Project ID: 201003000 Yakima Basin steelhead VSP monitoring

Title: Estimate viable salmon population (VSP) parameters for Yakima steelhead major population group (MPG)

Section 10 of 10: Project Narrative

A. Abstract

This proposal expands RM & E activities conducted by the co-managers in the Yakima Basin (Yakama Nation and Washington Department of Fish and Wildlife) to better evaluate VSP parameters (abundance, productivity, spatial structure, and diversity) for Yakima steelhead populations. This proposal builds upon the infrastructure and monitoring capacities of the YKFP umbrella M&E project (199506325). Data from this project will be used to evaluate population status and trends (including NOAA status reviews and the AMIP abundance triggers), and address critical uncertainties (e.g., the relationship between resident and anadromous life histories in the Upper Yakima and Naches populations), consistent with the NPCC Fish and Wildlife program, Columbia Basin research plan (uncertainties 3.1, 7.1 & 7.3), NOAA mid-Columbia steelhead recovery plan, and Fish Accords. Better understanding population performance will directly inform efforts to recover steelhead populations in the Yakima Basin.

Specific proposed activities include:

1. increased biological and DNA sampling at the Chandler juvenile, and Prosser and Roza adult monitoring facilities (Abundance, Productivity),

2. adult radio telemetry tagging at Prosser and Roza facilities and subsequent tracking throughout the Yakima Basin (Abundance, Productivity, Spatial Structure),

3. increased PIT tagging and detection throughout the Yakima Basin (Abundance, Spatial Structure),

4. evaluate flow and entrainment relationships at the Chandler (Prosser) diversion dam to refine steelhead smolt outmigration estimates (Abundance and Productivity),

5. analysis of existing and additional steelhead DNA samples to improve the genetic profile for all four populations in the MPG (Abundance, Productivity, Diversity, Spatial Structure),

6. expand spawner surveys and redd counts for steelhead populations (Spatial Structure), and

7. evaluate interactions in the upper Yakima, specifically between resident rainbow and steelhead trout (Diversity, Productivity).

This project addresses reasonable and prudent alternatives (RPAs) 50 and 62 in the FCRPS biological opinion.

B. Technical and/or scientific background

Populations of wild steelhead *Oncorhynchus mykiss* in the Columbia River Basin have declined dramatically from historical levels (Nehlsen et al. 1991; NRC 1996; Williams et al. 1999). Average abundance of wild steelhead in the Yakima River Subbasin over the last two decades is only 2% of pre-1890 abundance levels reported by Howell et al. (1985). Causes of these declines include a host of environmental and human-induced factors (NRC 1996; Williams et al. 1999). In 1997 steelhead in the upper Columbia River were listed as endangered under the Endangered Species Act (ESA) and those in the Snake River were listed as threatened (62 FR 43937-43954). Stocks originating in mid-Columbia Basin tributaries (including the Yakima River) were listed as threatened in 1999 (64 FR 14517-14528). No hatchery fish have been released in the Yakima Subbasin since 1993. Regional plans recognize the need to protect and enhance weak upriver steelhead populations and their habitat while maintaining the genetic integrity of those stocks (NPPC 1994).

Steelhead in the Yakima Basin are divided into four populations: the Satus Creek, Toppenish Creek, Naches River, and Upper Yakima River populations. The NOAA Interior Columbia Technical Recovery Team (ICTRT) identifies the Satus Creek population as steelhead that spawn in the Satus Creek drainage on the Yakama Indian Reservation, the mainstem Yakima River below Satus Creek, and tributaries to the lower mainstem. For management purposes, local planners have subdivided the Satus population into the Satus block, which spawns in the Satus Creek drainage, and a mainstem block, whose current and historic status is uncertain. The Toppenish population consists of steelhead that spawn in Toppenish Creek, its tributaries and the short stretch of the mainstem between Toppenish and Satus creeks, and is entirely on the Yakama Reservation. The Naches population includes steelhead spawning in the Naches River and its tributaries (including the Tieton, Little Naches, American, and Bumping rivers and Cowiche, Rattlesnake and Nile creeks), the mainstem Yakima from the Naches confluence to the Toppenish Creek confluence and the tributaries to that reach of the Yakima, including Ahtanum Creek. The Upper Yakima population consists of all steelhead that spawn in the Yakima River and its tributaries upstream of the Naches confluence. Together these four populations make up the Yakima MPG.

Estimates of the number of adult steelhead returning to the Yakima Basin prior to European settlement range from 20,800 to 100,000. In contrast, the number of adults passing fish counting facilities at Prosser Dam (on the mainstem Yakima downstream of virtually all current spawning locations) between 1985 and 2006 has ranged from 450 to 4,491 with an average of 1,764. The ICTRT estimated the 10-year (1996 to 2005) geometric average by population as 379 for the Satus population, 322 for the Toppenish population, 472 for the Naches population, and 85 for the Upper Yakima.

The ICTRT modeled the extent of historically available steelhead habitat. Steelhead spawning is widely distributed throughout the areas accessible to them, except in the lower Yakima River and its tributaries (below the Satus Creek confluence). The extent and distribution of spawning in the mainstem from the Columbia to Roza Dam is

uncertain. Steelhead currently cannot access the watersheds above Tieton, Bumping, Cle Elum, Kachess, and Kecheelus dams and a number of significant tributaries (e.g., Wenas, Manastash, and Naneum creeks in the Upper Yakima population area, and until just last year, Cowiche Creek in the Naches population area).

The Yakama Nation and WDFW have emphasized maintaining the natural genetic composition of Yakima Basin steelhead stocks. The last release of hatchery-origin juvenile steelhead in the Yakima Basin occurred in 1993. Stray hatchery-origin fish from other basins made up only 3% of the run from 1999 to 2005.

Instead of dying immediately after spawning like most salmon, steelhead can survive, return to the ocean, and spawn again. The Yakama Nation is currently capturing post-spawning steelhead (i.e., kelts) at Prosser Dam and reconditioning them in hatchery facilities to increase the number that survive to spawn again.

Our knowledge of steelhead status in the upper portions of the basin is complicated by the fact that steelhead and rainbow trout are different forms of the same species that can interbreed. Better understanding of the historic, current, and future potential for steelhead production in these areas will require determining how habitat conditions, intra-specific interactions, genetics, and survival rates for oceangoing smolts interact to affect the balance between resident and anadromous life histories.

The ICTRT assessed the viability of Yakima Basin steelhead populations and concluded that none currently meet its standards for viability. The Satus population comes nearest to meeting the ICTRT's standard, while the Upper Yakima population is farthest from the standard. The ICTRT analysis is based on NOAA Fisheries' Viable Salmonid Population (VSP) framework, which calls for managing salmon and steelhead populations based on an understanding of their abundance, productivity, spatial structure, and diversity.

Current estimates of steelhead VSP parameters for the Yakima MPG are limited for the following reasons:

1) Steelhead abundance (i.e., run size) is determined at Prosser Dam, but only at the MPG level.
2) No reliable spawner abundance estimates of individual populations exist.
3) Spatial structures of Naches and Upper Yakima populations are unknown.
4) Influence of resident *O. mykiss* in upper Yakima and Naches is unknown.
5) No estimates of juvenile productivity exist for any population.
6) Limited understanding of the relationship between life stage survival rates and habitat limiting factors.

This proposal uses the methodologies and infrastructure developed under the YKFP M & E umbrella project (199506325) to evaluate VSP parameters for steelhead.

C. Rationale and significance to regional programs

Improved information on Yakima Basin steelhead VSP parameters is needed to inform recovery efforts in the Yakima Basin and the Columbia Basin as a whole. The region convened a series of technical workshops in 2009 to "develop an efficient monitoring framework and project specific implementation strategy for anadromous salmon and steelhead monitoring based on the Viable Salmonid Population (VSP) parameters habitat effectiveness and hatchery effectiveness monitoring within the Columbia River Basin (coordinated with mainstem monitoring) that meets the needs of Recovery Plans, the Federal Columbia River Power System (FCRPS) BiOp, Northwest Power and Conservation Council Fish and Wildlife Program and other regional fisheries management objectives." This proposal was specifically identified in this process as filling a key data gap.

While some data have been collected on steelhead during ongoing spring Chinook research, monitoring and evaluation (RM & E) activities under the YKFP, significant gaps in most VSP parameters exist for every population in the major population group (MPG: Satus, Toppenish, Naches, and Upper Yakima). This project seeks to expand existing RM&E work (project 199506325) to fill those gaps.

The research, monitoring and evaluation activities described herein are designed to be consistent with the Northwest Power Act and the Northwest Power and Conservation Council's Fish and Wildlife Program, Yakima Subbasin Planning and Recovery efforts (specifically, the 2009 Yakima Steelhead Recovery Plan), the Columbia Basin Research Plan (3.1, 7.1, and 7.3), the objectives in the Columbia River Basin Accords, and the draft regional monitoring framework. This project addresses reasonable and prudent alternatives (RPAs) 50 and 62 in the FCRPS biological opinion.

D. Relationships to other projects

This project is directly related to:

Funding source	Project ID	Project Title	Relationship
BPA	199506325	Yakima Klickitat Fisheries Project - Monitoring and Evaluation - Yakima Basin	Umbrella RME project in Yakima Basin that has collected (and will continue to collect) much of the baseline information relevant to this project.
BPA	198812025	YKFP Management, Data, and Habitat	Core management and Administrative Support Services for all YKFP Tasks; includes habitat restoration and data management activities

BPA	199603501	Yakama Reservation Watersheds Project	This is a watershed scale restoration project intended to protect and enhance habitat for the native threatened summer steelhead stock, and a variety of cultural and natural resources.
BPA	199701325	Yakima Klickitat Fisheries Project - Operations and Maintenance - Yakima Basin	This proposal supports O & M for facilities used in this project.
BPA	200001700	Recondition Wild Steelhead Kelts	Continue to test and evaluate methods to recondition steelhead kelts, generate science-based management recommendations, and assist in their implementation to rebuild wild steelhead populations throughout the Columbia Basin. A large part of this work is conducted in the Yakima Subbasin.
BPA	200306200	Evaluate Reproductive Success Kelt Steelhead	This evaluation program is designed to investigate the reproductive success of hatchery-reared, natural-origin, and reconditioned kelt steelhead *Oncorhynchus mykiss* in three different evolutionary significant units (Upper Columbia, Mid Columbia, and Snake River) under natural conditions. The two major goals are 1) directly examine reproductive success in several streams; and, 2) replicate and evaluate kelt reconditioning procedures and protocols at a variety of locations. A large part of this work is conducted in the Yakima Subbasin.

In turn these projects are related to over 30 additional BPA-funded projects, which are directly implementing objectives and strategies defined in the Yakima Subbasin Plan (YSP, Tables 3-22, pages 17-35 of the Yakima Subbasin Supplement) and are consistent with the overarching objectives, vision, and treaty trust and mitigation obligations identified in the FWP (Council document 2000-19). Other funding sources (e.g., PCSRF) are also completing work consistent with these goals. The VSP data gathered through this proposal will directly inform our understanding of the relationship between population performance and habitat limiting factors. This is an essential step in long-term efforts to identify and prioritize existing and future habitat projects.

E. Project History

Although this is a new proposal, groundwork and data related to this project have been accomplished under project 199506325, YKFP umbrella M&E. These include:

Accomplishment
Since 2002 have been collecting baseline DNA sample data on steelhead from adults at Prosser and Roza Dams and from juveniles in tributary smolt traps.
Since 1987-88 run year, have been collecting redd count data in at least one major spawning tributary (Satus Cr.), expanding to five major locations (Satus, Toppenish, Ahtanum, Naches, and Upper Yakima-Roza) by 2003-04 run year.
For at least two decades have been collecting data on resident rainbow trout and interactions with other species in the Upper Yakima
Since 1983-84 run year have been collecting annual adult return data at Prosser Dam; also have adult return data for Roza Dam dating back to 1991-92 run year.
Have assembled a base dataset of adult and juvenile age structures for the composite Yakima MPG.

F. Proposal biological objectives, work Tasks, and methods

The overarching objective of this proposal is to address VSP and RPA data gaps as called for in the FCRPS BiOp and Mid-Columbia Steelhead Recovery Plan (which includes the Yakima River Steelhead Recovery Plan). Establishing robust estimates of steelhead VSP parameters is intended to direct future recovery actions and to provide benchmark values against which progress towards steelhead recovery in the Yakima MPG can be evaluated. Addressing VSP and RPA data gaps will contribute to the long term recovery objectives presented in the Yakima Sub-basin plan and the Yakima Steelhead Recovery Plan. Specific objectives of the proposed study are listed below.

Biological Objective 1: Determine spatial distribution and major (MSA) and minor (MiSA) spawning areas of steelhead spawning populations in the Yakima MPG. (RPA 50.6, 62.5)

Scope

Our current understanding of population spatial structure and major/minor spawning area occupancy of Yakima River steelhead comes from on ground spawner surveys and a recent upper Yakima radio telemetry study conducted from 2002-2005 (Karp, et al. 2009). Annual redd surveys have been conducted by the YN under the Yakama Reservation Watersheds Project (199603501) in Satus and Toppenish Creeks since 1988, and for Ahtanum Cr. since 2000. The surveys have, and will continue to provide sufficient spatial structure information for the Satus and Toppenish Cr. populations and partial information for the Naches population (Ahtanum Cr).

Improved tracking of the Upper Yakima and Naches population distributions is the primary focus of this objective. Redd surveying efforts led by the USFWS and WDFW have been conducted in the Naches watershed since 2004. These surveys have focused primarily on the tributaries of the Naches and have significantly expanded our knowledge of this population's spawning distribution but more effort is needed for mainstem spawning locations. The mainstem Naches in its entirety, and portions of the Yakima are areas that presumably support some level of steelhead spawning activity. These areas have been extremely difficult to survey due to lack of resources and/or inability to detect redds due to survey conditions. As a result, spawning activity in the mainstem Naches and Yakima River are not well understood. More precisely put, little to nothing is known regarding the downstream extension and potential spatial/temporal overlap between the Naches and Upper Yakima populations. We are proposing a three year radio telemetry study (Work Task 1A) to improve tracking of the Upper Yakima and Naches distributions and increase our understanding of mainstem spawners and their respective role within Yakima steelhead population dynamics. This is a recommended RM&E activity outlined in the chapter 7 of the 2009 Yakima Steelhead Recovery Plan. The study will also contribute valuable information needed for other Work Tasks. In addition to the radio telemetry study, spawner surveys will be expanded in the Naches (Work Task 1B) and Upper Yakima watersheds (Work Task 5B) for status and trend monitoring of spatial structure and MSA occupancy post telemetry era.

We propose to conduct a three year radio telemetry project in the Yakima River Basin (upstream of Prosser Dam). We will use methods similar to those described in Karp et al. (2009). Key issues the study would address would include:

1) Ground truth and refine GSI based population-specific abundance estimates.
2) Address uncertainties regarding the extent, distribution, and contribution of mainstem spawners.
3) Estimate the proportion of steelhead from each population that overwinters in the mainstem Yakima River versus tributaries.
4) Estimate survival to spawning rates for steelhead that overwinter in the mainstem versus tributaries of the Yakima River.
5) Describe prespawn migration patterns of steelhead.
6) Determine the timing and spawning distribution in each population.
7) Estimate the number of redds constructed per female.
8) Estimate the survival to kelting rates for each population.

Work Task 1A. Conduct radio telemetry study

Work element name:	Install fish monitoring equipment
Work element title:	Deploy fixed telemetry sites throughout Yakima Basin
Start date:	7/1/2010
End date:	8/1/2010
Duration :	2010-2014
Description: Install and operate fixed radio telemetry sites at selected sites throughout	

the Yakima Basin.	
Work element name:	Mark/Tag Animals
Work element title:	Insert radio and PIT tags in female steelhead
Start date:	7/1/2010
End date:	5/1/2011
Duration :	2010 – 2014
Description: Operate the denil trap at Prosser Dam and insert radio and PIT tags into a representative samples of steelhead into wild steelhead.	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Monitor radio tagged steelhead on spawning grounds
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2010 – 2014
Description: Deploy fixed radio transceivers and conduct mobile tracking of steelhead through the spawning period. Download data on a periodic basis.	
Work element name:	Analyze/Interpret Data
Work element title:	Analyze radio telemetry data
Start date:	7/1/2010
End date:	6/3/2011
Duration :	2010 – 2014
Description: Conduct spatial and temporal analysis of radio telemetry to determine survival, migration patterns, spawning distribution and timing of steelhead	

Background & Methods

Presumably, the large geographic distribution of steelhead in the Yakima Basin results in diverse pre-spawning migration patterns that influence the proportion of fish that survives to spawn. Estimates of run escapement at Prosser Dam may accurately reflect spawning escapement estimates of nearby populations (e.g., Satus) and poorly for other (e.g., Naches). This project would fund a three-year radio telemetry study that would better define the spawning distribution of steelhead in all four populations. Between 450 and 500 adult steelhead will be radio tagged from the annual total steelhead run at Prosser Dam as these fish migrate into the Yakima River Basin between the months of October and April. Fish captured for this study will be anesthetized, measured, sexed, tissue sampled for genetic analysis, scales collected for cohort analysis, and inserted with a12-month duration Lotek wireless radio transmitter. Fish will be held for a 12 hour period to ensure tag retention and survival from fish handling and tagging before being released upstream of Prosser Dam. A 12-month duration radio transmitter will be used so for tracking pre-spawn migration and holding patterns prior to, and through the spawning period, and during their subsequent outmigration to the Pacific Ocean. We are anticipating a small proportion of these tags will be recovered from out migrating kelts captured at the Prosser hatchery facility. Recovered tags may be used in addition to tag supply for subsequent year studies. Specifically, surplus tags can be used for tagging

additional steelhead at Roza Dam. Additional radio tagged adults in the Upper Yakima will contribute to several project objectives and work Tasks (e.g., 5B). We will use a combination of Lotek fixed-station radio receivers and ground surveys with mobile receivers to monitor survival, migration patterns, and final spawning locations for each tagged fish. Fixed-station radio receivers installed at important locations throughout the Yakima Basin (Figure 1) including mainstem locations and confluences of major tributaries to the Yakima River). Ground truthing surveys with hand-held radio-tracking equipment will help determine migration patterns, timing, and spatial distribution for tagged steelhead within each of the four independent Yakima River sub-populations which are identified as the Satus, Toppenish, Naches, and Upper Yakima sub-populations.

The proportion of tagged fish migrating into each of the four independent sub-populations can then be multiplied by the total steelhead run size counted at Prosser Dam to estimate steelhead abundance levels for each Yakima Basin steelhead sub-population. Estimates of prespawn mortality for each of the populations can also be applied to more accurately determine spawning escapement numbers. With greater knowledge of prespawn mortality numbers, managers can target efforts to reduce sources of mortality (e.g. poaching) where possible.

In addition, genetic samples collected from each tagged fish at the time of capture will be analyzed by the Washington Department of Fish and Wildlife (WDFW) Genetics Lab according to established sampling protocols. Because spawning locations for each genetically sampled fish can be tracked to one of the four independent sub-populations in the basin, the radio telemetry study will validate assignments made using the genetic baseline. Ultimately, the ability to genetically differentiate steelhead from the four Yakima River sub-populations will allow fishery managers to estimate productivity and diversity from routinely collected steelhead smolts as they migrate out of the basin.

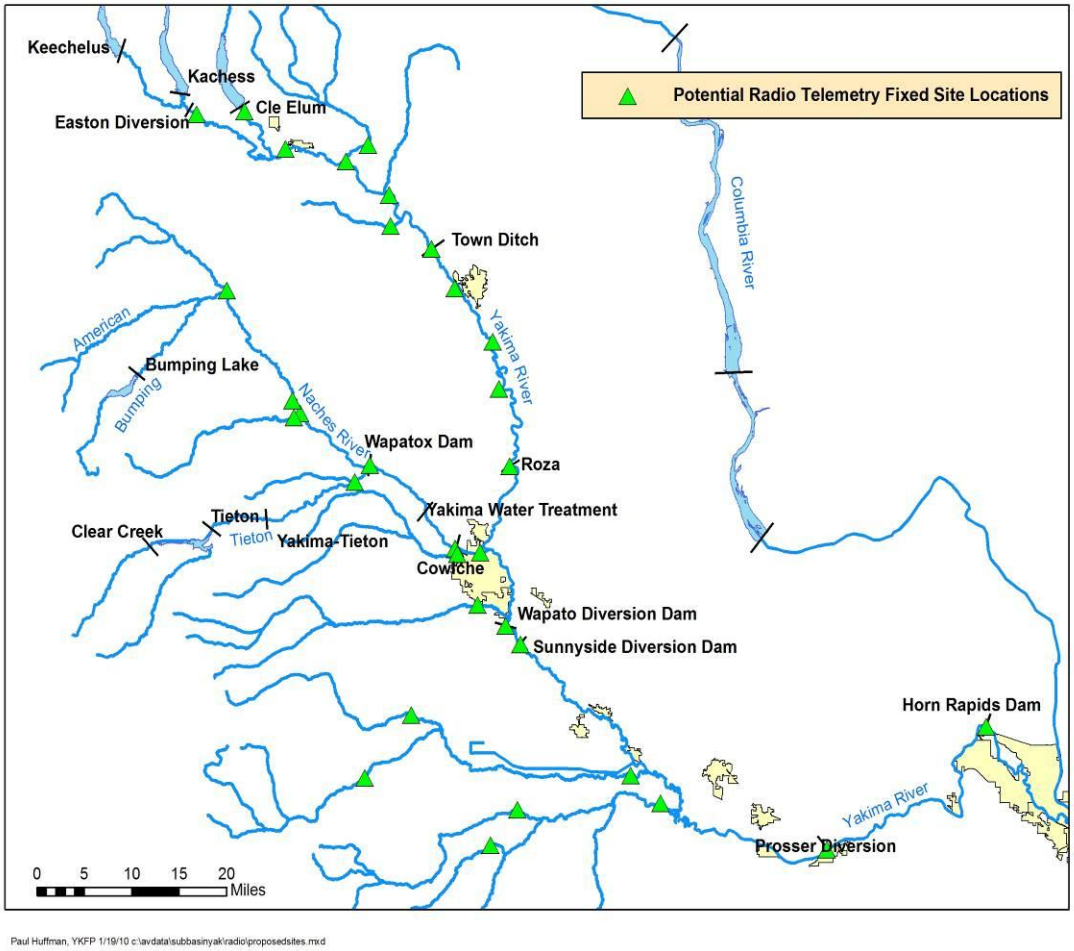

Figure 1. Proposed radio telemetry fixed site locations

Work Task 1B. Maintain/expand spawning distribution data for Naches and mainstem spawners

Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Foot surveys
Start date:	3/15/2011
End date:	6/15/2011
Duration :	2011-2017
Description: Conduct on ground spawner surveys in Naches tributaries	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Aerial Redd surveys
Start date:	3/15/2011
End date:	6/15/2011

Duration :	2010 – 2017
Description: Conduct aerial redd surveys within Naches basin and Yakima mainstem as needed	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Floating redd surveys
Start date:	3/15/2011
End date:	6/15/2011
Duration :	2010 – 2017
Description: Conduct floating redd surveys on Naches and Yakima mainstems as needed	

Background & Methods

Redd surveying efforts led by the USFS and WDFW have done opportunistic redd surveys in 5 out of 8 identified major spawning areas (Oak Creek in the Tieton, Little Naches in the Upper Naches, Nile Creek in the Middle Naches, Bumping, American, Rattlesnake). The surveys and index areas have not been consistent from year to year, but have allowed for an assessment of occupancy (TRT definition). This work task proposes to expand the Naches spawner surveys to include mainstem locations by means of aerial flights and floating surveys. Aerial flights will be scheduled weekly, or as needed, and flown every three years to document spawner presence and timing within mainstem index locations. Mainstem spawn timing and index locations will be established from a three year radio telemetry study outlined in Work Task 1A. Floating surveys will be used in addition to aerial flights at opportunistic times when survey conditions allow. Float surveys will focus in the off years of aerial flights and potentially within years in order to offset costs and/or increase effectiveness of surveying efforts.

Combing survey efforts expanded under this project with surveys efforts lead by the USFS and WDFW is expected to provide a total census of the Naches populations spatial distribution with the ability to detect a change in distribution of +/- 15% with an 80% certainty. If however, statistical criteria cannot be met for any particular reason (i.e, lack of resources) spawner survey efforts will need to consider a probabilistic sampling design for estimating changes in adult spawning area as suggested in Section 5.4 (Monitoring VSP Spatial Distribution) of NOAA's Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead (Crawford and Rumsey 2009). For example, index areas would be established in the upper and lower halves of the weighted spawning area within each major spawning area.

Work Task 1C. Determine fish response to passage improvement

Work element name:	Install fish monitoring equipment
Work element title:	Install PIT Tag Interrogation System on Manastash Cr
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2013
Description: Install PIT tag interrogation system in Manastash cr at the current	

diversion barrier	
Work element name:	Mark/Tag Animals
Work element title:	PIT Tag migrating adult steelhead
Start date:	12/1/2010
End date:	5/30/2011
Duration :	2010 – 2017
Description: PIT tag 100% of migrating adult steelhead at Roza Dam	
Work element name:	Mark/Tag Animals
Work element title:	PIT tag juvenile *O.mykiss*
Start date:	8/1/2010
End date:	6/30/2011
Duration :	2010 – 2017
Description: Electro-shock and PIT tag 1000 juveniles in selected Manastash stream reaches	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Download data from Interrogation systems
Start date:	1/1/2011
End date:	12/31/2011
Duration :	2011 – 2017
Description: Download data from Interrogation systems as needed	
Work element name:	Analyze/Interpret data
Work element title:	Enumerate adult and juvenile steelhead and determine Tag history
Start date:	8/1/2013
End date:	10/1/2013
Duration :	2013 – 2017
Description: Enumerate adult steelhead escapement into watershed and juveniles leaving the system	

Background & Methods

Fish passage improvement actions are often conducted to expand the current distribution of fish resources in aquatic systems. However, rarely are passage improvement projects evaluated to quantify the benefits to fish populations. We propose to quantify the biological benefits of removing a fish passage barrier in Manastash Creek, Washington. Manastash Creek has had a long history of irrigation development that impeded fish passage with at least 44 irrigation diversions identified at one time, although the potential for fish production in the absence of passage barriers was noted (McIntosh et al. 1990). Recent projects (BPA project 199803400 and 200202500) have made negotiations and substantial progress re-establishing fish passage into Manastash creek. We propose to install a PIT tag array (or possibly acoustic array) at the current upstream diversion

barrier. Installation of a stationary PIT tag array at this time, (prior to completion of anadromous passage) will provide 1) estimates of anadromous production from RxR crosses prior to barrier removal (Work Task 5C), and timing and recolonization rates of anadromous steelhead in future years (Work Tasks 5A, 5B). One obvious objective of barrier removal projects is to establish habitat connectivity and to instigate anadromous re-colonization to previously underutilized habitats. We will have the ability to monitor recolonization rates when they occur. However, if recolonization does not occur during the lifespan of this project, the data collected on resident female x resident male matings will still provide critical information for other biological objectives (e.g. Biological Objective 5).

Biological Objective 2: Estimate juvenile and adult abundance for individual populations (RPA 50.6)

Scope

No direct spawner abundance estimates exist for all populations of Yakima steelhead. Stock status assessments used for recovery planning by the ICTRT relied on a combination of methods for apportioning Prosser Dam adult counts to individual populations (ICTRT In press). These included the use of a 1990-92 radio-tracking survey (Hockersmith et al. 1995), redd counts from Satus and Toppenish creeks and Roza Dam counts. Similar to spawner abundance, no direct smolt abundance estimates exist for individual populations. Estimates do exist for the MPG as a whole but are not considered reliable due to methods currently used for expanding enumerated smolts entrained at the Chandler Juvenile facility. Expanded estimates rely on daily flow and entrainment relationships, canal survival, and sampling rate coefficients estimated for spring Chinook. The degree of bias introduced by this substitution is not known, but may be significant (YSFWRB 2009).

Work Tasks under this object will provide necessary field work, sampling and analytical methods for estimating adult and juvenile abundance for individual populations in the Yakima MPG. Partitioning adult and juvenile abundance will rely on GSI techniques and assignment probabilities. To date, limited sampling of juveniles has been used for a preliminary GSI analysis and associated assignment probabilities. Further sampling and GSI analysis of adults and juveniles are needed before GSI work can be used for population abundance and productivity estimates. Confidence limits for adult and smolt production estimates (by population) will be estimated to document the precision of GSI work used for partitioning productivity among the populations (Work Task 2B) within the Yakima Basin MPG. We will conduct a power analysis of the applied reference genetic baseline to quantify assignment precision of steelhead smolts collected from the Chandler Collection Facility. Observed assignment bias for Yakima Basin steelhead populations (if present) will be used to enhance precision of genetic methods.
Work Tasks under this objective will also expand the flow entrainment study at Prosser Dam to include the estimation precision of total steelhead smolt production. Known assignment bias, total smolt production estimates, and a fixed sampling rate of steelhead smolts at Chandler will be used to generate confidence intervals bounding the estimation of smolt production by stock.

Work Task 2A. Refine, and complete Genetic Stock Identification (GSI) for individual Yakima steelhead populations to maximize assignment probability of juveniles and adults

Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Collect adult and juvenile genetic samples
Start date:	7/1/2010
End date:	6/1/2011
Duration :	2010-2011
Description: Collect genetic samples from Adults trapped at Prosser and juveniles trapped in tributaries with screw traps and electro-shocking	
Work element name:	Analyze/Interpret Data
Work element title:	GSI Yakima MPG
Start date:	7/1/2010
End date:	6/1/2011
Duration :	2010 – 2012
Description: Conduct genetic analysis to refine GSI of Yakima MPG	

Background & Methods

A critical requirement of genetic population assignment methods is a reference baseline. Two general issues influence assignment probabilities: 1) the completeness of the reference baseline (i.e., all source populations present); and 2) the accurate characterization of reference collection genetic diversity and their distinctiveness. All populations that could contribute to Yakima Basin smolt production are present in the reference baseline (Table 1), so the assignment probabilities will not be misleading due to absent source populations (Issue #1). While the Yakima MPG reference collections have statistically different allele frequencies (data not shown), they are genetically closely related. This genetic affinity may result in certain genotypes having similar "likelihoods" calculated for more than one reference collection, which may result in low assignment probabilities and/or incorrect estimation of origin (Issue #2). We show this genetic similarity in Figure 2, a factorial correspondence analysis (FCA) plot on allele frequencies for the Yakima steelhead baseline (SPAN-standardized microsatellite data) collections. In this FCA, the relationship between any two individuals in n-dimensional space (n = number of alleles) is represented by their χ^2 distance. In this plot, the ordination is not based on all n-dimensions, but rather the three orthogonal vectors that represent the three largest sources of variance (i.e., eigenvalues) derived from the weighted contingency table (contingency table is individuals X alleles). Additionally, each individual was not shown, but rather the collection centroids, which are the "centers of mass" for each collection.

To what degree does the genetic similarity affect assignment probabilities? While we cannot currently calculate a specific assignment error for each juvenile analyzed, we assessed potential assignment error using the Anderson et al. (2007) bootstrap resampling procedure implemented in ONCOR (Kalinowski et al. 2007). Replicated data sets

composed solely of simulated individuals from a single reference collection are assigned against a full reference baseline (i.e., 100% simulations). The degree to which simulated individuals assign back to their respective populations gives an indication of reference baseline power. The "% self assignment" column in Table 1 summarizes results for baseline collections. Self assignment was above 90% for all collections except three, 2007 Satus, 2008 Satus, and 2006 Ahtanum. While assignment power of the baseline appears promising, other sources of error must be evaluated and further baseline refinements should be made prior to application of the reference baseline.

Genetic samples from adults with known spawning locations will be incorporated into the GSI baseline. This will be done during the first year of the radio telemetry study by including genetic samples of adults successfully tracked to final tributary spawning location with documented spawning activity. Additional juvenile sampling conducted at tributary screw traps and/or electro-shocking may also be included when deemed appropriate for filling spatial data gaps for sample size of individual populations.

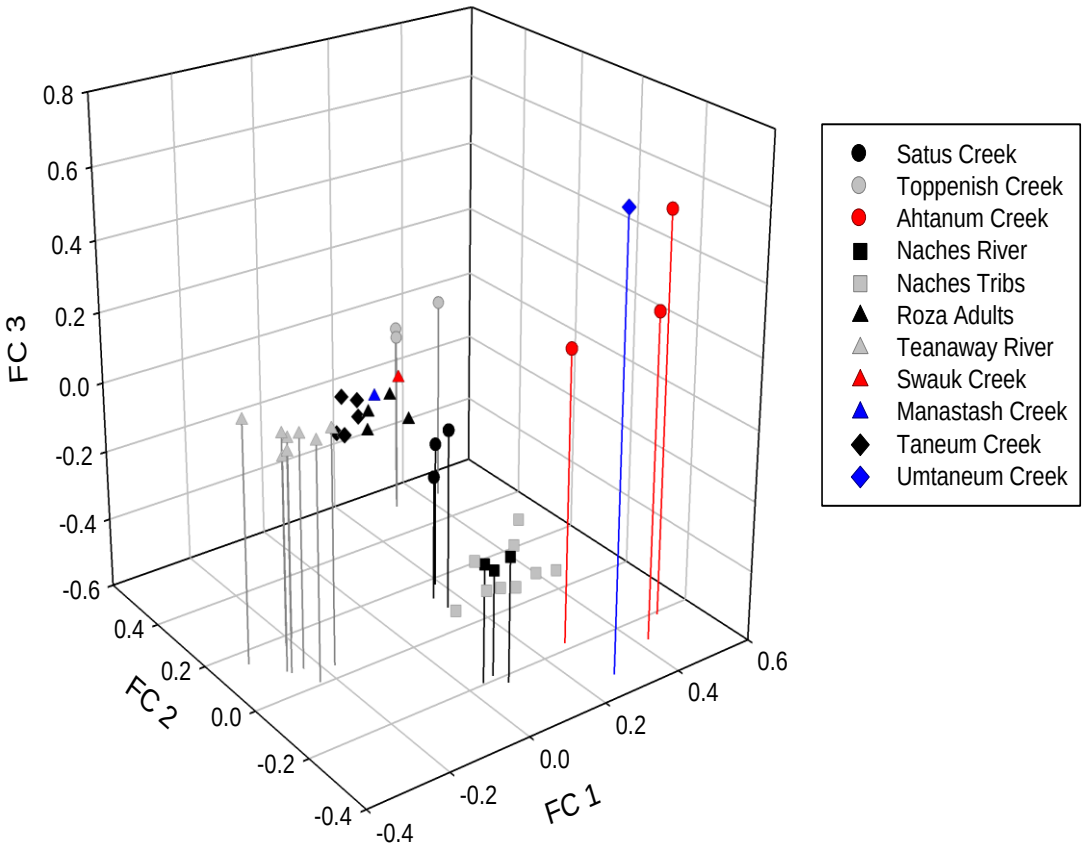

Figure 2. Factorial correspondence plot of collection centroids for Yakima Basin reference steelhead collections.

Table 1. Information for Yakima Basin steelhead collections used as genetic references. % self assign column corresponds to proportion of individuals from that collection which assign back to their respective MPG.

MPG	Location	Stage	Location (rkm)	Year	WDFW Code	N	% self assign
Satus	Satus	Smolt	2	2006	06KF	94	0.936
Satus	Satus	Smolt	2	2007	07MI	13	0.863
Satus	Satus	Smolt	2	2008	08KP	13	0.836
Toppenish	Toppenish	Smolt	48	2006	-	51	0.967
Toppenish	Toppenish	Smolt	48	2007	07MJ	48	0.973
Toppenish	Toppenish	Smolt	48	2008	08KQ	50	0.985
Naches	Ahtanum	Smolt	5	2001	01AX	76	0.980
Naches	Ahtanum	Smolt	5	2006	06KE	85	0.866
Naches	Ahtanum	Smolt	5	2008	08KO	16	0.969
Naches	Naches River	Smolt	30.8	2004	04BH	85	0.960
Naches	Naches River	Smolt	30.8	2005	05AZ	105	0.947
Naches	Naches River	Smolt	30.8	2006	-	55	0.972
Naches	Lil Rattlesnake Creek	Smolt		2005	-	36	0.936
Naches	Lil Rattlesnake Creek	Smolt		2008	-	10	0.902
Naches	Nile Creek	Smolt		2005	-	25	0.988
Naches	Nile Creek	Smolt		2008	-	34	0.928
Naches	Pileup Creek	Smolt		2005	-	15	0.949
Naches	Pileup Creek	Smolt		2008	-	5	0.998
Naches	Quartz Creek	Smolt		2005	-	18	0.997
Naches	Quartz Creek	Smolt		2008	-	8	0.935
Naches	NF Little Naches	Smolt		2008	-	21	0.990
Upper Yakima	Teanaway			2005	05ON	77	0.993
Upper Yakima	Teanaway	Smolt	0-8.2	Multiple	Multiple	80	0.987
Upper Yakima	Taneum	Smolt	6-22.0	2007	07KU	13	0.966
Upper Yakima	Teanaway	Resident	0-8.2	Multiple	Multiple	261	0.990
Upper Yakima	Manastash	Resident		2006	06DE	8	0.970
Upper Yakima	Swauk	Resident		2008	08AO	33	0.967
Upper Yakima	Taneum	Resident		Multiple	Multiple	96	0.984
Upper Yakima	Umtaneum	Resident	6-22.0	2008	08AO	21	0.907
Upper Yakima	Roza	Adult		2000	00AC	93	0.980
Upper Yakima	Roza	Adult		2001	01AV	93	0.920
Upper Yakima	Roza	Adult		2005	05AD	67	0.982
Upper Yakima	Roza	Adult		2006	06AC	65	0.979
Upper Yakima	Teanaway	Adult		Multiple	Multiple	130	0.991
Upper Yakima	Taneum	Adult		Multiple	Multiple	16	0.953
Skamania	Skamania H.	Adult	Reiter	2001	01GG	93	1.000
Skamania	Skamania H.	Adult	Skamania	2008	08CR	95	1.000

Work Task 2B. Improve entrainment rate calculations and smolt abundance estimates for steelhead juveniles at the Chandler Juvenile Monitoring Facility (located at Prosser Dam, rkm 75.6)

Work element name:	Mark/Tag Animals
Work element title:	PIT tag and release juvenile steelhead
Start date:	1/1/2011
End date:	6/15/2011
Duration :	2011-2017
PIT tag entrained juvenile steelhead at Chandler Juvenile Facility and release upstream for mark/recapture studies on a weekly basis	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Download PIT tag interrogation history from site locations
Start date:	6/15/2011
End date:	10/31/2011
Duration :	2011 – 2017
Description: Download data from local Interrogation system at Prosser and PTAGIS database for McNary Dam interrogations	
Work element name:	Analyze/Interpret Data
Work element title:	Build flow/entrainment model and estimate smolt abundance
Start date:	11/1/2011
End date:	4/30/2012
Duration :	2011 – 2017
Description: Build flow/entrainment model for juvenile steelhead using logistic regression analysis and generate smolt abundance estimate for Yakima MPG	

Background & Methods

Presently, project 199506325 includes tasks to subcontract with a biometrician to study flow/entrainment relationships and produce estimates of smolt passage at Prosser by stock. To date this work has focused on spring Chinook and coho resulting in an unknown proportion of steelhead smolts trapped daily throughout the migration period. Entrainment relationships are based on weekly mark recapture estimates of juveniles released upstream. The juvenile collection facility is located below the confluence of all Yakima River tributaries and steelhead populations, and therefore entrains smolts from all upstream populations. Methods for expanding daily smolt counts at the Chandler juvenile facility will use mark recapture methods from juvenile steelhead releases and flow entrainment models similar to those for spring Chinook and Coho provided in Task 1.e in Sampson et al. (2009). As an alternative to the tradition mark & recapture methods used for estimating entrainment rates, we are proposing a pilot study that would use acoustic tags and arrays to increase the precision of canal entrainment rates. Smolt entrainment models will provide a means for generating an outmigrating smolt abundance estimate for the Yakima River MPG while providing the basis for expanding

population specific juvenile abundance estimates needed to complete Work Tasks 2D, 3A, and 3B.

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Work Task 2C. Expand sampling at the Chandler juvenile monitoring facility to include a subsample of steelhead smolts and collection of any other appropriate data (e.g., measurements, scales, additional tagging, etc.)

Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Sub-sample juvenile steelhead for biological data
Start date:	1/1/2011
End date:	6/30/2011
Duration :	2011 – 2017
Description: Juvenile steelhead will be systematically subsampled for biological data including length, weight, scales and fin clip for DNA	

Duration/Timeline: Ongoing 05/01/2010 – 04/30/2017

Background & Methods

This work task is needed in direct support of work elements listed under 2D, 3A, and 3B. Presently, project 199506325 includes tasks to operate the Chandler juvenile monitoring facility for the majority of the winter and spring smolt migration period, generally from January through mid-July. This work task will expand these activities to include collecting data from an appropriate subsample of downstream migrating juvenile steelhead that are considered necessary to achieve biological objectives described herein. Subsample design and protocols will follow those used for spring Chinook sampling outlined in Neeley (2006). Total smolt production will then be apportioned to individual steelhead populations using DNA samples and GSI techniques as indicated in work task 2D.

Work Task 2D. Generate population-specific juvenile abundance estimates with Genetic Stock Identification (GSI) techniques

Work element name:	Analyze/Interpret Data
Work element title:	Apportion juvenile steelhead to individual populations
Start date:	8/1/2011
End date:	10/31/2011
Duration :	2011 – 2017
Description: Use Genetic Stock Identification(GSI) techniques to analyze genetic samples and assignment probabilities for apportioning smolts to individual populations	
Work element name:	Analyze/Interpret Data
Work element title:	Estimate smolt abundance for each steelhead population
Start date:	10/31/2011
End date:	4/30/2012
Duration :	2011 – 2017

Description: Estimate smolt abundance for each population by combining inividual population esimates and partition total smolt production accordingly

Background & Methods

Genetic methods provide a mechanism of apportioning smolts collected at the Chandler Facility to populations within the Yakima MPG. Fundamentally, the process compares an unknown-origin genotype against a set of reference populations (i.e., genetic baseline) and determines probabilistically the "likelihood" the genotype was derived from each reference population.

Population composition of mixed collections will be estimated using a partial Bayesian procedure based on the likelihood an unknown-origin genotypes derived from the baseline reference stocks/populations (see Table 1), given the allele frequencies for baseline stocks/populations. In brief, the MSA procedure is as follows. Within a mixture, we first generate the conditional probability of each genotype occurring in each reference population, based on the allele frequencies in the reference populations, using equation 10 of Rannala and Mountain (1997) (i.e., probability of the genotype, conditioned on the allele frequencies for each reference population). For each genotype in the mixture, we then calculate the probability (i.e., posterior probability) that the sample is from each reference population by taking the Rannala and Mountain (1997) conditional probability and multiplying it by a prior, and then dividing by a normalizing constant. Initially, the prior is uniform, 1/N, where N is the number of populations present in the reference baseline. The initial probability matrix provides information about the likely source population for each unknown individual, but more importantly, provides an estimate of which reference populations are contributing to the unknown mixture. If the reference populations do not contribute equally to the mixture, the initial use of a uniform prior can be improved. The mean probability for a reference baseline population in the mixture analyzed (i.e., mean posterior probability over all unknown individuals) is the estimated contribution of that reference population to the mixture. Therefore, the population composition of the mixture is represented by the mean posterior probabilities of all reference collections from the initial matrix. The newly gained information about the population composition of the mixture replaces the uniform prior during an additional round of probability estimation to generate a second probability matrix. Once again, the mean posterior probabilities that represent estimates of baseline population contributions to the mixture are used as new priors. This iterative refinement of the probability matrix continues until the mean posterior probabilities change less than a predefined threshold from round to round. This procedure results in the maximum likelihood solution for stock composition (Millar 1987). The stock composition point estimate is then reported as a summation of the individual stock assignments.

Assignment results (either mixture composition or individual assignments) will be partitioned by Yakima Basin MPG and not individual baseline populations. This reporting is accomplished by extracting the assignment data from the MSA and summing the final posterior probabilities over all reference populations within the MPG reporting group.

Work Task 2E. Extend Prosser Denil ladder sampling operations through spring migration period

Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Collect biological data on adult steelhead
Start date:	1/1/2011
End date:	5/31/2011
Duration :	2011 – 2017
Description: Sample migrating adult steelhead at Prosser Dam for length, weight, scales, Sex, DNA and external marks (including CWT and PIT tags)	
Work element name:	Mark/Tag animals
Work element title:	PIT tag adult steelhead
Start date:	7/1/2010
End date:	5/31/2011
Duration :	2010 – 2017
Description: PIT tag migrating adult steelhead caught in Denil trap at Prosser dam	

Background & Methods

Bio-sampling and enumeration of adult steelhead for the Yakima MPG aggregate occurs at three fish ladders located at Prosser dam (rkm 75.6). Prosser dam in itself is believed to be a migration barrier which required construction of River left, middle and right fishway ladders to allow upstream passage for migratory fish species. Migrating adults are enumerated either exclusively by video cameras located in all three fishways or by a combination of video cameras and adults trapped at the right bank denil trap.
Project 199506325 includes tasks to operate the Prosser right bank denil ladder and trap from early September through late November. Sampling includes documenting length, weight, sex, and marks (including CWT and PIT interrogation) for all fish captured. Operations also include taking scale and DNA samples on some or all of the fish using the trap. Trapping and bio-sampling of adult steelhead has coincided with trap operations focused on fall migration periods for fall Chinook and Coho. Incidentally, this has truncated, and limited the bio-sampling of adult steelhead to the initial 50-70% of the run. Temporal migration characteristics of Yakima River steelhead have demonstrated a bi-modal distribution, with peaks generally occurring in the late fall/early winter and late winter/early spring periods (Figure 3).

This work task will expand Prosser denil trapping operations and bio-sampling to include the spring migration period for steelhead (Jan.-May). Sampling across the entire migration period is necessary for differentiating temporal migration characteristics and life history traits of individual steelhead populations and also support the critical needs of work tasks 1A, 2A, 2B, 2F, and 3A.

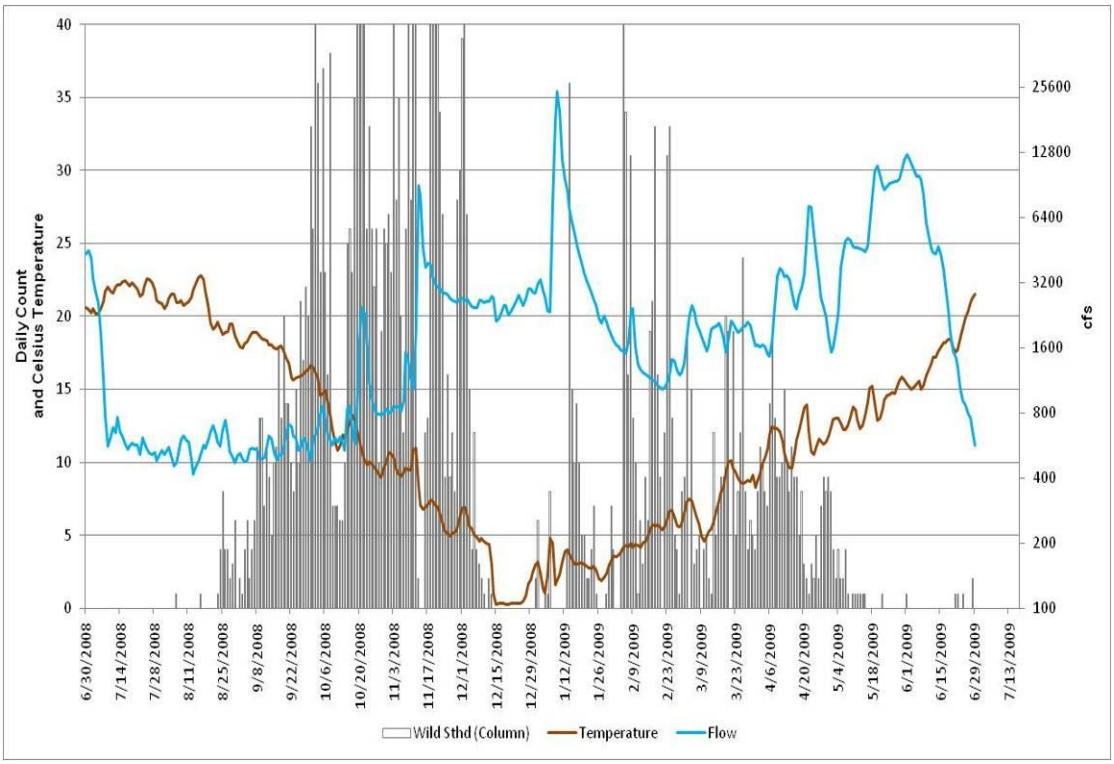

Figure 3. 2008-09 Yakima MPG Summer Steelhead run-timing through Lower Yakima River (Prosser Dam rkm 75.6)

Work Task 2F. Generate population-specific adult abundance estimates with Genetic Stock Identification (GSI) techniques and PIT tag interrogation histories

Work element name:	Analyze/Interpret Data
Work element title:	Generate prespawn population estimate
Start date:	7/1/2011
End date:	12/31/2011
Duration :	2011 – 2017
Description: Conduct analysis to expand adult GSI population partition to total MPG run at Prosser Dam	
Work element name:	Analyze/Interpret Data
Work element title:	Generate spawning population estimate
Start date:	7/1/2011
End date:	12/31/2011
Duration :	2010 – 2017
Description: Combine In-basin pre-spawn survival with Prosser Dam abundance estimates to generate spawner abundance estimates for each population	

Background & Methods

The primary objective of this work task is to use DNA information to disaggregate the adult counts (including video count periods) at Prosser Dam into population-specific

adult abundances. The unknown-origin adults interrogated at Prosser will be assigned to populations in Yakima Basin MPG using the reference genetic baseline (See Work Task 2A) and genetic mixed stock analysis (MSA) methods as described in Work Task 2D.

Abundance estimates of individual populations generated from disaggregating adult counts at Prosser dam will provide the basis for estimating spawner escapement. Estimates of pre-spawn mortality occurring after MPG disaggregation (Prosser Dam), but prior to spawn timing, will be used for adjusting Prosser Dam counts for spawner escapement estimates. Pre-spawn mortality will be estimated using two different methods for different time frames. Estimates for the first three years of the study will rely on data collected from the telemetry study (Work Task 1A). The second method will be needed for the post telemetry era using PIT-Tagged adults and interrogation histories at key locations in the basin (Work Task 3C). This approach meets the criteria for Method 1 escapement sampling design (Section 5.2.2 Adult Spawner Abundance Sampling Design) outlined in NOAA's Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead (Crawford and Rumsey 2009) and is consistent with their recommendation #5 (Section 3.4 Use a Master Sample Design To Integrate Stream Monitoring Programs).

This work task has secondary objectives that will leverage the adult assignment data. Population assignments for individual adults can be associated with measured adult phenotypic traits (Work Task 4B) to investigate whether phenotype and/or life history vary between populations. Another objective is to investigate the feasibility of using parentage analysis for steelhead passed above Roza Dam, as adults have been sampled at Roza Dam since 2002. Parentage information may contribute to a better understanding of population productivity and resident contribution to returning anadromous adults (Work Task 5C).

Biological Objective 3: Generate productivity estimates for individual populations
RPA 50.3, 50.6, 62.5

Scope
Population growth rate (productivity) and factors that affect population growth rate provide information on how well a population is performing in the habitats it occupies during the life cycle (McElhany et al. 2000) and is an important parameter commonly used in population viability analysis (PVAs). Partitioning productivity by life-stage provides a means for explaining shifts and trends in a population's productivity by isolating temporal and spatial characteristics of the environment ultimately affecting survival. Stage specific survival estimates can also assist direct measures of a population's productivity. For example, incorporating SAR results into population productivity estimates can be a powerful tool in reducing uncertainties due to high variations in marine survivals (Cooney, 2008).

Work Tasks under this objective will analyze data collected under numerous objectives for the purpose of generating smolt-to-adult return rates, adult to adult productivity, and freshwater productivity for individual populations. Precision of these work tasks will

rely on the quality and precision of data collected to generate abundance estimates for juveniles and adults.

Work Task 3A. Generate population-specific adult to adult productivity estimates

Work element name:	Analyze/Interpret Data
Work element title:	Estimate run escapement productivity
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Estimate adult to adult cohort productivity annually for each population. This will be done using run escapement and populaton specific age composition	
Work element name:	Analyze/Interpret Data
Work element title:	Estimate spawner escapement productivity
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Estimate adult to adult cohort productivity annually for each population. This will be done using spawner escapement estimates and population specific age composition	

Background & Methods

Adult to adult annual productivity can be estimated by several different methods depending on the type and quality of data available. Perhaps the easiest and most recognized method for determining a population's productivity is the number of returning spawners produced by a given number spawners of a specified brood year (adult to adult ratio). A time series of annual adult to adult estimates can be used to generate a population's geometric mean and associated variance. Information needed for generating this type of productivity estimate includes spawner abundance, age composition (needed for cohort tracking), sex ratios, and where applicable, proportion of hatchery-origin spawners on the natural spawning grounds (pHOS). Other methods that are commonly used for generating intrinsic productivity estimates rely on density dependent recruitment dynamics such as Beverton-Holt or Ricker recruitment models. In addition to the demographic data needs for producing adult to adult ratios, this method requires a total adult recruitment estimate consisting of spawner escapement, the number of fish harvested, and attrition losses from mainstem dams, predation or any other extrinsic factors. Both methods have merit, and will be evaluated for estimating productivity estimates for each population. The precision of each method will depend on the quality of data available for the analysis.

Expanded Denil trapping operations (Work Task 2E) will provide adequate adult sampling of genetic and demographic data needed for both types of analysis. Estimates of spawner abundance for each population will rely on GSI methods outlined in Work Task 2F. Adults will be sexed using ultrasound methods and sampled for scales needed for cohort analysis throughout the adult migration period. Several methods will be evaluated for estimating total adult recruitment prior to harvest and dam mortality. These

might include, but not limited to, the use of harvest estimates (incidental sport and treaty harvest) and dam mortality of A-run steelhead by US *v*. Oregon TAC, and/or adult PIT-tag detections at dam locations. Using adult PIT-tag detections may provide the best means for computing total recruitment barring a few potential constraints. Dividing PIT-tag detections at Prosser Dam by the number of detections at Bonneville Dam plus lower river incidental harvest mortality can provide a means for expanding the adult counts at Prosser to a total recruitment estimate, which can be expressed as:

$$R_t = A_p/(D_p/((D_b/DE_b)/(1-H_i))) \qquad \textit{Equation 1.}$$

Where:
R_t = Total recruitment
A_p = Adult abundance at Prosser dam
D_p = Number of PIT-tag detections at Prosser Dam
D_b = Number of PIT-tag detections at Bonneville Dam
DE_b = Detection efficiency at Bonneville Dam
H_i = Incidental harvest occurring below Bonneville Dam

Since the Yakima basin does not artificially propagate steelhead for either conservation or harvest augmentation purposes, estimating the proportion of hatchery origin fish is not applicable for generating productivity estimates for Yakima steelhead populations. Out-of-Basin hatchery strays do however; comprise roughly 3% (1999-2007) of the total steelhead run counted at Prosser dam. If the proportion of hatchery strays increase to a point where some natural production contribution is realized, adjustments in adult and juvenile productivity calculations may be deemed necessary to account for the artificial contribution.

Work Task 3B. Generate population-specific juvenile productivity estimates

Work element name:	Analyze/Interpret Data
Work element title:	Estimate freshwater productivity for Toppenish Cr population
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Conduct analysis to estimate freshwater productivity of Toppenish Cr population using screw trap data collected under Project 199603501	
Work element name:	Analyze/Interpret Data
Work element title:	Estimate freshwater productivity for Yakima MPG populations
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Conduct analysis to estimate freshwater productivity for MPG populations using smolt abundance estimates collected from Chandler Juvenile Facility	

Background & Methods

A population's freshwater productivity can be measured by the number of smolts produced per redd. Information needed to generate estimates of freshwater productivity requires abundance estimates for spawners and juvenile outmigrants, adult sex ratios, and freshwater age structures for apportioning smolts to brood year cohorts. Work Tasks 2A -2F will provide all the above necessary information for generating annual estimates of smolts per spawner. This work task will also generate confidence limits on smolt production estimates (by population) to document the precision of partitioning productivity among the Yakima MPG populations. Efficacy of the genetic methods to determine stock-of-origin for steelhead smolts collected from the Chandler Collection Facility will be investigated using a power analysis. Both the assignment capabilities of the reference baseline (i.e., origin known) and the confidence in assignments (i.e., assignment known) will be documented. Observed assignment bias for Yakima Basin steelhead populations (if present) will be used to enhance precision of genetic methods. The project will also expand the flow entrainment study at Prosser Dam to include the estimation precision of total steelhead smolt production. Known assignment bias, total smolt production estimates, and a fixed sampling rate of steelhead smolts at Chandler will be used to generate confidence intervals bounding the estimation of smolt production by stock.

Work Task 3C. Estimate In-river migration survival and Smolt-to-adult return rates (SARs)

Work element name:	Install fish monitoring equipment
Work element title:	Install PIT Tag Interrogation systems at mouths of selected Tributaries
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2010-2012
Description: Install PIT tag interrogation system at the mouths of Satus, Toppenish, and Naches Rivers	
Work element name:	Mark/Tag Animals
Work element title:	PIT Tag migrating adult steelhead
Start date:	8/1/2010
End date:	5/30/2011
Duration :	2013 – 2017
Description: PIT tag migrating adult steelhead using denil trap at Prosser Dam	
Work element name:	Mark/Tag Animals
Work element title:	PIT tag juvenile *O.mykiss*
Start date:	1/1/2011
End date:	6/30/2011
Duration :	2011 – 2017
Description: PIT tag juvenile O.mykiss within selected tributaries and at Chandler Juvenile Monitoring Facility	
Work element name:	Collect/Generate/Validate Field and Lab Data

Work element title:	Download data from Interrogation systems
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Download data from Interrogation systems as needed from remote site locations and PTAGIS	
Work element name:	Analyze/Interpret data
Work element title:	Estimate juvenile migration survival rates
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Estimate juvenile outmigration survival from tagging sites in tributaries to Prosser and McNary Dams, and from tagging at Prosser to McNary dam	
Work element name:	Analyze/Interpret data
Work element title:	Estimate adult migration survival and SARs
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Estimate pre spawn mortality and SARs from juvenile and adult detection histories at selected PIT tag array locations	

Background & Methods

This work task will generate in-basin survival estimates for transient rearing juveniles, out-migrating smolts, and pre spawn holding adults. Smolt-to-adult survival will also be estimated from smolts tagged at key locations in the basin. In addition to the sites listed under Work Task 1C and 5A, either PIT or Acoustic tag arrays will be installed at, or near the mouths of Satus Cr., Toppenish Cr., Naches River, and possibly the Yakima River above Roza Dam. Redd counts may not provide reliable estimates of spawner escapement in watersheds where high flows and turbidity conditions limit visibility and frequency of surveying. Some watersheds present surveying problems in mainstem areas for similar reasons. However, permanent PIT tag arrays situated at tributary mouths can be used to detect movements and minimum spatial distribution of adult (and juvenile) migrants. Long term PIT tag data collection at the mouth of tributary streams will, at a minimum, provide tributary specific abundance trend data, and potentially, abundance and productivity information for individual tributaries. The radio tracking data associated with this proposal will provide data to correct tributary PIT tag adult counts for prespawn mortality and to estimate adult spawner abundance in tributary streams.

<u>Biological Objective 4:</u> Characterize and differentiate phenotypic and genotypic life-history traits within and among Yakima steelhead populations

Scope

A population's viability and long-term persistence strongly depends on its ability to withstand environmental perturbations and changes caused by either natural or anthropogenic induced factors. Diversity allows a species to use a wider array of

environments than they could without it (McElhany et al 2000), and populations exhibiting greater diversity are generally more resilient to these environment changes in the short and long term (ICTRT 2007b). A population's diversity comprises a broad range of phenotypic life history traits and underlying genetic diversity. Characterizing and understanding these traits within and among populations will provide the framework for recovery planners to build more explicit recovery criteria for the diversity component of the VSP framework (YSFWRB 2009). Furthermore, this type of information should be considered essential for understanding temporal and spatial linkages between a population's life history traits, and the habitat types utilized by them.

Our current understanding of life history traits within and among Yakima steelhead populations is limited due to partial sampling, site locations, and analytical techniques (or lack thereof). Work conducted under this biological objective will focus on analyzing biological data collected under work tasks 1A, 2A, 2C, 2E and project 199603501 to not only characterize and differentiate life history traits within and among populations, but to further our understanding of the extent and role of phenotypic and genetic diversity exhibited by individual populations. Life history information will contribute to assessing an overall risk rating for the spatial structure and diversity VSP parameters by providing data needed for assessing individual metrics in NOAA's hierarchical format as outlined the document Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs (ICTRT 2007b).

Work Task 4A. Synthesis and analyze biological data collected on juveniles and adults sampled at the chandler juvenile facility, Prosser and Roza dams, and other site locations. (Phenotypic and life history trait analysis)

Work element name:	Analyze/Interpret Data
Work element title:	Analyze biological data sampled from adult and juveniles
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2010 – 2017
Description: Analyze biological data collected from sampled taken from juveniles and adults to determine population life history traits including age composition, sex ratios,	
Work element name:	Analyze/Interpret Data
Work element title:	Analyze temporal data collected on adults and juveniles
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2010 – 2017
Description: Analyze temporal life history traits of populations including adult migration and spawn timing, and juvenile rearing and outmigration timing	

Background & Methods

Expanded sampling protocols, time frames, locations and analytical techniques (Work Tasks 1A, 2A, 2C, 2E, and project 199603501) are expected to provide sufficient data for analyzing life history traits for individual populations. Adult sampling throughout the

migration period (Work Element 2E) combined with GSI techniques (Work Element 2A) will be used for estimating adult migration timing, age structures (including iteroparity rates), length at age, and sex ratios for individual populations. Rigorous statistical analysis will test for significant differences (among populations) and temporal variance (within and among populations) of life history traits.

Methods and data time series available for computing spawn timing have varied across populations. Spawner surveys have been the primary means of estimating spawn timing, having been intermittent for the Naches and Upper Yakima populations. Future estimates of spawn-timing will continue to use information derived from spawner surveys for Toppenish and Satus Cr populations covered under project 199603501, and spawner surveys covered under Work tasks 1B and 5B for the Naches and Upper Yakima populations.

Outmigration timing, age composition, length at age, and condition factor of smolts will be estimated for individual populations based on juveniles sampled and partitioned at the Chandler Juvenile Facility (Work Element 2A & 2C). Rigorous statistical analysis will test for significant differences (among populations) and temporal variance (within and among populations) of life history traits.

Juveniles will also be sampled and PIT-tagged from screw traps located within natal tributaries including Satus, Toppenish, Ahtanum (project 199603501) and potentially the Naches and Upper Yakima (Work Element 5A). Interrogation histories from juveniles detected at tributary mouths (Work tasks 1C & 3C), Prosser Dam (rkm 75.6), and mainstem Dams (i.e. McNary Dam) will be used to evaluate temporal and spatial rearing life history patterns exhibited within and among populations. As an example, 1986-1989 juvenile trapping operations at Wapatox Dam (Naches River, rkm 27.5) observed two distinct migration periods for both spring Chinook and *O.mykiss* juveniles. In addition to the spring outmigration period commonly observed for smolting juveniles, a late fall/early winter migration was observed for transient rearing juveniles that presumably overwintered in mainstem floodplain reaches before smolting the following spring (Joel Hubble, Personal communication). Quantifying juvenile life history traits and temporal/spatial rearing patterns is an essential first step for understanding complex relationships between a population's freshwater productivity and the habitats they reside in.

Work Task 4B. Synthesis and analyze genetic data collected on juveniles and adults sampled at the chandler juvenile facility, Prosser and Roza dams, and other site locations. (Genetic Diversity analysis)

Work element name:	Analyze/Interpret Data
Work element title:	Analyze genetic data collected on juveniles and adults
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Conduct genetic diversity analysis using standard metrics for documenting and	

comparing within populaton genetic diversity

Methods

In coordination with work element 4A, life history diversity information (by population) will be associated with investigation of genetic diversity and differentiation. Standard diversity metrics will be used to document and compare within-population genetic diversity (e.gs, allelic richness, heterozygosity, genetic equilibrium). Population genetics methods will be used to compare the degree to which Yakima Basin steelhead are differentiated. Among-population comparisons will be made at the MGP level, and any additional hierarchical levels justified by observable life history differences. Standard metrics will be used including (but not limited to) allele frequency differences (i.e., genetic tests), F-statistics (ANOVA framework), and factorial correspondence analysis.

<u>Biological Objective 5:</u> Evaluate sympatric population dynamics and the effects on population viability between resident and anadromous forms of *O. mykiss*

RPA 50.3, 50.6

Scope

The Yakima Basin Sub-basin plan (Yakima Subbasin Fish and Wildlife Planning Board 2004) identified several key uncertainties and prioritized research needs consistent with steelhead recovery in the Yakima Basin. In 2009 a final draft of the Yakima Steelhead Recovery Plan was developed that addressed key uncertainties associated with steelhead recovery in the Yakima MPG (Yakima Subbasin Fish and Wildlife Planning Board 2009). One key uncertainty identified is the relationship between resident and anadromous life histories present in the basin. This is particularly important in the Upper Yakima River because it supports a robust resident population (Temple et al. 2009) exhibiting some hatchery introgression (Campton and Johnston 1985) and the resident and anadromous forms are known to interbreed (Pearsons et al. 2007; Blankenship et al. 2009). The interplay between the resident and anadromous forms of *O. mykiss* deserves attention because it is poorly understood and there is a strong potential for the resident form to either contribute to, or to limit recovery of the anadromous form (Allendorf et al. 2001; Thrower et al. 2004). In addition, the interplay between the forms has the potential to confound evaluation of population level productivity, spatial structure, and diversity of the anadromous form. The interactions between forms should certainly be considered in population viability analysis (ISAB 2005).

Work Task 5A. Install PIT-Tag arrays and expand juvenile PIT tagging in Upper Yakima

Work element name:	Install fish monitoring equipment
Work element title:	Install PIT Tag Interrogation System on Upper Yakima selected Tributaries
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2010-2012
Description: Install PIT tag interrogation system in selected tributaries at key locations	

Work element name:	Mark/Tag Animals
Work element title:	PIT tag juvenile *O.mykiss*
Start date:	8/1/2010
End date:	5/31/2011
Duration :	2011 – 2017
Description: Electro-shock and PIT tag 1000 juveniles in each selected tributary	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Collect biological data on juveniles
Start date:	8/1/2011
End date:	5/31/2012
Duration :	2011 – 2017
Description: Collect biological on O.mykiss juveniles including DNA, length, scales, weight and sex	
Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Download data from Interrogation systems
Start date:	8/1/2011
End date:	5/31/2012
Duration :	2011 – 2017
Description: Download data from Interrogation systems as needed	
Work element name:	Analyze/Interpret data
Work element title:	Juvenile abundance and demographic analysis
Start date:	7/1/2011
End date:	6/31/2012
Duration :	2011 – 2017
Description: Estimate juvenile abundance and conduct demographic analysis from biological data collected from juveniles	

Background & Methods

Understanding how the resident form of *O. mykiss* acts as a source or a sink to recovery of the anadromous form in the Upper Yakima River will be a difficult task. However, recent advances in genetic evaluations and in tagging technology can be combined to provide a viable means to understanding the relationship. We propose to install passive integrated transponder (PIT) tag detectors in important anadromous steelhead spawning tributaries as identified in Karp et al. (2009) and will be confirmed with the radio tracking component of this proposed research. We propose to install PIT tag arrays at the mouth of Swauk creek, the Mainstem Teanaway River, and the North Fork Teanaway River. In addition, a PIT tag array is scheduled to be installed near the mouth of Taneum Creek in the spring of 2010 (funded by the U. S. Bureau of Reclamation). Thus, the major tributaries used by anadromous adults will have PIT tag detection capability for both adults and juveniles. Approximately 50% of the anadromous spawning in the upper

Yakima Basin occur in these streams (Karp et al. 2009), with the majority of tributary spawning occurring in the Teanaway Basin.

Rearing juvenile abundance will be estimated in established tributary index monitoring sites following the protocols recommended in NOAA's Guidance for Monitoring Recovery of Pacific Northwest Salmon and Steelhead (Crawford and Rumsey 2009) and detailed by Temple and Pearsons (2006; 2007). Briefly, rearing juvenile abundance will be collected under existing collaborative projects (YKFP) following the mark-recapture electrofishing methods detailed in Temple and Pearsons (2006; 2007). Rearing juvenile fish will be PIT-tagged; a genetic sample (e.g. fin clip) will be collected, and released unharmed near their point of capture. Our target will be to sample 1000 rearing O. mykiss in each tributary stream. Previous experience indicates this is a realistic number of rearing fish to tag (WDFW unpublished data). Migrants will be monitored in subsequent years either as recaptures in future electrofishing samples, or when detected at mainstem dams as migrants. The juvenile genetic samples will be banked for future analysis and will be analyzed if a sample becomes known to be anadromous (e.g. detections at main stem dams) or resident (e.g. recaptured in subsequent years in spawning condition). Fish of known origin (e.g. location and life history type) will have genetic samples processed and combined to the genetic baseline.

Work Task 5B. Estimate the distribution, spawn timing and mating behavior of steelhead and Resident trout spawning in the Upper Yakima River

Work element name:	Collect/Generate/Validate Field and Lab Data
Work element title:	Conduct spawner surveys
Start date:	3/1/2011
End date:	6/30/2011
Duration :	2011 – 2017
Description: Conduct spawner surveys in upper Yakima for estimating spatial distribution and spawning interactions between resident and anadromous *O.mykiss*	
Work element name:	Analyze/Interpret Data
Work element title:	Spatial structure and spawner interaction analysis
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Determine spatial structure of upper Yakima population and evaluate mating behavior between Resident and anadromous *O.mykiss*	
Work element name:	Analyze/Interpret data
Work element title:	Juvenile life history analysis
Start date:	7/1/2012
End date:	6/30/2013
Duration :	2012 – 2017
Description: Evaluate Interrogation history from Upper Yakima PIT tag arrays and conduct a spatial and temporal life history analysis of *O.mykiss*	

Background & Methods

Steelhead that spawn in the upper Yakima Basin (upstream of Roza Dam) comprise less than 10% of the total return to the Basin. Due to the low abundance few steelhead are expected to be radio-tagged (Work Task 1A) and alternate methods are needed to better understand the distribution of this population. A total census of steelhead migrating over Roza Dam (project 199506325) provides excellent information on abundance and demographic data (sex, age, size). The entire population can be PIT- tagged and some additional fish radio tagged if deemed necessary. This work task will Collect and analyze data from PIT tag antenna arrays installed on selected tributaries (Work Task 1C and 5A) in the upper Yakima Basin to increase our knowledge of the spatial and temporal distribution of steelhead and resident trout spawning upstream of Roza Dam. Spawner surveys will be conducted to observe the spawning interactions and mating schemes between resident and anadromous forms of *O.mykiss*. While the abundance of the upper Yakima Basin steelhead population is the lowest in the MPG, the resident population in the largest. The influence of the resident population on the anadromous population is unknown and a major data gap. Ongoing activities in the upper Yakima River focused on rainbow trout (project 199506325) provide an opportunity to PIT tag a large number of fish annually and evaluate spatial and temporal overlap between the two segments of the population. PIT tag arrays deployed in this population can be used in long term monitoring of steelhead distribution that is simply not possible with radio tags. Arrays may also be used in conjunction with other ongoing studies focused on spring Chinook and coho salmon.

Work Task 5C. Determine relative production of anadromous life-history type from both fidelity and hybrid crosses of anadromous and resident O.mykiss

Work element name:	Analyze/Interpret Data
Work element title:	Parent/progeny analysis for Upper Yakima population I
Start date:	7/1/2011
End date:	6/30/2012
Duration :	2011 – 2017
Description: Conduct parentage analysis using adult and juvenile samples to determine relative anadromous production of Sympatric population of *O.mykiss*	
Work element name:	Analyze/Interpret Data
Work element title:	Parent/progeny analysis for Upper Yakima population II
Start date:	7/1/2012
End date:	6/30/2013
Duration :	2012 – 2017
Description: Conduct parentage analysis using adult samples to determine adult contribution from resident and anadromous origins and population productivity	

Background & Methods

To determine the base level of smolt production from resident x resident crosses, we propose to PIT tag rearing juvenile O. mykiss in areas known to have little anadromous adults spawning. The lack of anadromous input ensures any migrants detected at downstream locations were offspring of purely resident matings. In a previous radio tracking study, no steelhead migrated upstream from Easton dam near the town of Easton, Washington (Karp, et al. 2009), or into Manastash creek near the town of Ellensburg, Washington. We propose to collect and PIT tag 1000 juvenile *O. mykiss* rearing in the Yakima River upstream from Easton dam, and an additional 1000 in Manastash creek. These two locations represent main stem Yakima River and Yakima tributary habitats and will provide data related to the proportion of migrants produced from resident crosses in the main stem and from a tributary stream. Fish will be collected using electrofishing methods detailed in Temple and Pearsons (2007), PIT tagged, genetically sampled (e.g. fin clip) as described above, and released unharmed near their point of capture. The proportion of anadromous offspring collected from resident crosses will provide information on how the resident component of the population should be viewed in terms of population viability.

An additional genetic analysis may be used to determine the relative anadromous production from the four potential breeding crosses of resident and anadromous forms of *O.mykiss* (A_f x A_m, A_f x R_m, R_f x R_m, R_f x A_m). This will be accomplished with a parentage analysis using samples from adults collected at Roza dam (census sampling) and juvenile samples collected in the tributaries (Work Task 5A). To ensure juveniles expressing the anadromous life history are used for the analysis, samples from outmigrating juveniles detected at downstream locations (i.e. Prosser and McNary Dams) will be selected from the pool of samples. It is anticipated the number of juveniles PIT tagged (Work Task 5A) in the tributaries will produce a sufficient sample size for the analysis. Presence or absence of anadromy from maternal and paternal origins will indicate one of four breeding crosses. This information will provide the basis for determining the relative production of each across the total samples used in the analysis. In addition, a parentage analysis may be used to estimate adult contribution from both forms and population productivity. However, this type of analysis may be compromised if spawning occurs below Roza Dam, thus limiting the sampling of the population. This type of analysis will be considered after the spatial structure has been determined (Work Task 1A), and is deemed feasible.

Work Task 5D. O. mykiss Life History Model Development

Work element name:	Analyze/Interpret Data
Work element title:	*O.mykiss* life history model development
Start date:	7/1/2010
End date:	6/30/2011
Duration :	2010 – 2017
Description: Continue developing sympatric life history model for generating and testing hypothesis and conducting viability analysis for Sympatric populations of *O.mykiss*	

Background & Methods

Sympatric population dynamics between anadromous and resident forms of *O.mykiss* are not well understood. In particular, little has been done in quantifying the function of resident *O.mykiss* in determining the viability of the anadromous form. Currently, NOAA's viability analysis and recovery criteria (YSFWRB 2009) are based solely on the anadromous form (distinct population segment) for all four Yakima steelhead populations. Spawning interactions between the two forms have commonly been observed in two of the four populations (Naches and Upper Yakima). Spawning interactions resulting in varied offspring production from different breeding crosses should be used for assessing abundance and productivity viability criteria. In addition to abundance and productivity, other viability metrics should be considered such as: 1) the ability of one ecotype to maintain spatial structure and diversity in absence of the other and 2) the ability of one life history type to successfully re-populate the other life history type if extinction were to occur.

A sympatric life cycle model has been constructed by the YKFP and Cramer Fish Sciences to identify the survival and productivity tradeoffs that dictate the balance of residency and anadromy in a sympatric fish population. This model has provided a tool for generating hypotheses and conducting pilot viability model runs for the upper Yakima sympatric population. This work task will further develop this model and provide the basis for future viability analyses. The current model can be found at: http://www.fishsciences.net/projects/yakima.

G. Facilities and equipment

This project will maximize existing project infrastructure and investments in the Yakima Basin (see project 199606325). Anadromous salmonids in the Yakima Subbasin can probably be monitored more thoroughly than in any other river in the Pacific Northwest. Full implementation of this project will increase monitoring power even further. All steelhead can be enumerated via video monitoring at Prosser Dam in the lower Yakima, as well as Roza Dam on the middle Yakima. A subset of the MPG can be monitored extensively using the Prosser adult right bank denil ladder and trapping facility and the entire upper Yakima population can be sampled at the Roza Dam adult monitoring facility. These trapping facilities allow detection of previously marked fish, sampling for biological and genetics data, and additional tagging (e.g., for radio telemetry RM&E efforts). Stock-specific counts of migrating smolts can be made at the Chandler Juvenile Monitoring Facility (also located at Prosser Dam), which is equipped with two PIT-tag detectors. Automatic PIT tag detection is now possible at Prosser and Roza Dams for migrating adults as well, as tag detection installations were completed at these installations in recent years.

We propose to install passive integrated transponder (PIT) tag detectors in important anadromous steelhead spawning tributaries in the upper Yakima River as identified in Karp et al. (2009) and will be confirmed with the radio tracking component of this proposed research. We propose to install PIT tag arrays at the mouth of Swauk creek, the West and North Forks of the Teanaway River, and Manastash Creek. In addition, a PIT tag array is scheduled to be installed near the mouth of Taneum Creek in the spring of

2010 (funded by the U. S. Bureau of Reclamation), and one will be installed in the lower reaches of the Main stem Teanaway River under a collaborative project (YKFP). Thus, the major tributaries used by anadromous steelhead adults will have PIT tag detection capability for both adults and juveniles. Approximately 50% of the anadromous spawning in the upper Yakima Basin occur in these streams (Karp et al. 2009), with the majority of tributary spawning occurring in the Teanaway Basin. The additional array installed in Manastash Creek near the town of Ellensburg, Washington will be used to evaluate anadromous production from resident X resident matings, and anadromous recolonization from passive improvement projects.

Project management personnel work out of the YKFP's Central Office in Toppenish, the WDFW regional office in Yakima, WDFW central offices in Olympia, the Nelson Springs Office and Research Facility northeast of Yakima, and satellite offices in Ellensburg and Cle Elum. The Nelson Springs office also serves as the central facility for Project data base management equipment and personnel.

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I. Key personnel

Key project personnel for this proposal are listed in Table 2. Other project personnel are identified under the YKFP M&E (199506325), Hatchery O&M (199713025) and Data, Management, and Habitat (198812025) proposals.

Table 2. Key project personnel and project-related duties.

Name	Title	Duties
David Fast	Senior Research Scientist YN	YN technical lead; *participation covered under 198812025 YKFP Management, Data, and Habitat
Andrew Murdoch	Research Scientist WDFW	WDFW technical lead; *participation covered under 199506425 WDFW Policy/technical involvement in YKFP
Scott Blankenship	Research Scientist WDFW	Lead geneticist
Gabriel Temple	Fisheries Biologist WDFW	Scientist
Christopher Johnson	Fisheries Biologist WDFW	Scientist
Anthony Fritts	Fisheries Biologist WDFW	Scientist
Chris Frederiksen	Biologist	Research Scientist
Doug Neeley	Consultant	Biometrician
Mark Johnston	Research Scientist YN	Lead field biologist