological order that they will be addressed during the life of the project.

Role of habitat in fish productivity and expression of anadromy

H1: Pre-treatment expression of anadromy is limited by current physical habitat conditions within the treatment reach. [Limiting factors concept]

H2: Pre-treatment growth of parr and/or age at smolting is limited by temperature and/or food. [Bioenergetics concept]

H3: Pre-treatment fish growth, survival, and expression of anadromy are limited by lack of connectivity of habitats within the treatment reach. [Intra-connectivity concept]

H4: Pre-treatment fish growth, survival, and expression of anadromy are limited by lack of connectivity of habitats between the treatment reach and neighboring stream reaches. [Inter-connectivity concept]

Effectiveness of restoration for increasing fish productivity and expression of anadromy (Pre vs Post Treatment)

H5: Restoration efforts increased capacity for targeted fish species by improving and/or increasing spawning and rearing space in the restoration reach. [Limiting factors concept]

H6: Restoration efforts increased capacity for targeted fish species by improving thermal properties and/or food production in the restoration reach. [Bioenergetics concept]

H7: Restoration efforts improved survival of natal parr: Parr that are natal to the restoration reach but move, downstream or upstream, have similar or different growth, age structure at smolting, and survival to those that stay in this section. [Intra-connectivity concept]

H8: Restoration efforts improved survival of non-natal parr: Parr that move from other natal areas and into the restoration reach have similar or different growth, age structure at smolting, and survival to those that stay in their natal area. [Inter-connectivity concept]

H9: Past or current hatchery management practices did not limit the response of the targeted fish species. [Biotic resistance concept: wild and hatchery fish interactions]

H10: Response from other members of the fish assemblage (e.g., non-anadromous rainbow trout, mountain whitefish, brook trout, and sculpin) and other members of the aquatic community (e.g., competitors, predators) did not limit the response of the targeted fish species. [Biotic resistance concept: aquatic community interactions]

<u>**Project-Specific Objectives and Tasks**</u>
A list of the major activities and planned in 2009-2014 is provided in Table 1. The location and timing of the activities is presented in Table 2 and under the objective or task where appropriate. The general location of the "restoration reach" referred to below is that portion of the mainstem Methow River labeled as "M2" (rkm 66-79) in Figure 1. Two reference reaches have been identified based on relative lack of disturbance, proximity to the restoration reach, and relative unconfined geomorphology: 1) Upper Methow River (the unconfined reach within Big Valley and downstream of Wieman Bridge, rkm 85-90), and 2) Chewuch River (rkm 4-11). A control reach has been identified based on similar disturbance as that found in the restoration reach, proximity to the restoration reach, and relative unconfined geomorphology: mainstem Methow River downstream of the restoration reach (rkm 57-64).

A. Determining the importance of connectivity to fish production: downstream, upstream, and lateral

Objective 1. Assess productivity and connectivity of the restoration reach and neighboring reaches, and their tributaries, with emphasis on target fish species Chinook, steelhead, and bull trout.

Task 1.1. Conduct continuous fish snorkeling surveys in the restoration, reference, and control reaches multiple times within the year.
<u>Timing:</u> March 2009-September 2014.
<u>Methodology:</u> In the reference reach, conduct snorkel efforts multiple times during the year: one time in March before high flows, one time in July after high flows, two times per month during August and September, and one time during October and November. In the reference and control reaches, the snorkel efforts will be conducted once during the months of March, August, September, and October. A continuous sampling approach within 5 km of stream will be conducted, from upstream to downstream counting fish over 150 mm in length, largely following protocols developed by Brenkman and Connolly (2008), which corresponds with previous work by Torgersen et al. (1999), Torgersen (2002), and Fausch et al. (2002).

Task 1.2. Conduct point-abundance surveys at fixed-sites by electrofishing in the restoration, reference, and control reaches multiple times within the year.
<u>Timing:</u> March 2009-September 2014.
<u>Methodology:</u> We will sample three sections of treatment reach (upper, middle, lower) and one section in the reference and control reaches. In each section of the reaches, we will sample stream margins of one bank of a contiguous section of three pools and three non-pools. These surveys will be conducted multiple times during the year: one time in March before high flows, one time in July after high flows, and one time in late September or October. This approach is largely derived from Connolly and Brenkman (2008), which corresponds with previous work by Janac and Jurajda (2007) and Quist et al. (2006).

Task 1.3. Conduct mark-recapture and/or pass-removal electrofishing surveys to derive fish assemblage, abundance, and density estimates in 4-6 side-channels, including the side-channels chosen for install of PIT tag interrogation systems (see Task 1.5).
<u>Timing:</u> July 2009-September 2014.
<u>Methodology:</u> Mark-recapture will follow PNAMP protocols (*http://www.pnamp.org/web/workgroups/documents.cfm#18*, accessed 4 February 2008). Pass-removal methodology will follow Connolly (1996), Peterson et al. (2004), and Martens and Connolly (2008). Just prior to these sampling efforts, we will conduct intensive habitat surveys of sampling sections. The data collected during these intensive surveys will include habitat type (e.g., pool, glide, riffle), habitat unit dimensions (length, width, maximum depth), and instream and overhead cover.

Task 1.4. Conduct mark-recapture and/or pass-removal electrofishing surveys to derive fish assemblage, abundance, and density estimates in one reach (500-1000 m) in each of two tributaries chosen for install of PIT tag interrogation systems in reference reaches upstream of the restoration reach (Wolf and Eightmile creeks are primary candidates) and in two tributaries that enter below the restoration reach (Beaver, Gold, and Libby creeks are primary candidates).
Timing: March 2009-September 2014.
Methodology: Methods used will be identical to those described in Task 1.3. As envisioned, Beaver Creek will be sampled each year, and it will be combined with Gold Creek (2008 [completed], 2010) and Libby Creek (2009, 2011) in alternating years.

Task 1.5. Install and run three PIT tag interrogation systems (PTIS; with multiple antennas and multiplex capability) at key locations above and below the treatment reach: 1) in the mainstem Methow River just above its confluence with the Chewuch River, 2) in the Chewuch River near its mouth, and 3) in the mainstem Methow River just above its confluence with the Twisp River.
Timing: Install two systems by September 2009, install additional system by September 2010; maintain all through September 2014.
Methodology: See Figure 1 for a general depiction of where these PTIS will be installed. Installs are expected to be similar to those described by described in Martens and Connolly (2008), and data procurement will follow recommendations of Connolly et al. (2008). These interrogators will be maintained for continuous operation throughout the year. Stationary PIT-tag readers offer the potential for full-year, everyday monitoring of fish movement in and out of a stream system (Armstrong et al. 1996; Nunnallee et al. 1998; Zydlewski et al. 2001, 2006; Connolly et al. 2005). Efficiency of detection is expected to vary with size of the PIT tag unit, site characteristics, and size of the system. Following Connolly et al. (2008), estimates of detection efficiency will be determined when and where feasible. The amount of detection efficiency achieved will guide us as to how many PIT tags we will need to deploy in order to adequately detect an acceptable level of change in various fish metrics as a result of stream restoration (see Task 2.1 for more information on planned power analyses).

Task 1.6. Install and run small PIT tag interrogation systems (with single antennas) in side-channels of the restoration and reference reaches.
Timing: July 2009-September 2014.
Methodology: We plan to install these small PIT tag interrogators in at least four side channels, at least two within the restoration reach and at least two within a reference reach. See Figure 1 for a general depiction of where these PTIS will be installed. As with the larger PTIS described in Task 1.5, these interrogators will be maintained for continuous operation throughout the year, and estimates of detection efficiency will be determined when and where feasible.

Task 1.7. Maintain and manage data from four existing PIT tag interrogation systems in lower Methow tributaries: one in lower Beaver Creek, one each in lower Libby, and two in lower Gold creeks.
Timing: March 2009-September 2014.
Methodology: These systems and locations are described in Martens and Connolly's (2008) report. The PIT tag detections by these systems have shown a high degree of habitat-use connectivity between upstream mainstem Methow reaches and lower Methow tributaries for juvenile and adult steelhead and Chinook. See Figure 1 for general location. As with the PTIS described in Task 1.5 and 1.6, these interrogators will be maintained for continuous operation

throughout the year, and estimates of detection efficiency will be determined when and where feasible.

Task 1.8. Install and run a rotary screw trap in the Chewuch River upstream and near its confluence with the Methow River.
Timing: July-November 2009; March-November 2010-2014.
Methodology: We will check the trap on a daily basis. All fish will be identified, measured for length and width (a subsample may be derived on large catch days), all or some PIT tagged, and released. To test capture efficiency, we will mark fish (largely with PIT tags), and release fish over a 100 m upstream in order to have a chance to catch them again and calculate recapture rate.
Note: The budgeting for this task assumed a 5-foot rotary screw trap will be available from Reclamation. Season and hours per day of trapping will largely depend on state and federal permit limitations.

Task 1.9. Insert PIT tags in fish caught during electrofishing (see Task 1.2-1.4), smolt trapping (see Task 1.8), or other means (e.g., seining, angling). Total PIT tags expected to insert is about 5,000-6,000 per year. Species to be tagged include: Chinook, coho, steelhead, rainbow trout, bull trout, cutthroat trout, whitefish, and brook trout.
Timing: March 2009-September 2014.
Methodology: Both 12-mm and 8-mm tags (full duplex) will be deployed, reserving the 8-mm tags for fish too small to PIT tag with 12-mm tags (e.g., juvenile Chinook between 55-70 mm). All PIT tagging of juveniles will follow the procedures outlined by Columbia Basin Fish and Wildlife Authority (1999). See Table 3 for locations and site-specific numbers. We plan to tag 250-500 steelhead and 250-500 Chinook salmon at each major reach or tributary in the study. Based on projections presented in Attachment 1, tagging 250 individual steelhead or Chinook will, at a minimum, result in information from about 50 or more fish to analyze for smolt age structure and survival. Based on information gathered on realized performance of the PIT tag interrogation systems in 2009, number of recaptured PIT tagged fish, and the variability in the types of data collected for analyses (see Objective 2), we will conduct a power analysis to adaptively assess if we need to enhance the detectability of interrogators, increase effort to recapture PIT tagged fish, and/or increase the number of fish to be PIT tagged (see Task 2.1).

Task 1.10. Mark targeted fish species collected in the upper Methow River (reference reach) that are too small to PIT tag with 8-mm tags by an alternative method.
Timing: October 2008-September 2014.
Methodology: Marking these fish will be an exploratory attempt to assess amount and importance of movement of young-of-year from upper Methow River to the restoration reach downstream. One method we plan to explore is the use of a calcein bath to batch mark these fish (Mohler 2003). It is anticipated that we will be able to mark hundreds of young-of-year steelhead and Chinook by this method, and that we will be able to recapture these fish during subsequent electrofishing and smolt trapping efforts. The degree of movement, growth, and condition of recaptured fish will be determined to help assess the relative benefits and risks of staying in or moving from natal areas.

Task 1.11. Collect and store tissue samples (such as fin clips) for genetic analysis from a subsample of naturally-produced steelhead and Chinook salmon collected during fish sampling efforts.
Timing: March 2009-September 2014.

Task 1.12. Collect and archive otoliths from fish mortalities encountered during sampling activities.
Timing: March 2009-September 2014.

Task 1.13. Install and maintain thermographs at key locations.
Timing: March 2009-September 2014.
Methodology: Many key locations already have thermographs deployed by various agencies (Reclamation, WDFW, YN, and others). We will assess the adequacy of coverage, and we will install and maintain thermographs at sites identified as gaps. We anticipate that this may require up to 10 additional thermographs.

B. Measuring the response to restoration

Objective 2. Assess changes in fish population metrics as a result of stream restoration actions in the treatment reach.

Task 2.1. Assess changes in the following metrics for steelhead and spring Chinook between pre-treatment and post-treatment periods in the treatment, reference, and control reaches:
Smolt age structure
Annual and seasonal growth of parr (length, mass)
Parr-to-parr survival
Parr-to-smolt survival
Smolt-to-adult survival
Degree of retention of fish natal to the treatment reach
Degree of retention of fish not natal to the treatment reach
Number of smolts produced (from natal fish, and from non-natal fish temporally retained)
Residualism of natal and non-natal wild steelhead
Residualism of hatchery released steelhead (which could be related to habitat availability, and also hatchery practices)

Analysis: As conceived, the sampling design conforms to an asymmetrical, before-after control-impact paired model (BACIP), as described by Smith (2002). A total of three control sites (upstream: Upper Methow, Chewuch; downstream: mainstem Methow reach "M3") will be used in an ANOVA to assess changes in the single treatment reach "M2". The difference in upstream versus downstream location of the control reaches will be assessed, which may require partitioning of the analysis in case of interaction effects among control sites, as described by Underwood (1994) and Michener (1997). Various covariates will be introduced to the model to test their effectiveness in explaining the variability in the data (e.g., stream temperature, stream width, pool metrics, riparian condition, pool:non-pool ratios). Many of these metrics are highly interrelated, and these relationships will be explored through life history modeling (see Objective 3). For example, change in growth can be density-dependent, which will much depend on the retention and survival of natal and non-natal fish. Growth in turn is expected to influence parr-to-parr survival, smolt age structure, and degree of residualism (in steelhead). And in turn, smolt age structure is expected to influence smolt-to-adult survival. Ability to detect change in some of these metrics, especially smolt-to-adult survival will much depend on the species' life history and the duration of the study, which may extend past the planned duration of the study (beyond 2014).

Based on information gathered on realized performance of the PIT tag interrogation systems in 2009, the number of recaptured PIT tagged fish, and the variability in the types of data collected for analyses, we will conduct a power analysis to assess the level of detectability of change expected from restoration actions. If level of detectability is deemed too low, we will adaptively assess if we need to enhance the detectability of interrogators, increase effort to recapture PIT tagged fish, and/or increase the number of fish to be PIT tagged. The effort by USGS to adequately meet PIT tagging and detection needs is much dependent on collaborative efforts with WDFW (see Task 5.2, Table 3).

Task 2.2. Assess changes in the following metrics for individual species and/or the multiple species within the fish community between pre-treatment and post-treatment periods in the treatment, reference, and control reaches:

Fish species presence or absence
Relative abundance fish within the assemblage
Relative abundance, size, and/or age structure of competitors
(e.g., mountain whitefish, brook trout, sculpin)
Relative abundance, size, and/or age structure of predators
(e.g., bull trout)

Analysis: These analyses will be similar to those described in Task 2.1

Task 2.3. Determine if there was a change in nutrient production and/or nutrient retention between pre-treatment and post-treatment periods in the restoration reach.
Analysis: This assessment is expected to be done largely by collaborative efforts of other entities, as described under Objective 4. One study already planned is to be conducted by graduate student, Ryan Bellmore, whose major professor is Dr. Colden Baxter of Idaho State University. Yakama Nation is also expected to launch a nutrient study in the near future (2009), which we believe will be a highly collaborative and compatible effort.

C. Modeling the potential fish response to restoration

Objective 3. Develop a reach-based fish production model to incorporate the dynamics and capacity of anadromous salmonids in the Methow watershed, with ability to assess role of fish movement and habitat connectivity and to assess potential effectiveness of restoration actions.

Task 3.1. Model major aspects of population dynamics (fish growth, survival), life history strategies (movement, age at smolting, age at adult return), and species interactions (competition, predation) to gage potential response of target fish species (Chinook, steelhead, bull trout) and other fish species (rainbow trout, cutthroat trout, mountain whitefish, dace, sculpin, and others) to the restoration effort.
Timing: October 2008-September 2011.
Methodology: One underlying theme we will want to incorporate is the efficiency of response of fish to find more optimal habitat when it exists upstream or downstream. This response could range from highly efficient, i.e., conforming to tenets of ideal free distribution (Fretwell and Lucas 1972, Grand 1997) whereby fish readily move downstream or upstream to find better habitat conditions) to poorly efficient, i.e., decision to move based on immediate habitat conditions and species interactions, and this movement may or may not be met with better conditions for survival and/or growth. Another aspect that we will model is predator-prey dynamics based on bioenergetic factors of consumption rates mediated by stream temperature and velocity. We will generally try for a high degree of compatibility with the effort described by Quantitative Consultants for the Lemhi and South Fork Salmon rivers (Chris Beasley, pers. comm.), and use the guidelines for evaluation of restoration effectiveness described by the Independent Multidisciplinary Science Team (2007). In addition to using EDT (see Allen and Connolly report in Attachment 2) and a cohort life-cycle model (under developed by P.J.

Connolly) to gage potential response to restoration, we will use the program STELLA and start with Ford's (1999) Tucannon River coho salmon model, to develop a dynamic, user-friendly model that should be readily usable by managers to help understand potential fish response to the treatment. Various other theoretical approaches are likely to be modeled.

Task 3.2. Collaborate in ongoing efforts with colleagues from agencies, universities, private entities, and Tribes to assess primary driver variables and to derive pertinent models that describe fish and habitat relationships and that estimate productivity.
Timing: October 2008-September 2014.
Note: Our Methow work is viewed as a part of a larger need for this modeling tool in the Columbia River Basin. For example, PI Pat Connolly will be participating in existing PNAMP Fish Monitoring group, and he will be participating in a developing team that will attempt to create a multi-faceted steelhead model. This team is comprised of Chris Jordan (NMFS), Gordie Reeves (USFS), Hiram Li (OSU), Jason Dunham (USGS), Michael Newsom (Reclamation), and others.

D. Assessing food-web dynamics

Objective 4. Assess the current food web and potential for biotic resistance imparted by presence and abundance of other interacting fish (e.g., native, nonnative, hatchery releases) and other members of the aquatic community (e.g., predators, competitors) in the restoration and potentially connected reaches in the mainstem Methow and Chewuch rivers based on aquatic productivity and fish diet information.

Task 4.1. Assess productivity and food web dynamics in the restoration reach.
Methodology: This will involve an assessment of diet for the primary fish in the reach (e.g., steelhead, Chinook, bull trout, rainbow trout, cutthroat trout, and mountain whitefish). We will estimate the contribution of the diet from different trophic stages to the annual growth of target species, competitors, and predators. It is anticipated that Dr. Colden Baxter will have graduate student Ryan Bellmore on this task during 2009-2011 as part of his doctoral work.
Timing: October 2008-December 2014.

Task 4.2. Collaborate with and assist Yakama Nation in their effort to assess effects of added nutrients to portions of the Methow subbasin.
Timing: It is expected that YN will launch their nutrient study in the near future (2009).

E. Collaborating with management agencies

Objective 5. Collaborate with and participate in a multi-agency effort to develop and implement a coordinated inter-agency basin-wide research and monitoring program for the Methow River. Use efforts underway by other agencies to supplement project activities to further tasks and objectives included in this agreement.

Task 5.1. Collaborate with WDFW, USFS, and YN to help ensure that systematic redd surveys in the potentially connected reaches in the mainstem Methow and Chewuch rivers are conducted throughout spawning times of Chinook, steelhead, coho, and bull trout.
Timing: October 2008-September 2014.

Task 5.2. Collaborate with WDFW to help ensure their planned smolt trapping, PIT tagging, and deployment of PIT tag interrogation systems are conducted during March-November at the specified sites, in the Twisp River and the mainstem Methow River near McFarland Creek. (See Figure 1 for general location.)
Timing: October 2008-September 2014.

Task 5.3. Collaborate with and provide technical assistance to Reclamation (e.g., Multiple Pathways and Indicator [MPI] surveys), USFS, YN, and other agencies and entities to ensure appropriate habitat variables for understanding fish-habitat relationships are being taken in the restoration reach, in control and reference reaches, and in selected side channels.
Timing: March 2009-September 2014.

Task 5.4. Coordinate and share resources with other projects that monitor the status and trend of listed salmon, steelhead and bull trout in the basin. These agencies and entities include USFWS, BPA, NMFS, WDFW, YN, and Upper Columbia Regional Technical Team.

Task 5.5. Coordinate and share resources with other agencies or projects that would provide data related to relative reproductive success of hatchery and naturally produced anadromous fish in the Methow subbasin.

Task 5.6. Coordinate and provide expertise as needed to further scientific equipment necessary to accomplish a pre-treatment restoration reach based study. These activities would include identifying potential cost share partners and technical expertise for PIT tag detector sites that would support the experimental design for this study (activity identified as Critical Uncertainty #4 below).

Task 5.7. Coordinate and provide expertise as needed to further scientific data and samples necessary for genetic information related to assessing reproductive success of listed fish in the basin.

Task 5.8. Give technical presentations related to the project activities at Columbia Basin effectiveness monitoring meetings, interagency workgroups, watershed councils, landowner coordination meetings, and other appropriate scientific and public outreach forums.

F. Managing the database

Objective 6. Create and manage an electronic database of protocols used and data collected**.**

Task 6.1. Enter data in a standard electronic format, and ensure high quality of data (QA/QC).

Task 6.2. Provide protocol and data inputs to the Integrated Status and Effectiveness Monitoring Project (ISEMP) in the effort to test the robustness of monitoring protocols, indicator metrics, and sampling designs currently used in monitoring programs.

Task 6.3. Contribute and coordinate with the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) in their effort to produce a comprehensive network of effective aquatic monitoring programs in the Pacific Northwest.

Schedule

October 2008—September 2009

- Initiate pre-treatment data collection (PIT tagging, snorkeling, etc.) in October 2008
- Purchase PIT tag interrogator equipment and build antennas in winter 2008/2009
- Initiate smolt trapping in July 2009
- Complete installation of two multiplexing PIT tag interrogation systems by September 2009
- Complete installation of four single-antenna PIT tag interrogation systems in side-channels by September 2009
- Initiate food web study (i.e., assisting MS student Ryan Bellmore) in April 2009

October 2009—September 2011 (note: two years)

- Complete food web study by June 2011 (To be conducted by Idaho State University's Ryan Bellmore, as a doctoral student under Dr, Colden Baxter.)
- Complete installation of one multiplexing PIT tag interrogation systems by September 2010
- Complete modeling effort by September 2011
- Continue pre-treatment data collection until time of restoration actions begin

October 2011—September 2012

- Continue pre-treatment data collection through at least May 2012
- Commence post-treatment data collection once restoration actions begin

October 2012—September 2014 (note: two years)

- Continue post-treatment data collection
- Final report on pre-treatment findings in February 2013

Deliverables

December 15, 2009	Progress Report stating the progress of each activity by objective and task
December 15, 2010	Progress Report stating the progress of each activity by objective and task
December 15, 2011	Progress Report stating the progress of each activity by objective and task
December 15, 2012	Interim Report in scientific format on the methods and results for data collected during the pre-treatment phase of the project
December 15, 2013	Progress Report stating the progress of each activity by objective and task
December 15, 2014	Final Report submitted in scientific format, publications, data and/or data summaries in usable electronic format

Critical Uncertainties (CU)

CU1) Effect of hatchery fish program: limitations of response of wild fish because of past, current, and near-future hatchery management (e.g., change in release numbers, location of releases, size of releases, or stock(s) released).

CU2) Confounding effect of recent and near-future changes in water management, e.g., changes to MVID.

CU3) Confounding effect of recent and near-future restoration efforts within control reaches or in other areas of the watershed.

CU4) Commitment from PUD and WDFW for smolt trapping, PIT tagging, and installing/maintaining PIT tag interrogation systems are key elements for the success of this project.
CU5) Extent and nature of the restoration actions that will be implemented in the restoration reach.

Permitting and logistical needs (PL)

PL1) Permitting will need to be completed for siting PTISs and the smolt trap (JARPA, fish sampling). Status as of this writing: JARPAs are in review. Fish permits are already largely secured.
PL2) Restoration project activities and schedule need to be highly coordinated with the sampling effort. Status as of this writing: Continuing to work closely with a USBOR team that is modeling river flow in the treatment reach.

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Table 1. Pre- and post-treatment data collection and analysis in 2009-2014.

Assessment / Methods	Sampling design	Analysis
Fish assemblage/abundance/density		
Snorkeling	Fish > 150 mm: Mar, Jul-Nov (n=9)	Fish use; seasonal relative abundance
Smolt trapping	Daily trapping; marked fish for efficiency	Annual out-migration; timing of movement
Electrofishing	Tributaries (4), side channels (2-3); mainstem (restoration reach, 3 controls)	Fish use; seasonal abundance (#/m^2, g/m^2)
Juvenile growth/survival		
Electrofishing	Capture-recapture	Change in length and weight; condition
Smolt trapping	Capture-recapture	Change in length and weight; condition
PIT tagging	Capture-recapture	Individual growth; survival; condition
Juvenile age structure		
Smolt trapping	Daily trapping; marked fish for efficiency;	Length-frequency; age analysis
PIT tagging	Capture-recapture	Individual age at size; survival; habitat use
PIT tag readers	Detection of PIT-tagged fish	Individual age at moving and/or smolting
Juvenile movement		
Electrofishing	Capture-recapture	Natal area; time in reach; survival
Smolt trapping	Capture-recapture	Time in reach; survival; young-of-year movement
PIT tagging	Capture-recapture	Time in reach; survival
PIT tag readers	Detection of PIT-tagged fish at key locations (mainstem, tributaries, and side channels)	Time in reach; survival
Adult return		
Redd surveys	Continuous, nearly 100%	Abundance, smolt-to-adult survival
Wells Dam counts	PUD methods at dams	Abundance, smolt-to-adult survival

Table 2. List of fish assessment activities and their timing in the Methow watershed in 2009-2014.

Activity/Site or action	Who	Timing	Fish monitoring and handling activities
Smolt trapping			
Methow or Chewuch R.			
-ab treatment reach	USGS	Mar-Nov+	Assemblage, abundance, length, weight, PIT tag/detection
Twisp R.	WDFW	Mar-Nov+	Assemblage, abundance, length, weight, PIT tag/detection
Methow-at McFarland	WDFW	Mar-Nov+	Assemblage, abundance, length, weight, PIT tag/detection
PIT tag interrogation systems			
Beaver Cr. (Stokes)	USGS	Jan-Dec	Movement data
Gold Cr. (lower, upper)	USGS	Jan-Dec	Movement data
Libby Cr. (lower)	USGS	Jan-Dec	Movement data
Chewuch R. (mouth)	USGS	Jan-Dec	Movement data
Methow -ab Chewuch R.	USGS	Jan-Dec	Movement data
Side-channels (n=2)			
within reference reach(es)	USGS	Jan-Dec	Movement data
Side-channels (n=2)			
within treatment reach	USGS	Jan-Dec	Movement data
Methow “M2” -ab Twisp R.	USGS	Jan-Dec	Movement data
Twisp R.	WDFW	Jan-Dec	Movement data
Methow mouth	WDFW[1]	Jan-Dec	Movement data
Instream fish assessment			
Snorkel-mainstem	USGS	Mar-Nov	Assemblage, abundance
Electrofish-4 mainstem areas	USGS	Mar-April; Jul-Oct	Assemblage, abundance, length, weight, PIT tag; movement
Electrofish-4 tributaries	USGS	Mar-April; Jul-Oct	Assemblage, abundance, length, weight, PIT tag; movement
Electrofish-4 side channels	USGS	Mar-April; Jul-Oct	Assemblage, abundance, length, weight, PIT tag; movement
Hook and line	WDFW, USGS	Jan-Dec	Assemblage, abundance, length, weight, PIT tag; movement
Redd surveys	WDFW, YN	Jan-Dec	Spawner abundance and distribution, timing of spawning
PIT tagging	USGS, WDFW	Jan-Dec	Movement, growth, survival

[1]Partially installed in October 2008; planned to operational in spring 2009.

Table 3. Level of PIT-tagging efforts for Chinook salmon and steelhead in the Methow watershed during each year of the project, 2009-2014.

Site	Group	PIT tags	USGS effort of total
Smolt traps (n=2, existing))	WDFW	2,000	0
Smolt traps (n=1, new)	USGS	1,000	1,000
Methow R.-upper	USGS and WDFW	1,500	1,000
Methow R.-treatment	USGS and WDFW	1,000	500
Methow R.-middle	USGS and WDFW	1,000	500
Chewuch River	USGS and WDFW	1,500	1,000
Twisp River	WDFW	500	0
Wolf Creek.	USGS	500	500
Eightmile Creek	USGS	500	500
Beaver Creek	USGS	500	500
Gold and Libby creeks	USGS	500	500
Hatchery(s)	WDFW	5,000	0
	Totals	15,500	6,000

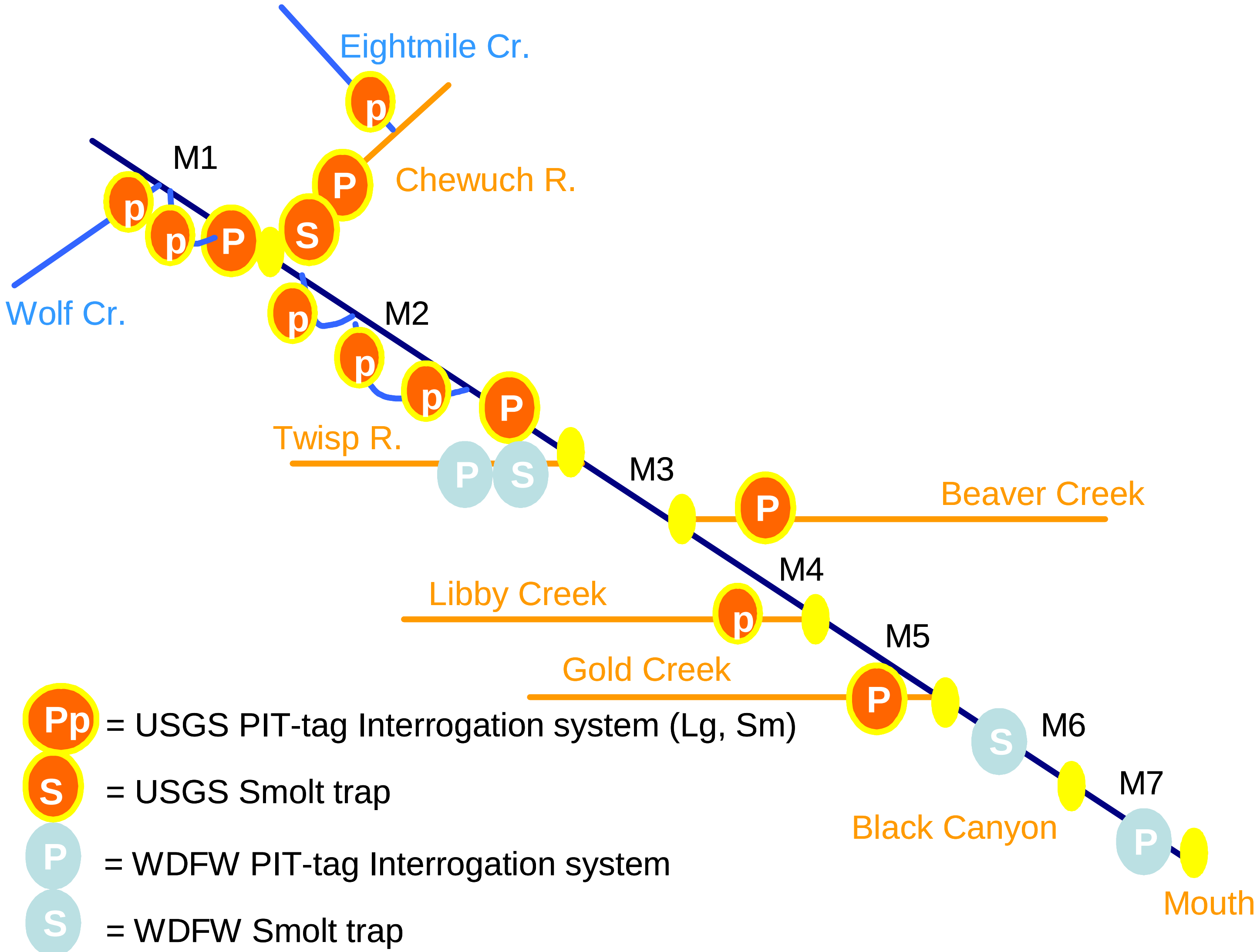


Figure 1. Location of fish monitoring gear already in place or planned in the Methow River watershed by Washington Department of Fisheries and Wildlife (WDFW) or U.S. Geological Survey (USGS). New installs are planned for completion in 2009. The restoration reach is denoted as "M2", P or p = large or small PIT-tag interrogation system (PTIS), and S=smolt trap.

Attachment 1. Likelihood of detecting PIT tagged fish.

Attachment Table 1.1. Number of PIT-tagged juvenile steelhead and spring Chinook estimated to survive and to be detected, based on 1,000 and 250 tags, at various end points based on site where PIT tagged and age at tagging and age at smolting. These estimates are derived from estimated survival and PIT tag detection efficiency at various sites in the Methow and Columbia rivers (see Attachment Table 1.2 for these estimates by site). See map in Figure 1 for location of sites.

		Steelhead (n = 1,000) (Age-1 parr to age-3 smolt)			Spring Chinook (n = 1,000) (Age-1 parr to age-2 smolt)		
PIT tagging site	End point	Number surviving	Number detected	Percent detected	Number surviving	Number detected	Percent detected
Chewuch	M2-downstream end	503	636	64%	670	770	77%
	Methow mouth	419	705	70%	558	826	83%
	Columbia mouth	76	742	74%	155	863	86%
Upper Methow	M2-downstream end	513	618	62%	684	761	76%
	Methow mouth	427	692	69%	570	820	82%
	Columbia mouth	78	731	73%	158	859	86%
M2-within	M2-downstream end	540	360	36%	720	480	48%
	Methow mouth	450	489	49%	600	616	62%
	Columbia mouth	82	558	56%	167	702	70%
M3-within	M2-downstream end	600	0	0%	800	0	0%
	Methow mouth	500	224	22%	666	290	29%
	Columbia mouth	91	340	34%	185	465	47%

		Steelhead (n = 250) (Age-1 parr to age-3 smolt)			Spring Chinook (n = 250) (Age-1 parr to age-2 smolt)		
PIT tagging site	End point	Number surviving	Number detected	Percent detected	Number surviving	Number detected	Percent detected
Chewuch	M2-downstream end	126	159	64%	168	192	77%
	Methow mouth	105	176	70%	140	206	83%
	Columbia mouth	19	186	74%	39	216	86%
Upper Methow	M2-downstream end	128	155	62%	171	190	76%
	Methow mouth	107	173	69%	142	205	82%
	Columbia mouth	19	183	73%	40	215	86%
M2-within	M2-downstream end	135	90	36%	180	120	48%
	Methow mouth	112	122	49%	150	154	62%
	Columbia mouth	20	140	56%	42	176	70%
M3-within	M2-downstream end	150	0	0%	200	0	0%
	Methow mouth	125	56	22%	167	73	29%
	Columbia mouth	23	85	34%	46	116	47%

Attachment Table 1.2. Estimated survival and PIT tag detection efficiency at various sites in the Methow and Columbia rivers. Those values in **bold** are the ones that differ between juvenile steelhead and spring Chinook. Values for survival and detection efficiency are based on available literature and best professional judgment.

			Steelhead (Age-1 parr to age-3 smolt)				Spring Chinook (Age-1 parr to age-2 smolt)			
Reach	Site		Between survival	Site survival	PIT tag detection efficiency	Steelhead Notes	Between survival	Site survival	PIT tag detection efficiency	Chinook Notes
Chewuch	Chewuch									
	[rearing to smolt phase]	Between	**0.60**			a	**0.80**			a
Chewuch	PTIS-1 (USGS)	At		1.00	0.70	a		1.00	0.70	a
		Between	0.95			a	0.95			a
Chewuch	Smolt Trap-1 (USGS)	At		0.98	**0.10**	b		0.98	**0.07**	b
		Between	1.00			a	1.00			a
M2	PTIS-2 (USGS)	At		1.00	0.60	a		1.00	0.60	a
		Between	0.90			a	0.90			a
McFarland	Smolt Trap-2 (WDFW)	At		0.98	**0.05**	c		0.98	**0.04**	c
		Between	0.85			a	0.85			a
Methow mouth	PTIS-3 (USGS)	At		1.00	0.40	a		1.00	0.40	a
		Between	0.90			a	0.90			a
Columbia Rive	Wells Dam	At		1.00	0.00			1.00	0.00	
		Between	0.90			a	0.90			a
Columbia Rive	Rocky Reach Dam	At		1.00	0.02	d		1.00	0.02	d
		Between	0.90			a	0.90			a
Columbia Rive	Rock Island Dam	At		1.00	0.05	d		1.00	0.05	d
		Between	**0.82**			e	**0.88**			h
Columbia Rive	Wanapum Dam	At		1.00	0.00			1.00	0.00	
		Between	**0.82**			e	**0.88**			h
Columbia Rive	Priest Rapids Dam	At		1.00	0.00			1.00	0.00	
		Between	**0.82**			e	**0.88**			h
Columbia Rive	McNary Dam	At		1.00	0.25	f		1.00	0.25	f
		Between	**0.81**			g	**0.87**			i
Columbia Rive	John Day Dam	At		1.00	0.25	d		1.00	0.25	d
		Between	**0.81**			g	**0.87**			i
Columbia Rive	The Dalles Dam	At		1.00	0.00			1.00	0.00	
		Between	**0.81**			g	**0.87**			i
Columbia Rive	Bonneville Dam	At		1.00	0.36	d		1.00	0.36	d
		Between	0.85				0.85			
Columbia Rive	Estuary	At		1.00	0.03	d		1.00	0.03	d

Notes for Attachment Table 1.2:

a Estimate based on professional opinion.

b Data from WDFW's Twisp smolt trap for 2005. Reference: Snow, C. and A. Fowler. 2006. Methow River Basin Spring Chinook and Steelhead Smolt Monitoring in 2005. Washington Department of Fish and Wildlife, Olympia WA.

c WDFW 2005 Methow trap with increased estimate based on professionoal opinion. Reference: Snow, C., and A. Fowler. 2006. Methow River Basin Spring Chinook and Steelhead Smolt Monitoring in 2005. Washington Department of Fish and Wildlife, Olympia WA.

d USGS CRRL data: (Beaver creek weir - 2006).

e Average survival for 1998-2002 from RIS to McN: 0.55 (0.82*0.82*0.82 =0.55), includes passage over dam and its pool. Reference: FPC (Fish Passage Center). 2008. http://www.fpc.org/survival/juvenile_queries.html (January 2008).

f DE=0.2499 Reference: Columbia River DART (Data Access in Real Time). 2008 http://www.cbr.washington.edu/dart/ (5 January 2008).

g Average survival from McN-BON: 0.54 (0.81*0.81*0.81=0.53), includes passage over dam and its pool Reference: Williams, J.G., S.G. Smith, W.D. Muir, B.P. Sandford, S. Achord, R. McNatt, D.M. Marsh, R.W. Zabel, and M.D. Scheuerell. 2004. Effects of the Federal Columbia River Power System on Salmon Populations. National Oceanographic and Atmospheric Administration, Fisheries Ecology Division, Seattle, WA.

h Average survival for 1998-2002 from RIS to McN: 0.69 (0.88*0.88*0.88= 0.68), includes passage over dam and its pool. Reference: FPC (Fish Passage Center). 2008. http://www.fpc.org/survival/juvenile_queries.html (January 2008).

i Average survival from McN-BON: 0.67 (0.88*0.88*0.88=0.68), includes passage over dam and its pool Reference: Williams, J.G., S.G. Smith, W.D. Muir, B.P. Sandford, S. Achord, R. McNatt, D.M. Marsh, R.W. Zabel, and M.D. Scheuerell. 2004. Effects of the Federal Columbia River Power System on Salmon Populations. National Oceanographic and Atmospheric Administration, Fisheries Ecology Division, Seattle, WA.

Attachment 2: EDT model results (Allen and Connolly report)

Prepared by B. Allen and P.J. Connolly, USGS, Columbia River Research Laboratory, Cook, WA.

Spring Chinook and summer steelhead abundance, capacity, and productivity for the Methow River were estimated using the Ecosystem Diagnosis and Treatment model. I used the habitat attribute values for historical and current conditions that are the default data values registered to the EDT website and compiled by Casey Baldwin of WDFW. The habitat attribute values for the PFC conditions are given as a standardized scenario. The PFC habitat conditions, in general, are an 80% improvement in conditions from current back to historic pre-European settlement conditions. The fish metric outputs for the PFC condition are about 80 to 90 % of historic (Table 1 and Figure 1).

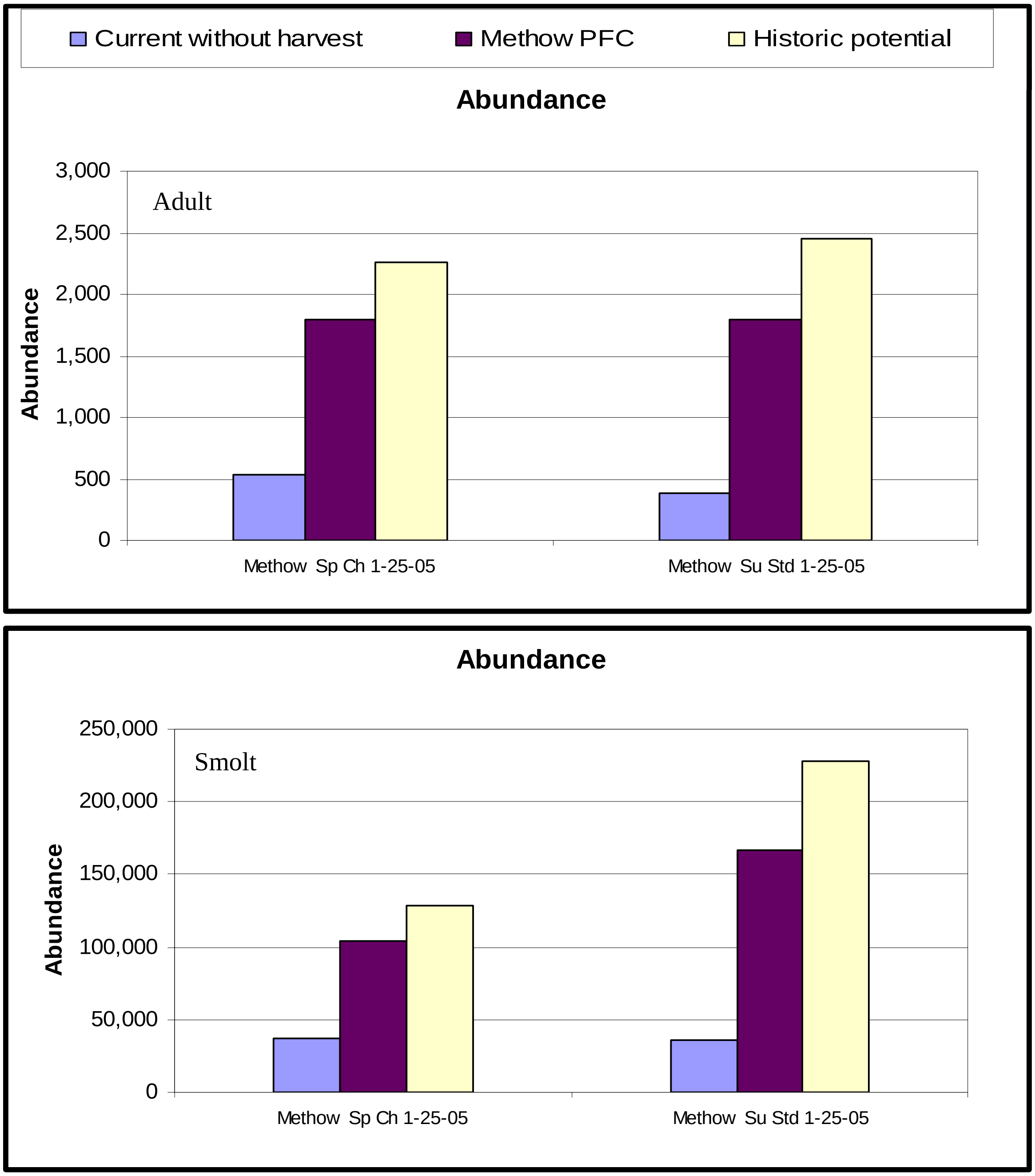
To model the change in fish population metrics due to proposed restoration actions in the M2 reach, I adjusted the attributes to mimic the historical conditions for two EDT reaches (M11 and M12), which largely covered the M2 reach from Winthrop to Twisp. The modeled conditions would be a best case scenario for those reaches. The conditions included a total removal of all man-made floodplain confinement, a return of LWD to historic levels, no harassment of pre-spawning adult fish, no hatchery outplants, a reduction of summer water temperatures, historic levels of salmon carcasses, historic sediment levels, etc. Therefore these results should be considered to be the effect of a fully restored M2 reach, combined with a removal of the effects of hatchery fish in the M2 reach. The differences in the fish metrics as a result of changing habitat attributes from current conditions to M2 restored conditions should be considered the largest effect possible given the values available in the registered datasets (Table 1 and Figure 2).

To estimate the change in wild spring Chinook and summer steelhead abundance, capacity, and productivity due to the elimination of hatchery fish outplanting, I changed that parameter to historical conditions (no stocking) using the scenario builder provided by Mobrand (Table 1). In another model run, I changed hatchery fish outplanting and fish pathogen parameters to the historic conditions (Figure 3). Fish pathogen attribute rankings are largely derived from fish stocking frequency and location, unless specific pathogens have been identified in a specific reach. Therefore eliminating hatchery fish outplanting from all reaches would also change the fish pathogen attribute rankings in all reaches except those where a wild fish health survey identified pathogens.

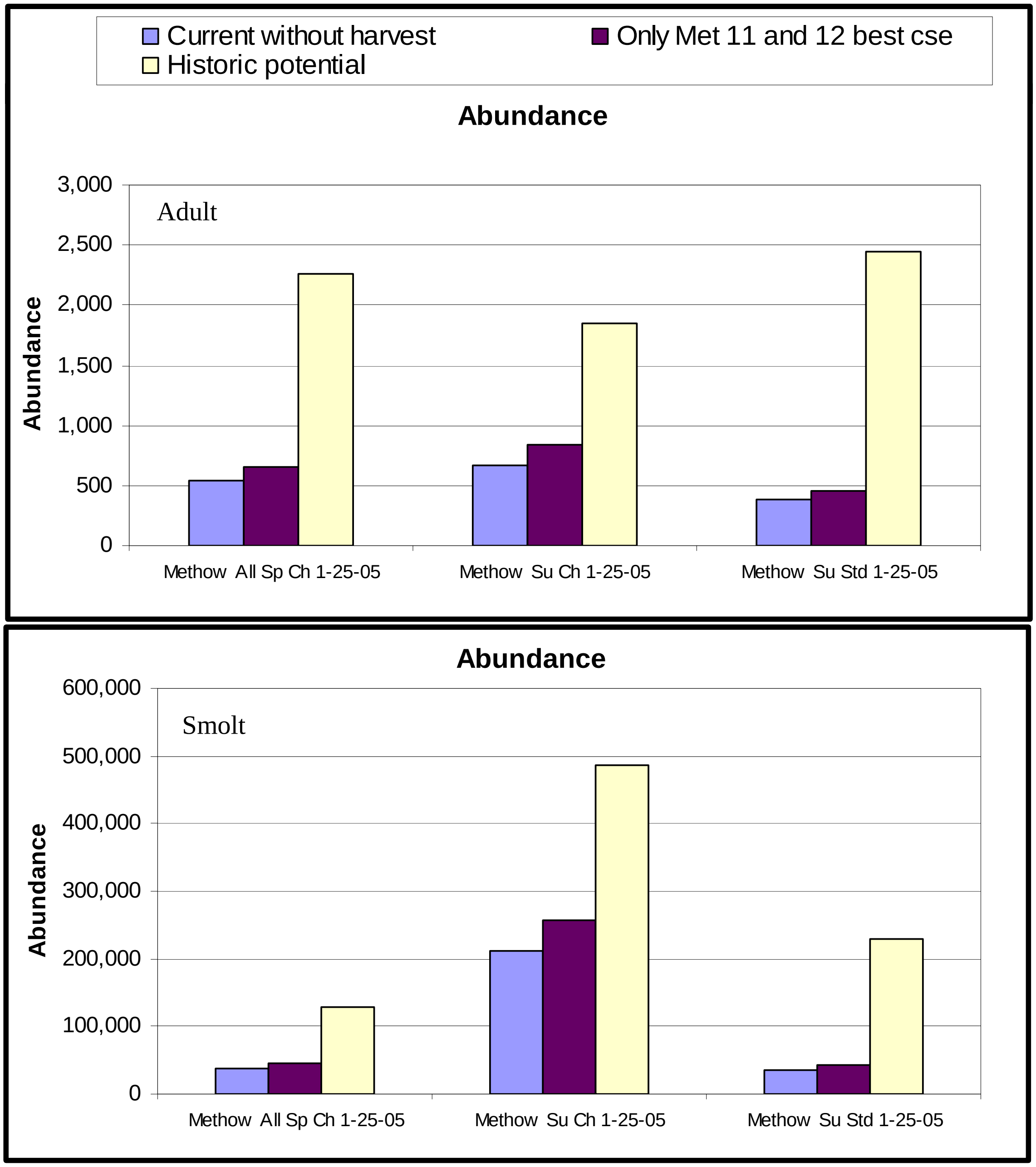
The results indicate that the elimination of hatchery fish outplanting would benefit spring Chinook as much as the restoration of the M2 reach to historic conditions. Steelhead would benefit more from the elimination of stocking than the complete restoration of the M2 reach. If we include the likely changes to the fish pathogen parameter that would result from the elimination of fish stocking the modeled benefits to spring Chinook and summer steelhead populations is even greater (Figure 3). The restoration of the M2 reach to historical conditions would be unlikely to be fully achieved and so the model results would be a best case scenario for changing the fish abundance, capacity, and productivity.

Attachment Table 2.1. Outputs for several EDT model runs: comparison of fish production metrics for the entire Methow River. The conditions modeled were: historical, current, PFC restoration of the entire watershed, elimination of hatchery fish outplanting, and post-treatment best case restoration of the M2 Reach.

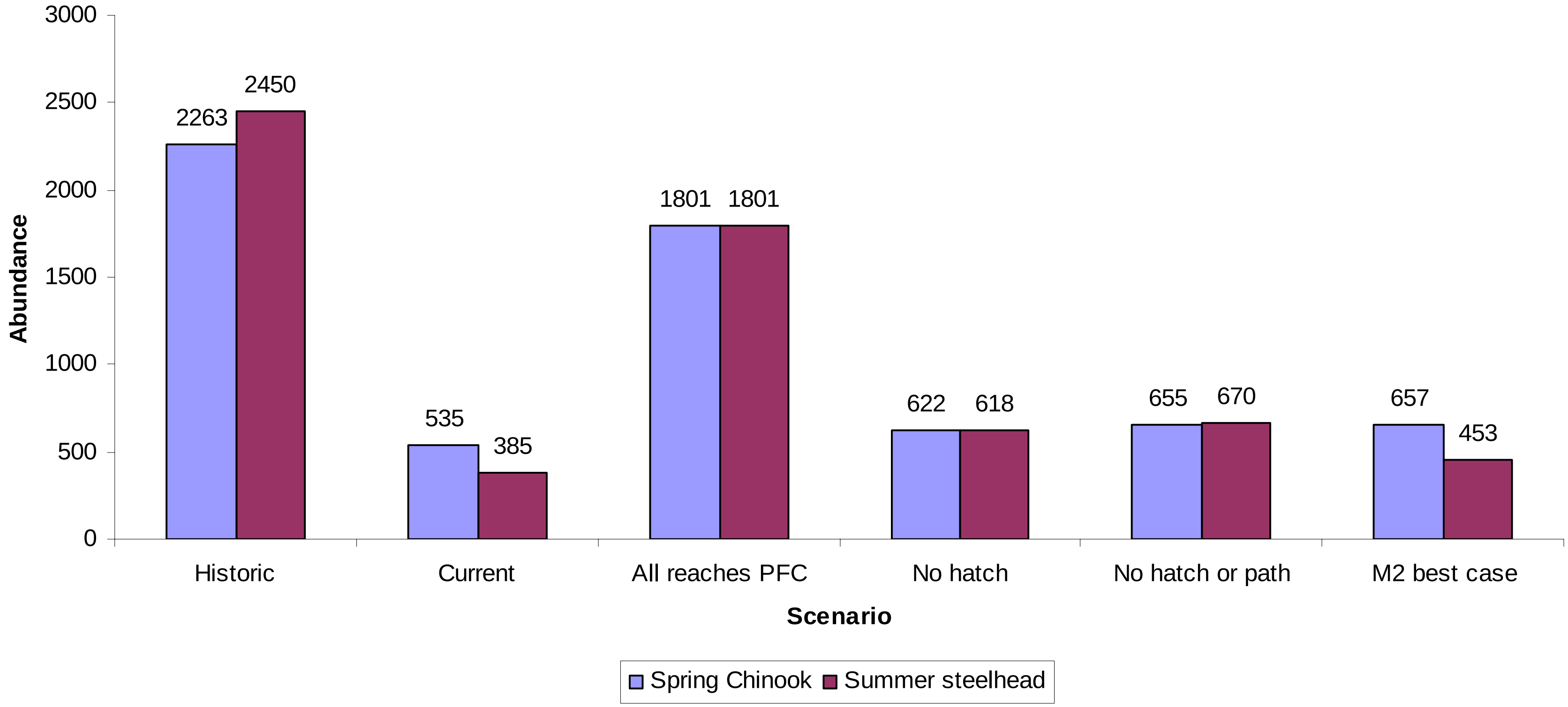
Descriptor:	**Historical**	**Current conditions pre-treatment**	**PFC restoration**	**No hatchery fish ouplanting.**	**M2 proposed restoration post-treatment**
Restoration actions:	None	None	All possible actions in Methow River watershed.	Elimination of hatchery fish outplanting in entire watershed, with no other changes	Best case scenario for M2 reach restoration with no other changes.
Fish Metric					
Abundance					
Spring Chinook	2263	535	1801	622	657
Summer steelhead	2450	385	1801	618	453
Capacity					
Spring Chinook	2922	1116	2600	1179	1240
Summer steelhead	3813	2370	3553	2459	2388
Productivity					
Spring Chinook	4.4	1.9	3.3	2.1	2.1
Summer steelhead	2.8	1.2	2	1.3	1.2



Attachment Figure 2.1. Abundance of adult (top) and juvenile (bottom) spring Chinook and summer steelhead in the Methow River based on current habitat conditions, properly functioning condition (PFC) for all reaches of the Methow, and historic habitat conditions.



Attachment Figure 2.2. Abundance of adult (top) and juvenile (bottom) spring Chinook, summer Chinook, and summer steelhead in the Methow River based on current habitat conditions, restoration in the Met 11 and Met 12 reaches (Winthrop to Twisp), and historic habitat conditions. Changes in habitat conditions due to restoration in the Met 11 and Met 12 reaches reflect the best case scenario of a nearly fully functional riparian, abundant LWD, no hatchery stocking, no adult harassment, and no artificial confinement.



Attachment Figure 2.3. Abundance estimates for the entire Methow River watershed from the EDT model results. The registered dataset was used to generate the historic and current abundance estimates. The scenario builder was used to generate the abundance estimates for all reaches of the Methow River being restored to properly functioning condition (PFC); for eliminating the influence in all reaches of hatchery fish outplants (hatch) for eliminating the influence in all reaches of hatchery fish outplants (hatch) and pathogens (path, which is typically derived from hatchery fish outplanting frequency and location); and for restoration of the M2 reach (EDT reaches Met 11 and Met 12,from Winthrop to Twisp) to historic conditions.