Yakima Steelhead VSP Project

Yakima River Steelhead Population Status and Trends Monitoring

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Table of Contents

List of Figures

List of Tables

Executive Summary

This project expands research, monitoring, and evaluation (RM&E) activities conducted by the co-managers in the Yakima Basin (Yakama Nation and Washington Department of Fish and Wildlife-WDFW) to better evaluate viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity) for Yakima River steelhead (*Oncorhynchus mykiss*) populations. It was developed to fill critical monitoring gaps identified in the 2009 Columbia Basin monitoring strategy review and the FCRPS Biological Opinion reasonable and prudent alternative (RPA) review. Using information developed from this project (including the companion component monitoring resident/anadromous interactions) as well as the restoration and research, monitoring and evaluation work of several related projects (1995-063-25, 2008-458-00, 2007-401-00, 1997-051-00, 1996-035-01, and 1997-013-25), this report provides the latest status and trend information with respect to Yakima River Basin steelhead VSP metrics relative to data collected by the Yakama Nation.

The Yakima River steelhead major population group (MPG) is believed to consist of four individual, genetically unique populations spawning in the following areas: the Upper Yakima River consisting of the mainstem and all tributaries above the confluence with the Naches River; the Naches River system including Ahtanum Creek and Yakima Mainstem extending from the confluence of the Naches down to Toppenish Creek; Toppenish Creek; and Satus Creek. Adult population and productivity metrics for the Yakima River steelhead MPG are trending upwards. For the most recent five steelhead run years (June 30, 2008 to July 1, 2013) mean annual abundance was 5,521 steelhead for the MPG (average abundance at Prosser Dam) and 317 steelhead for the proportion of the Upper Yakima population spawning above Roza Dam (average abundance at Roza Dam). This compares to average annual abundance estimates of about 1,400 steelhead for the MPG and fewer than 25 steelhead spawning above Roza Dam in the 1980s and 1990s. Data also indicate that Yakima River MPG steelhead are experiencing improved survival relative to other steelhead streams above Bonneville Dam over and above survival increases due to common freshwater and marine conditions. Habitat restoration actions in the Yakima River Basin (see 1997-051-00, 1996-035-01, and Yakima Basin Fish and Wildlife Recovery Board summary), the Yakima kelt reconditioning program (see 2008-458-00 and 2007-401-00), as well as ongoing efforts to improve fish passage (see Yakima River Basin Water Enhancement Project) and limiting factors in the Yakima Subbasin (see Yakima Basin Fish and Wildlife Recovery Board) may partially explain these results.

Juvenile abundance and productivity metrics are generally positive at the MPG level, but these metrics are not as reliable as adult metrics due to uncertainties and complexities involved with estimating total juvenile abundance from relatively small samples of juvenile outmigrants. Redd survey and passive integrated transponder (PIT) detection data indicate that steelhead are fairly broadly distributed spatially throughout most known steelhead streams in the Yakima River Basin. Evaluation of data from adult sampling at Prosser and Roza Dams demonstrate that, on average, about 70% of the adult steelhead returning to the Yakima Basin are female. The vast majority (about 95%) of MPG steelhead returning to the Yakima River Basin are in the "Group A" size management range (< 78cm fork length) which is used for fishery management purposes in the Columbia River Basin.

We are still compiling and evaluating age-at-migration and age-at-return information; more complete presentations and analyses using these data will be available in subsequent annual reports.

Although annual adult abundance of Yakima River steelhead at the MPG level can be estimated fairly reliably using Prosser Dam counts, there is a need for spawner abundance estimates for individual populations. In accordance with RPA 50.6 (Improve Fish Population Status Monitoring), this project is conducting a three year telemetry study that will provide spawner abundance estimates for each Yakima MPG steelhead population (preliminary results from the first year of this study are provided in Appendix B). The 3-year study will also test and validate the efficacy of other proposed adult abundance monitoring methods needed for long-term status and trends monitoring including genetic stock identification (GSI) and the installation and management of PIT arrays to detect fish returning to specific tributaries. This project will also provide necessary field work, sampling, and analytical methods for estimating juvenile abundance for individual populations in the Yakima MPG using GSI techniques and assignment probabilities. As this project progresses and matures over time, more complete presentations and analyses using this new information will be provided in subsequent annual reports.

Introduction

This project expands research, monitoring, and evaluation (RM&E) activities conducted by the co-managers in the Yakima Basin (Yakama Nation and Washington Department of Fish and Wildlife-WDFW) to better evaluate viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity) for Yakima River steelhead (*Oncorhynchus mykiss*) populations. It was developed to fill critical monitoring gaps identified in the 2009 Columbia Basin monitoring strategy review and the FCRPS Biological Opinion reasonable and prudent alternative (RPA) review. Data from our research will be used to evaluate population status and trends, inform NOAA status reviews and implementation of the Federal Columbia River Power System (FCRPS) Biological Opinion, and address critical uncertainties (e.g., the relationship between resident and anadromous life histories in the Yakima River Basin), consistent with the Northwest Power and Conservation Council (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. The improved understanding of steelhead population performance and dynamic interactions between anadromous and resident O. *mykiss* produced by this project will directly inform efforts to recover steelhead populations in the Yakima Basin.

This report presents fish population status and trend metrics for the Yakima River steelhead major population group (MPG). The Yakima River steelhead MPG is believed to consist of four individual, genetically unique populations spawning in the following areas: the Upper Yakima River consisting of the mainstem and all tributaries above the confluence with the Naches River; the Naches River system including Ahtanum Creek and Yakima Mainstem extending from the confluence of the Naches down to Toppenish Creek; Toppenish Creek; and Satus Creek (Loxterman and Young 2003). This report also updates the status of a three year radio telemetry study (September 2011 through June 2014) to apportion the Yakima River MPG run size enumerated at Prosser Dam to individual population spawner abundances (ICTRT 2007, YBFWRB 2009) and to address spatial distribution uncertainties relative to the Naches and Upper Yakima steelhead populations (Figure 1). The study will also test alternative methods for apportioning the total run at Prosser Dam to monitor long term status and trends at the population level. Another major aspect of this project is monitoring resident/anadromous interactions; for the latest results see Temple et al. (2014) (for additional reference see Pearsons et al. 2007, Courter et al. 2013).

This work relies heavily on the infrastructure and staffing associated with the Yakima/Klickitat Fisheries Project (YKFP) and other related projects in the Yakima Basin. Status and trend metrics for spring Chinook (*O. tshawytscha*), summer/fall Chinook (*O. tshawytscha*), and coho (*O. kisutch*) RM&E work are reported under 1995-063-25. Related steelhead kelt reconditioning is reported under CRITFC projects 2008-458-00 and 2007-401-00. YKFP-related habitat activities for the Yakima Subbasin are addressed under project 1997-051-00. Yakama reservation habitat and RM&E activities are addressed under project 1996-035-01. Hatchery Production Implementation (Operation and Maintenance) is addressed under project 1997-013-25. **Data and findings presented in this report should be considered preliminary until results are published in the peer-reviewed literature.**

Purpose and Need for Project

Although annual adult abundance of Yakima River steelhead at the MPG level can be estimated fairly reliably using Prosser Dam counts, there is a need for spawner abundance estimates for individual populations. Stock status assessments used for recovery planning by the Interior Columbia Technical Review Team (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.

In accordance with RPA 50.6 (Improve Fish Population Status Monitoring), this project is conducting a three year telemetry study that will provide spawner abundance estimates for each Yakima MPG steelhead population. The 3-year study will also test and validate the efficacy of other proposed adult abundance monitoring methods needed for long-term status and trends monitoring. The methods that will be tested during the 3 year telemetry study include:

1) **The use of Genetic Stock Identification (GSI)-** The concept of using GSI techniques for stock partitioning will be based on stratified genetic sampling taken from the adult steelhead run at large at Prosser Dam. The sampling will be conducted across the entire adult run-timing beginning in September and extending into the early part of May. Population-of-origin assignments from individual fish will be compared to actual spawning locations of those fish using information from the telemetry study.

2) **The use of Remote Instream Passive Integrated Transponder (PIT) detection Arrays-** Several instream arrays will be placed adjacent to radio telemetry fixed sites in areas below known spawning distribution of the Satus and Toppenish Creek steelhead populations. The functionality and detection efficiencies of the arrays will be evaluated and information gained will contribute to refinement of spawner abundance estimates.

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. While no hatchery programs exist within the Yakima Basin, stray hatchery-origin fish from other basins make up approximately 3% of the total steelhead run into the basin. The VSP project's primary focus is monitoring natural-origin abundance at the population scale, but will also enumerate and report on the number of out-of-basin stray hatchery spawners that are observed within each of the four Yakima River steelhead populations.

Steelhead smolts entrained into the Chandler Canal at Prosser Dam, and representing the entire Yakima steelhead MPG, are counted throughout the outmigration period each year. Smolt counts can be expanded to total downstream passage if the flow-dependent entrainment rate and the survival rate from the diversion headgate to the counting facility can be reliably estimated. This requires paired releases of PIT-tagged smolts into the dam forebay and at the canal headgates at a variety of river flows through several outmigration seasons, with tag detection in the fish screen bypass and the fish sample room. At present, steelhead smolt passage estimates rely on spring chinook flow-entrainment and canal survival estimates with no information on their applicability between species. The spring chinook passage estimates themselves have proven so unreliable in recent years, probably due in part to fluctuations in migration paths over Prosser Dam, that passage estimation using joint PIT-tag detections with downstream dams to estimate entrainment rate is likely to replace the current flow-entrainment model for that species. This alternative method is facilitated by the fact that over 40,000 hatchery juvenile spring chinook are PIT-tagged each year in the upper Yakima River. The same passage estimation method could be employed for juvenile steelhead, although substantially fewer PIT-tagged steelhead are available.

This project will provide necessary field work, sampling and analytical methods for estimating 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 smolt production estimates (by population) will be developed to document the precision of GSI work used for partitioning productivity among the populations 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.

This 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.

Our current understanding of life history and other population diversity traits within and among Yakima steelhead populations is limited because sufficient time and resources have not been dedicated to this task. 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 2007). 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 necessary information for recovery planners to build more explicit recovery criteria for the diversity component of the VSP framework (YBFWRB 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.

This project will analyze biological data collected by three projects: 1995-063-25, 1996-035-01, and this project. 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 in the document "Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs" (ICTRT 2007).

Study Area

The Yakima Subbasin is located in south-central Washington. It drains an area of 6,155 square miles and contains about 1,900 river miles of perennial streams (Figure 1). The Yakama Nation Reservation is located in the southwest corner of the subbasin just south of the city of Yakima. Major Yakima River tributaries contained within the Reservation include Satus and Toppenish watersheds. The Yakima River originates near the crest of the Cascade Range above Keechelus Lake at an elevation of 6,900 feet and flows 214 miles southeastward to its confluence with the Columbia (RM 335.2). Major tributaries outside the Yakama Nation Reservation include the Kachess, Cle Elum and Teanaway rivers in the northern part of the subbasin, and the Naches River in the west. Six major reservoirs are located in the subbasin. The Yakima River flows out of Keechelus Lake (157,800 acre feet), the Kachess River from Kachess Lake (239,000 acre feet), the Cle Elum River from Cle Elum Lake (436,900 acre feet), the Tieton from Rimrock Lake (198,000 acre feet), and the Bumping from Bumping Lake (33,700 acre feet). Topography in the subbasin is characterized by a series of thrust fault ridges extending eastward from the Cascades. These Ridges divide the Yakima River into several macro floodplain reaches, each unique to its own physical characteristics. Elevations in the subbasin range from about 7,000 feet in the Cascades to about 350 feet at the confluence of the Yakima and Columbia rivers.

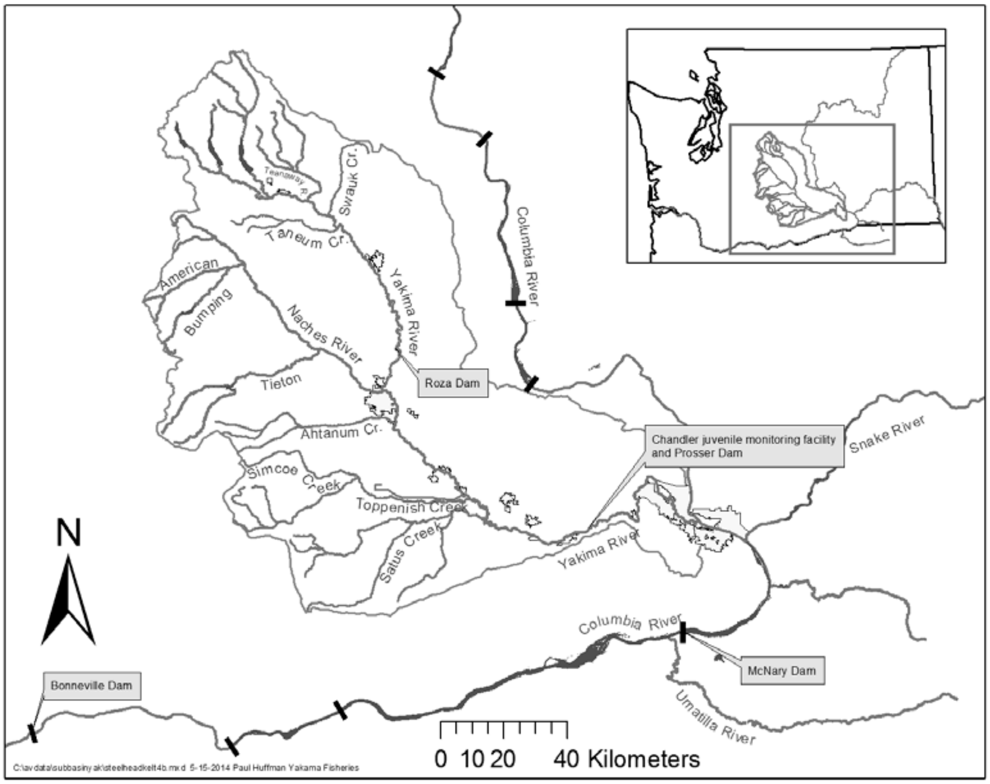

Figure 1. Yakima River Basin showing major steelhead streams and monitoring locations (map courtesy of Paul Huffman).

Project Map: *http://www.cbfish.org/Project.mvc/Map/2010-030-00*

Contract Map(s): *http://www.cbfish.org/Contract.mvc/Map/55510*

Status and Trend of Adult Fish Populations (Abundance)

Methods:

Summer-run steelhead in the Yakima River Basin are enumerated at Prosser and Roza Dams (Rkm 75.6 and Rkm 205.8 respectively) using video equipment installed in adult fish ladders (monitoringmethods.org methods 143, 144, 307, 418, 515). At both Prosser and Roza Dams, adult fish traps are also used on a seasonal basis for biological sampling and enumeration (monitoringmethods.org methods 135, 522). When the Roza adult trap is not in operation, video equipment is also employed at the adult fish ladders there. However, camera placement and actual viewing area are limited; these combined with water clarity issues during certain river conditions all affect video enumeration at Roza Dam. Automatic Passive Integrated Transponder (PIT) tag detectors are also employed at all fish ladders at both dams (monitoringmethods.org method 987). For the safety and protection of personnel and equipment, video and PIT-detection equipment are removed during periods of high river flow. In these instances, biologists attempt to extrapolate fish counts using data from before and after the high flow event. Although adult passage over spillways is believed to occur when flows are favorable, Prosser Dam counts are generally considered by Yakama Nation biologists to be within +/- 5% of actual fish passage. Roza Dam counts during trap operation (generally the entire spring steelhead counting period, February-May) are considered virtually 100% accurate; however during the late fall and winter counting period when video equipment is used at least part of the time, accuracy may fall to only 50-75% of actual fish passage based on preliminary evaluation of PIT tag detection data. Fish are denoted as hatchery- or natural-origin based on presence or absence respectively, of observed external or internal marks (monitoringmethods.org method 341).

At Prosser Dam, time-lapse video recorders (VHS) and a video camera were used at viewing windows at each of the three fishways. Digital video recorders (DVR) and progressive scan cameras (to replace the VHS systems) were tested at each of the three Prosser fishways in 2007 and became fully operational in February of 2008. The new system functions very similarly to the VHS system but provides digital video data readily downloadable to the viewing stations in Toppenish. This new system also allows technicians in Toppenish to scan rapidly to images of fish giving a more timely and accurate fish count. The technicians review the images and record various types of data for each fish that migrates upstream via the ladders. These images and information are entered into a Microsoft Access database, and daily dam count reports are regularly posted to the ykfp.org and Data Access in Real-Time (DART) web sites. Similarly at Roza Dam, adult trap data are entered into a Microsoft Access database, and daily dam count reports (with video counts integrated) are regularly posted to the ykfp.org and DART web sites. Post-season, counts are reviewed and adjusted for data gaps and knowledge about adult and jack lengths from sampling activities. Historical final counts are posted to the ykfp.org and DART web sites.

Results:

Table 1. Yakima Basin steelhead counts at Prosser and Roza Dams, 1983 – present.

Run Year[1]	Prosser Dam			Roza Dam		
	Wild	Hatchery	Total	Wild	Hatchery	Total
1983-84	911	229	1,140	15		15
1984-85	1,975	219	2,194	6		6
1985-86	2,012	223	2,235	3		3
1986-87	1,984	481	2,465	0		0
1987-88	2,470	370	2,840	0		0
1988-89	1,020	142	1,162	0		0
1989-90	686	128	814	0		0
1990-91	730	104	834	0		0
1991-92	2,012	251	2,263	107	9	116
1992-93	1,104	80	1,184	15	0	15
1993-94	540	14	554	28	0	28
1994-95	838	87	925	22	1	23
1995-96	451	54	505	90	2	92
1996-97	961	145	1,106	22	0	22
1997-98	948	165	1,113	51	0	51
1998-99	1,018	52	1,070	14	0	14
1999-00	1,571	40	1,611	14	0	14
2000-01	3,032	57	3,089	133	7	140
2001-02	4,491	34	4,525	236	2	238
2002-03	2,190	45	2,235	128	6	134
2003-04	2,739	16	2,755	211	2	213
2004-05	3,377	74	3,451	224	3	227
2005-06	1,995	10	2,005	121	2	123
2006-07	1,523	14	1,537	60	0	60
2007-08	3,025	285	3,310	171	5	176
2008-09	3,444	25	3,469	204	2	206
2009-10	6,602	194	6,796	311	15	326
2010-11	6,064	132	6,196	337	9	346
2011-12	6,206	153	6,359	408	5	413
2012-13	4,516	271	4,787	278	18	296
Means:						
1983-13	2,348	136	2,484	107	4	110
2004-13	3,949	117	4,067	233	6	239
2009-13	5,366	155	5,521	308	10	317

[1] July 1 to June 30 run year.

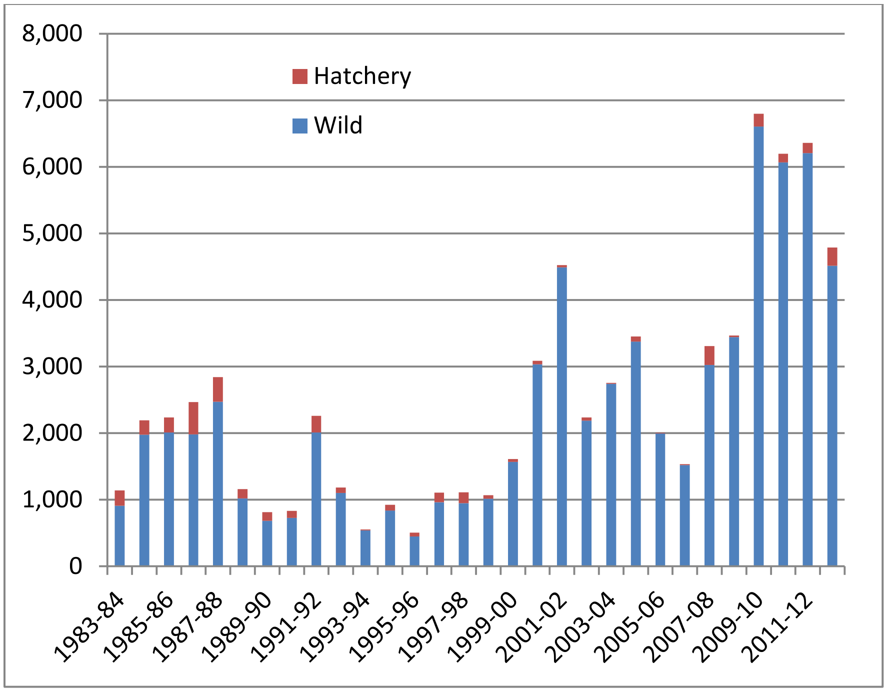

Figure 2. Estimated counts of wild and hatchery-origin steelhead at Prosser Dam, 1983-present.

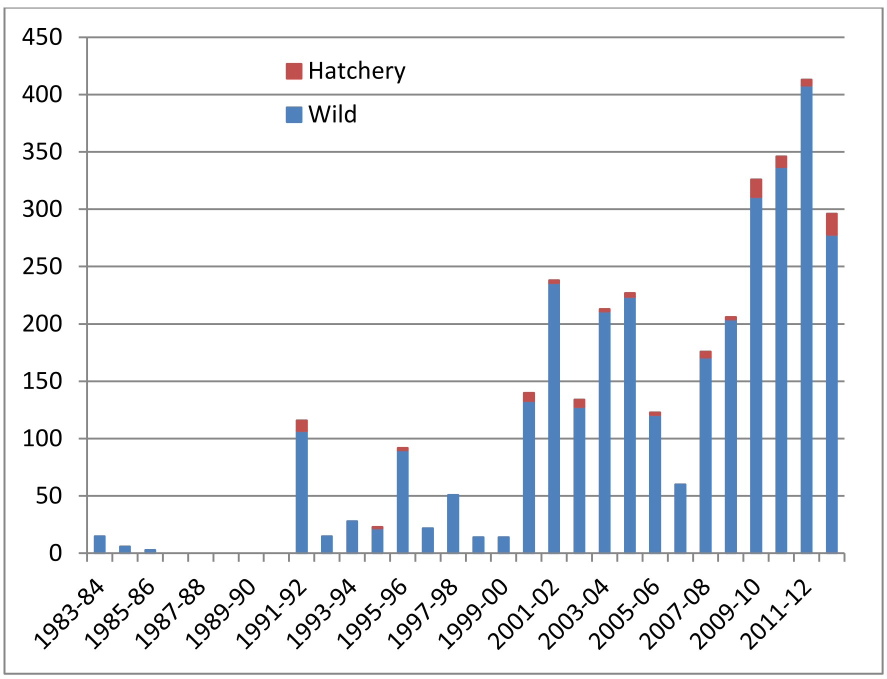

Figure 3. Estimated counts of wild and hatchery-origin steelhead at Roza Dam, 1983-present.

Discussion:

Trends in annual abundance of Yakima River MPG steelhead (Prosser Dam; Figure 2) and Upper Yakima steelhead (Roza Dam; Figure 3) are increasing. For the most recent five steelhead run years (June 30, 2008 to July 1, 2013) mean annual abundance was 5,521 steelhead for the MPG and 317 steelhead for the portion of the Upper Yakima population spawning above Roza Dam (Table 1). This compares to average annual abundance estimates of about 1,400 steelhead for the MPG and fewer than 25 steelhead for the Upper Yakima population (proportion spawning above Roza Dam) in the 1980s and 1990s. The observed increases in annual abundance can generally be attributed to habitat restoration actions in the Yakima River Basin (see 1997-051-00, 1996-035-01, and Yakima Basin Fish and Wildlife Recovery Board summary), the Yakima kelt reconditioning program (Hatch et al. 2013), improved freshwater passage conditions, and improved marine survival. Notable droughts occurred during 2001 and 2005 which may have impacted adult returns.

Historically there have been no artificial breeding programs for Yakima River steelhead though in some years out-of-basin hatchery-origin releases occurred but these were discontinued in 1994. For the most recent 10 return years, both the aggregate MPG and the Upper Yakima population returns have averaged about 97% wild with some hatchery-origin strays from other Columbia River Basin tributaries (Table 1, Figures 2 and 3).

Steelhead counts at Prosser Dam represent total adult escapement for the Yakima River Major Population Group (MPG). The large geographic distribution of steelhead in the Yakima Basin results in diverse pre-spawning migration and holding patterns that influence the proportion of fish that survives to spawn. Historically, there have been no reliable means of estimating population-specific spawner abundances due to limited methods, enumeration points, and unknown pre-spawn mortality rates. This project is currently conducting a 3 year radio telemetry study that will estimate spawner escapement for the Yakima River steelhead populations including Satus Creek, Toppenish Creek, Naches River, and Upper Yakima River populations. In addition to estimating spawner escapement for 3 consecutive years, the study is assessing and ground-truthing potential long term monitoring methods including the use of GSI and PIT-tagging techniques for apportioning the total run at Prosser Dam. Preliminary population-specific spawner escapement estimates using data from the telemetry study for the 2011-2012 Yakima Basin steelhead return are presented in Appendix B. Additional results will be submitted in subsequent reports.

Status and Trend of Adult Productivity

Methods:

We are still in the process of compiling a comprehensive adult age-at-return database for Yakima steelhead using scale and PIT sampling data from the Prosser denil adult sampling operation (monitoringmethods.org methods 135, 522). Until additional data are available, we are using average age-at-return estimates (from 1986-87, 1990-92, and 2002-2004) for years lacking such data in order to conduct brood year cohort analysis (monitoring methods.org method 438) for the time series spanning 1985-2013. Adult-adult return rate estimates presented in Figures 4 and 5 are preliminary and derived from a single enumeration point (Prosser Dam). These estimates have not been adjusted for density dependent effects, harvest, or additional pre-spawn mortality factors. Therefore, these values should not be used to estimate the Intrinsic Productivity for the Yakima River steelhead MPG.

We also assessed the status of the Yakima steelhead MPG relative to the aggregate Bonneville Dam wild Group A population (all wild steelhead <78cm fork length destined to any tributary above Bonneville Dam) by simply dividing the Prosser wild steelhead count for a given steelhead run year (Figure 2) by the Bonneville Dam "Group A" wild steelhead count for the same return year (ODFW/WDFW 2014).

Results:

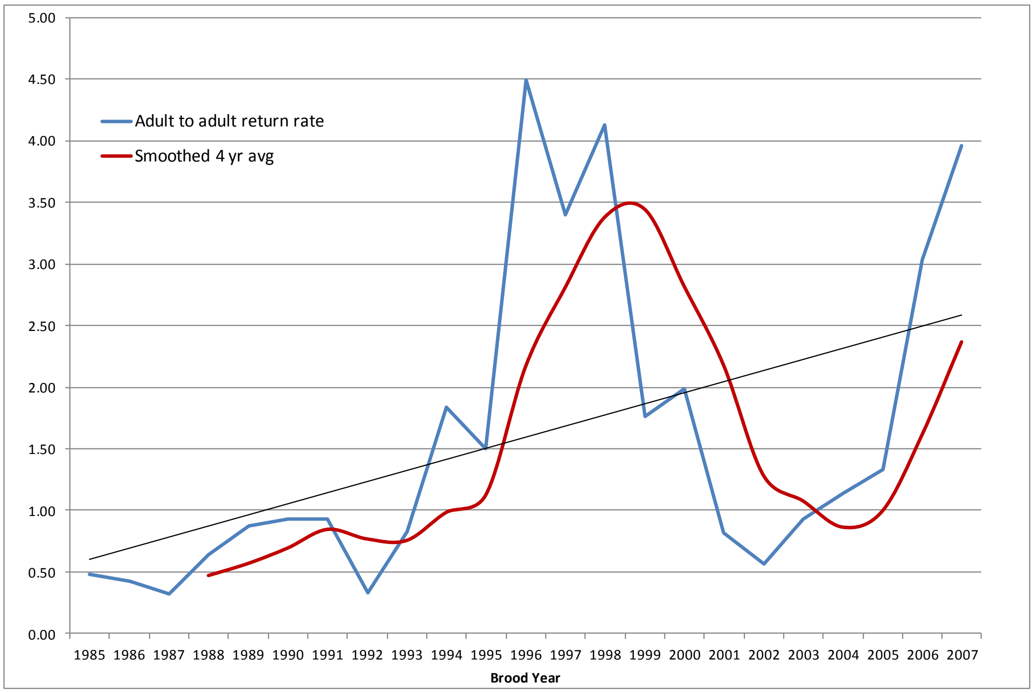

Figure 4. Surrogate adult-to-adult return rate indices for Yakima River MPG steelhead. The majority of age structures used for brood year cohorts rely on averages of age-at-return derived from 9 of 23 years, and are subject to revision when additional age data becomes available. The "smoothed" line represents a four-year running average.

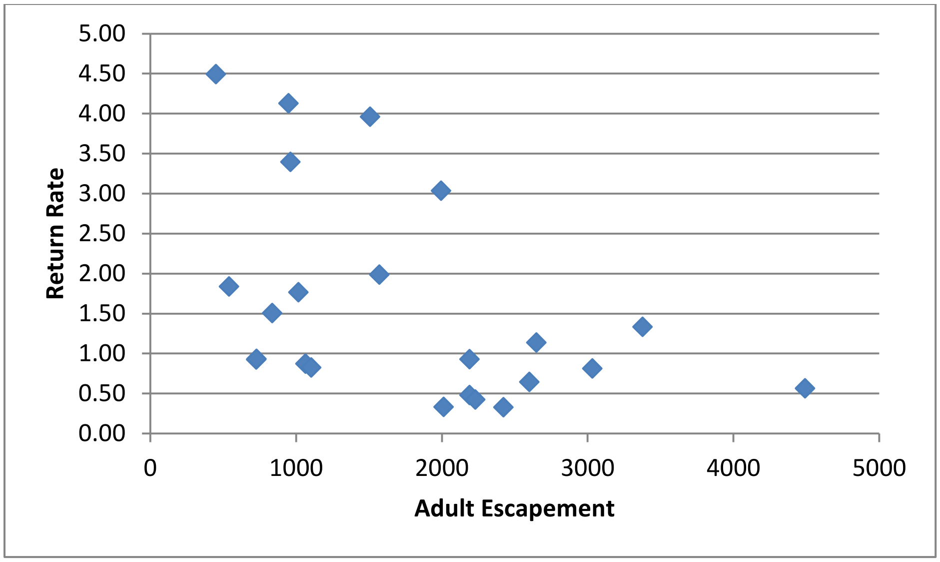

Figure 5. Yakima River MPG steelhead adult-to-adult return rate index.

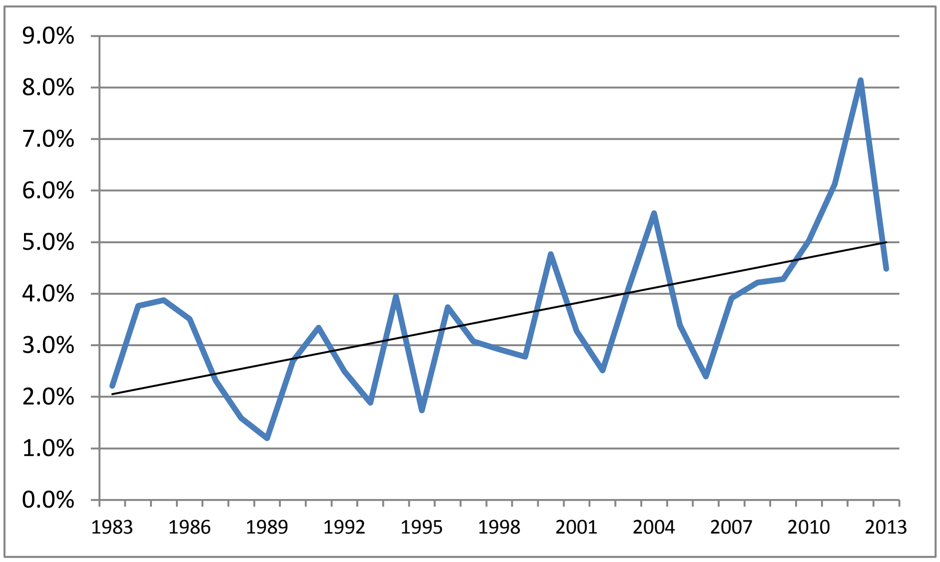

Figure 6. Yakima River MPG steelhead (Prosser wild abundance) as a percentage of Bonneville Dam wild Group A steelhead abundance, 1983 to present.

Discussion:

Adult productivity indices for Yakima River MPG steelhead are presently trending upward (Figures 4 and 6). Under present conditions, productivity appears to peak at about 1,000 to 1,500 spawners and decline at higher spawner abundances (Figure 5). These data indicate that density-dependent limiting factors (see YSFWPB 2004) depress natural productivity at fairly low population abundance in the Yakima River Basin. However, Figure 6 indicates that Yakima River MPG steelhead are experiencing improved survival relative to other steelhead streams above Bonneville Dam over and above survival increases due to common freshwater and marine conditions. Habitat restoration actions in the Yakima River Basin (see 1997-051-00, 1996-035-01, and Yakima Basin Fish and Wildlife Recovery Board summary), the Yakima kelt reconditioning program (Hatch et al.

2013), as well as ongoing efforts to improve fish passage (see Yakima River Basin Water Enhancement Project) and limiting factors in the Yakima Subbasin (see Yakima Basin Fish and Wildlife Recovery Board) may partially explain these results.

Status and Trend of Juvenile Abundance and Productivity

Methods:

Steelhead smolts entrained into the Chandler Canal at Prosser Dam (Figure 1), and representing the entire Yakima steelhead MPG, are counted throughout the outmigration period each year (generally late winter through early summer). Smolt counts can be expanded to total downstream passage if the flow-dependent entrainment rate and the survival rate from the diversion headgate to the counting facility can be reliably estimated. This requires paired releases of PIT-tagged smolts into the dam forebay and at the canal headgates at a variety of river flows through several outmigration seasons, with tag detection in the fish screen bypass and the fish sample room. For additional discussion of these methods see Neeley 2010 and 2012 and monitoringmethods.org methods 422, 512, and 519.

At present, Prosser MPG steelhead smolt passage estimates rely on spring chinook flow-entrainment and canal survival estimates with no information on their applicability between species. The spring chinook passage estimates themselves have proven so unreliable in recent years, probably due in part to fluctuations in migration paths over Prosser Dam, that passage estimation using joint PIT-tag detections with downstream dams to estimate entrainment rate is likely to replace the current flow-entrainment model for that species. This alternative method is facilitated by the fact that over 40,000 hatchery juvenile spring chinook are PIT-tagged each year in the upper Yakima River. The same passage estimation method could be employed for juvenile steelhead, although substantially fewer PIT-tagged steelhead are available. As part of this project, we will continue to explore and evaluate alternative methods for estimating juvenile abundance.

In addition to enumeration, biological data were collected from a portion of salmonid outmigrants sampled at Chandler on a daily basis and all PIT tagged fish were interrogated. Sampling methods were described in Busack et al. (1997) and were consistent with monitoringmethods.org methods 549, 583, 977, 1562, 1563, 1595, and 1614.

As described earlier in this report, we are still in the process of compiling a comprehensive adult age-at-return database. Until such time as this database is available, we developed a surrogate smolt-to-adult return index from Prosser juvenile and adult abundance estimates assuming all smolts outmigrate at age-2 and all adults return at age-4.

Results:

Table 2. Yakima River MPG Natural-origin steelhead smolt (estimates at Prosser) by brood year and outmigration year. Returning natural-origin adults counted at Prosser 2 years after that smolt migration, and surrogate smolt-to-adult return (SAR) index, 1988-present. Note these data are preliminary and subject to change. DO NOT CITE.

Year	Steelhead Smolts[1]		Adults[2]		SARs	
	Brood Year	Outmigrant Year	Produced by Brood Year	Produced by Outmigrant Year	Brood Year Cohort	Outmigrant Year Cohort
1985	93,477	83,461	1,001	1,700	1.07%	1.89%
1986	86,944	96,639	917	1,877	1.05%	1.81%
1987	49,194	89,657	786	917	1.60%	0.95%
1988	41,009	61,338	1,672	879	4.08%	1.33%
1989	38,058	38,536	927	1,004	2.44%	2.42%
1990	45,864	31,206	673	1,549	1.47%	4.62%
1991	30,238	29,933	679	875	2.25%	2.72%
1992	25,875	50,104	667	624	2.58%	1.16%
1993	31837	24,529	907	687	2.85%	2.60%
1994	47,003	26,748	993	625	2.11%	2.17%
1995	86,760	26,331	1,261	932	1.45%	3.29%
1996	102,951	69,454	2,021	962	1.96%	1.29%
1997	72,490	117,771	3,263	1,229	4.50%	0.97%
1998	36602	70,297	3,914	1,994	10.69%	2.64%
1999	47,597	36,293	1,809	2,641	3.80%	6.77%
2000	33,168	45,127	3,191	4,661	9.62%	9.60%
2001	46,122	31,391	2,473	1,099	5.36%	3.26%
2002	39,044	42,522	2,544	3,570	6.52%	7.81%
2003	46,343	32,599	2,136	3,052	4.61%	8.71%
2004	43,427	37,915	3,163	1,806	7.28%	4.43%
2005	26,113	50,550	4,527	2,040	17.34%	3.75%
2006	22,083	18,265	6,054	3,175	27.41%	16.85%
2007	28,527	30,650	5,977	4,489	20.95%	14.07%
2008	45,380	26,251	N/A	6,227	N/A	23.65%
2009	68,098	28,754	N/A	5,908	N/A	20.55%
2010	N/A	57,948	N/A	N/A	N/A	N/A
2011	N/A	76,000	N/A	N/A	N/A	N/A
2012	N/A	83,000	N/A	N/A	N/A	N/A
Mean	49,368	50,474	2,242	2,181	6.22%	5.97%
Geomean	45,138	44,758	1,752	1,701	3.95%	3.77%

[1]Juvenile age data available from 1985-2007. 2008-09 Used average age structures from prior years.
[2]Adult age data available 1986-87,1990-92, 2002-2005. All other years used averages from available years.

Discussion:

Since 2000, annual returns of specific adult salmon *Oncorhynchus spp.* runs to the Columbia River Basin have often reached numbers not observed in many decades, with different species doing better in different years. At Bonneville Dam (Figure 1), steelhead counts were especially high in 2001-2002 and 2009-2011 (ODFW/WDFW 2014). Ocean conditions have frequently been cited as one of the factors for the increased abundance (e.g., Williams et al. 2014). However, there have also been many actions taken in recent years to improve passage and habitat conditions throughout the Columbia River Basin (NOAA 2014). Thus it is not unreasonable to expect to observe some evidence of increased productivity throughout the Columbia Basin such as that indicated for the Yakima River steelhead MPG in Figures 4 and 6 and Table 2. In fact, Williams et al. (2014) reported SARs as high as 23.5% for Columbia River sockeye salmon *O. nerka* coincident with recent large adult returns.

Still, there is much reason for caution in interpreting these results. Smolt accounting at Prosser Dam is based on statistical expansion of Chandler smolt trap sampling data using available flow data and estimated Chandler entrainment rates. Chandler smolt passage estimates are prepared primarily for the purpose of comparing relative marked versus unmarked passage estimates and not for making survival comparisons. While these Chandler smolt passage estimates represent the best available data, there may be a relatively high degree of error associated with these estimates due to inherent complexities, assumptions, and uncertainties in the statistical expansion process. Therefore, these estimates are subject to revision.

Given these complicating factors, Table 2 presents a surrogate smolt-to-adult survival index for Yakima River MPG steelhead. Because of the complexities noted above, these data are useful for analysis of trends but should not be used as direct citations of smolt-to-adult survival rates. The reader is encouraged to contact Yakama Nation technical staff to discuss these and other issues prior to any use of these data or any other estimation of Yakima Basin SARs that may be available through data obtained from public web sites such as RMPC, PTAGIS, DART, or other.

Status and Trend of Spatial Distribution

Methods:

Regular foot and/or boat surveys (**monitoringmethods.org** methods 30, 97, 131, 285, 1508) were conducted within the established geographic range for each species. Redds were individually marked during each survey. The Yakama Nation conducted surveys in Satus, Toppenish, and Ahtanum Creeks. The U.S. Forest Service, WDFW, and other collaborators conducted surveys in the Naches River system. There are currently no organized efforts to conduct redd surveys within the geographic range of the upper Yakima population. River conditions vary from year to year and frequently preclude complete accounting due to issues such as water clarity, flow, and access.

In addition to redd surveys, the 3 year telemetry study is assessing and documenting the spatial distribution of radio tagged adult spawners. Detection methods include the use of fixed site locations and mobile tracking efforts with vehicles, boats, foot, and aerial surveys (planes and helicopters). Over the last 10 years, the spatial distribution of adult spawners has been well documented for the Satus and Toppenish Cr populations through redd surveys. Detailed results and maps illustrating the redd locations and spawner distribution for these populations can be viewed in reports provide by project 1996-035-01. The spawning distribution of the upper Yakima population has been estimated and documented from past radio telemetry efforts including a study spanning 1989-1993 (Hockersmith et al. 1995) and a study spanning 2002-2006 (Karp et al. 2009). Here, we present tracking and spawning distribution information for the Naches population generated from 2012 telemetry tracking efforts. A more complete analysis of spatial distribution information will be included in subsequent reports covering the 2012-14 telemetry study, and for the entire Yakima MPG.

Results:

Table 3. Yakima Basin steelhead escapement and spawning summary, 1987 – present.

Run Year[1]	Prosser Dam Count	Redd Counts by Survey Stream					Roza Dam Count
		Satus	Toppenish	Ahtanum	Naches	Total	
1987-88	2,840	445				445	
1988-89	1,162	404	45			449	
1989-90	814	289	26			315	
1990-91	834	125				125	
1991-92	2,263						116
1992-93	1,184	73				73	15
1993-94	554	114				114	28
1994-95	925	85				85	23
1995-96	505	148				148	92
1996-97	1,106	76	5			81	22
1997-98	1,113	190	13			203	51
1998-99	1,070	130	78			208	14
1999-00	1,611	169	185	11		365	14
2000-01	3,089	252	355	8		615	140
2001-02	4,525	295	111	13		419	238
2002-03	2,235	319	161	16		496	134
2003-04	2,755	117	56	12	94	279	213
2004-05	3,451	110	99	16	140	365	227
2005-06	2,005	60	21	1	19	101	123
2006-07	1,537	87	44	4	44	179	60
2007-08	3,310	110	68	8	11	129	176
2008-09	3,469	119	79	3	29	230	206
2009-10	6,796	465	105		116	686	326
2010-11	6,196	293	100	28	77	498	346
2011-12	6,359	152	46		60	258	413
2012-13[2]	4,787	223	78	20	60	381	296

Blank = no data available
All surveys were partial or affected by poor redd visibility due to spring conditions.
[1] July 1 to June 30 run year.
[2] Preliminary.

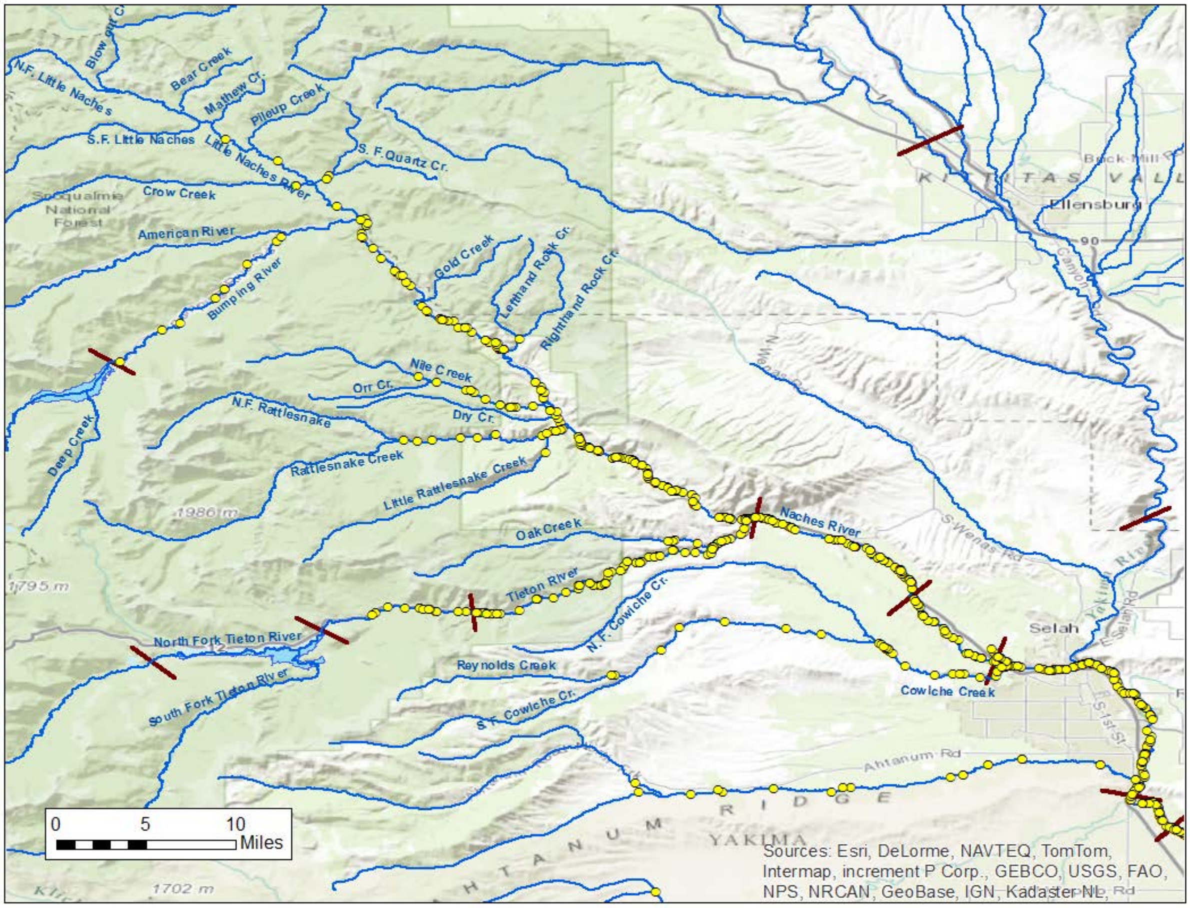

Figure 7. Synthesis of 2012 Detection points of adult steelhead holding and spawning locations for the Naches population.

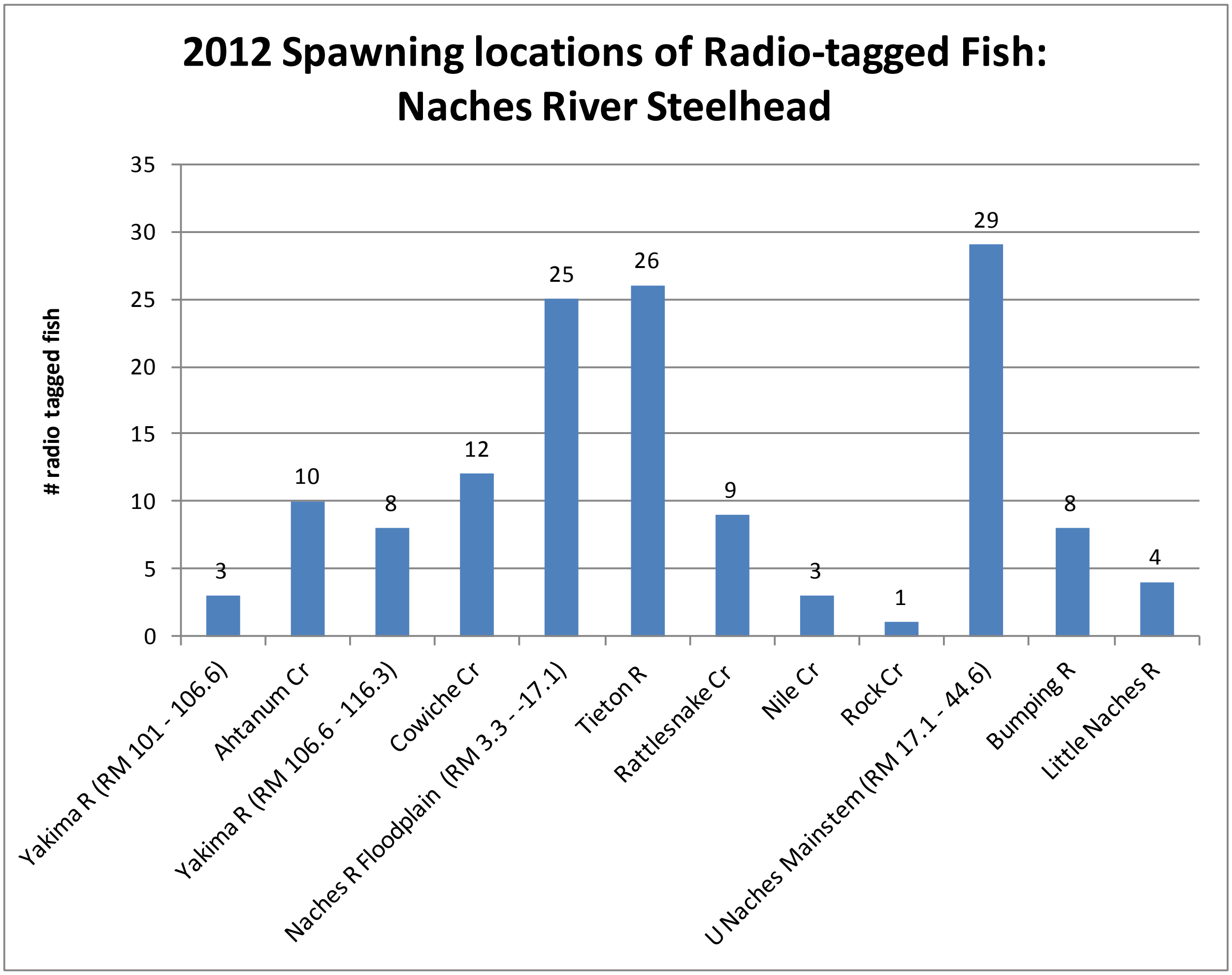

Figure 8. Number and location of Naches River Steelhead spawners in mainstem and tributary locations

Discussion:

During the spring of 2012, 138 radio-tagged steelhead presumably spawned within the geographic distribution of the Naches Steelhead population, which includes the Naches watershed in its entirety, the Yakima mainstem extending from the mouth of the Naches down to the Toppenish Cr confluence (RM 116.3-80.4), and Ahtanum Creek. A synthesis of combined holding and spawning detection points are summarized in Figure 7. The distribution of radio tagged steelhead among mainstem and tributary locations are summarized in Figure 8. Prior to the 2012 telemetry study, many of these tributary locations had documented spawning activity from either historical telemetry studies (Hockersmith et al 1995), or recent redd surveys conducted between 2004 and 2011. Tributaries that were regularly surveyed during this time frame include Ahtanum Cr, Oak Cr (Tributary to Tieton River), Rattlesnake Cr, Nile Cr, Bumping R, and various parts of the Little Naches drainage. To no surprise, radio tagged steelhead were detected in all of these tributary locations during the spring of 2012.

Other tributary and mainstem areas of special interest are those with little known or documented spawning activity. These include the Yakima River from Toppenish Cr (RM 80.4) to the confluence with the Naches River (RM 116.3), the Naches River floodplain reach (RM 3.3-17.1), Cowiche Cr, Tieton River, Rock Cr, numerous other Naches Mainstem reaches above the confluence with the Tieton, and other small tributaries in the Naches watershed. For many of these areas, not only were radio-tagged steelhead present, but several had unexpectedly high numbers of radio tagged fish that presumably spawned within them. The Tieton River system, for example, was assumed to be void of steelhead with the exception of Oak Cr, due to unsuitable conditions caused by altered flow regimes, reduction in sediment transport, and channel simplification (YSFWPB 2009). Yet among the tributaries of the Naches Subbasin, the Tieton River had the highest number of radio-tagged spawners, totaling 26 (Figure 8). The Naches River mainstem also had a presumably high number of steelhead spawners, both the floodplain reach between Cowiche Dam (RM 3.3) and Wapatox Dam (RM 17.1), and the upper mainstem above Wapatox Dam. Respectively, these areas had approximately 25 and 29 radio tagged steelhead spawners. For the upper mainstem above Wapatox Dam, nearly all the spawning activity took place above Horseshoe Bend (RM 21.2). Approximately 8 radio-tagged steelhead presumably spawned in the Yakima River mainstem between Wapato Dam (RM 106.6) and the Naches confluence (RM 116.3). The 1989-1993 telemetry study also found steelhead spawning in this reach, totaling 4% of the fish radio tagged at Prosser spanning all 3 years of the study (Hockersmith et al. 1995). An improbable find during the 2012 study revealed that 3 radio-tagged steelhead may have spawned within a 5.6 mi stretch of the Yakima River extending from Wapato Dam, and into the floodplain below Sunnyside Dam (RM 101-106.6). The detection histories of these fish were consistent with spawning and kelt like behavior, with none of these fish having migrated above Wapato Dam. Years 2 and 3 of the telemetry study should provide further evidence and validate the presence or absence of steelhead spawners within this section of the Yakima River.

Status and Trend of Diversity Metrics

Methods:

Sampling methods for evaluating juvenile steelhead at Chandler were consistent with monitoringmethods.org methods 549, 583, 977, 1562, 1563, 1595, and 1614. At both Prosser and Roza Dams, adult fish traps were used on a seasonal basis for biological sampling and enumeration (monitoringmethods.org methods 135, 522). Methods for sampling and enumerating downstream migrating kelt (post-spawned) steelhead were described in Hatch et al. (2013). We used these data to describe and evaluate migration timing of juveniles, adults, and downstream migrating kelts; and sex ratios and size distribution of returning adults at Prosser and Roza dams.

Results:

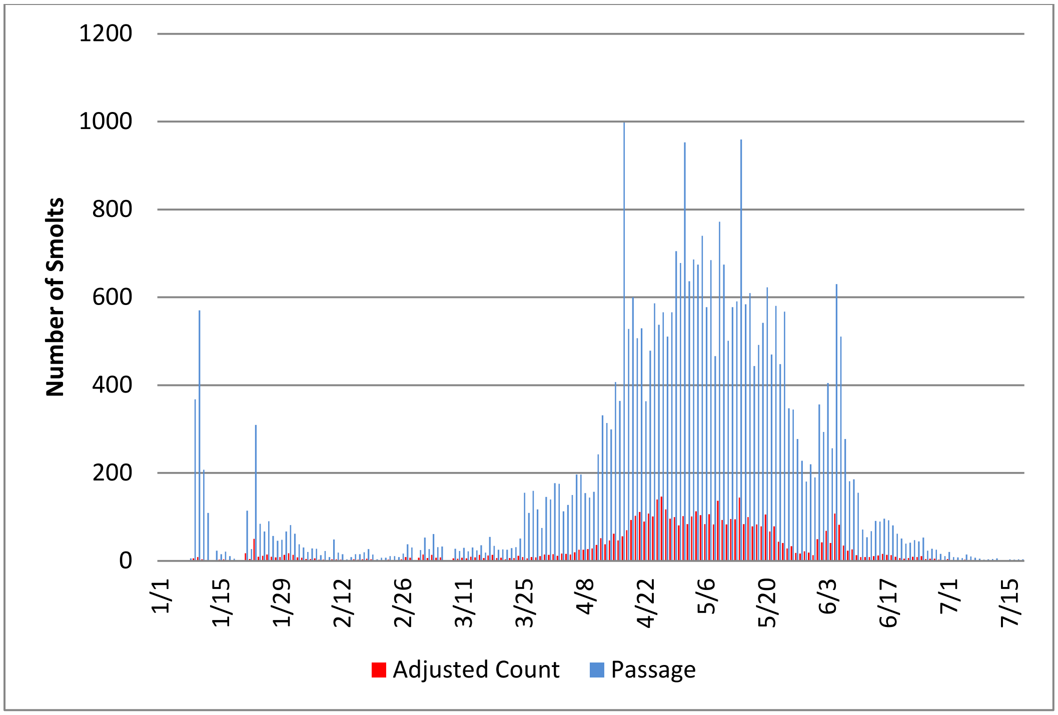

Figure 9. Distribution, average adjusted daily sample count, and estimated smolt passage of Yakima MPG Steelhead at Prosser Dam, 2000-2009.

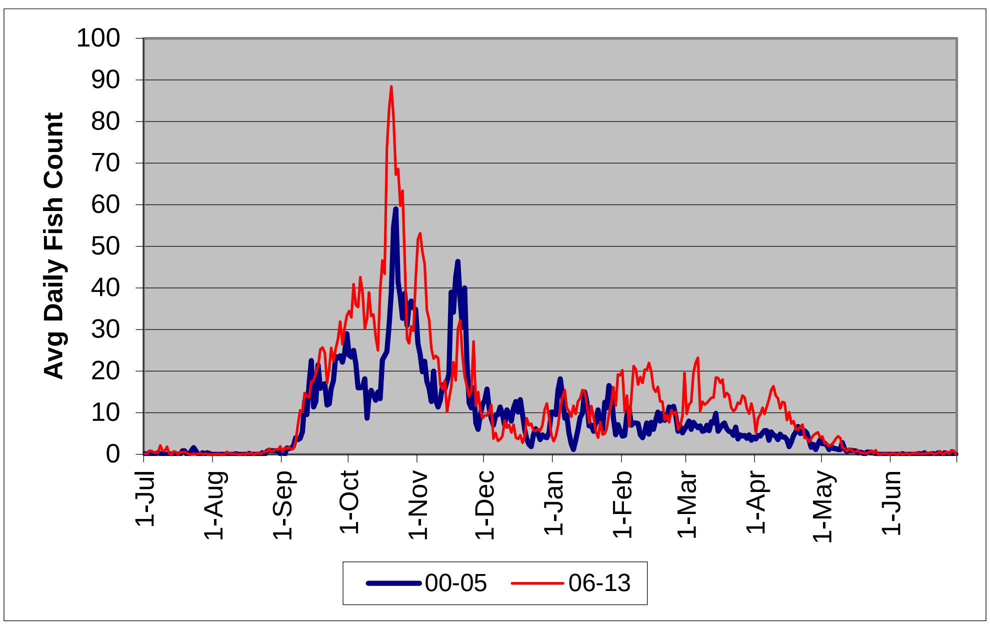

Figure 10. Average Adult Steelhead Run Timing at Prosser Dam, 2000-2005 compared to 2006-2013.

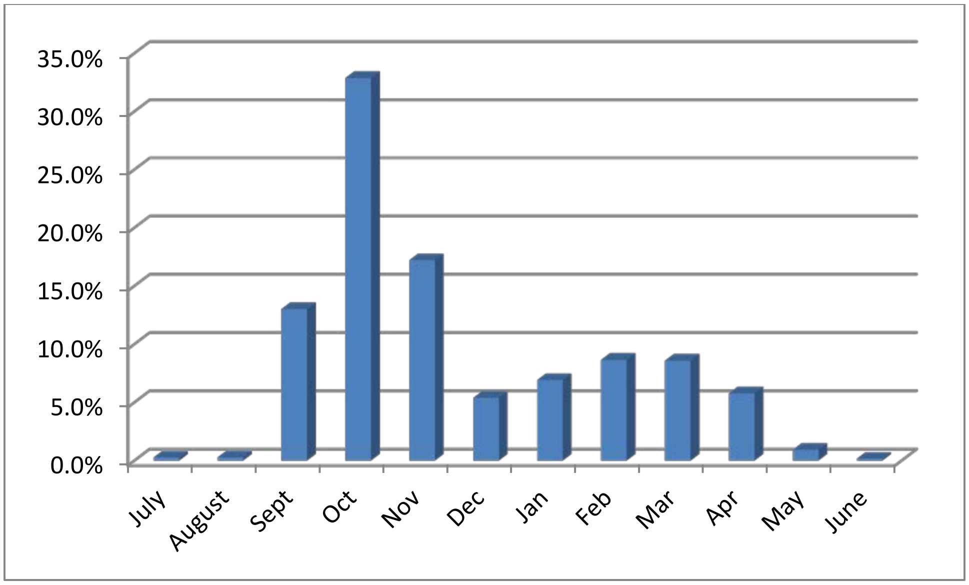

Figure 11. Recent 10-year Average Adult Steelhead Passage Proportions by Month at Prosser Dam.

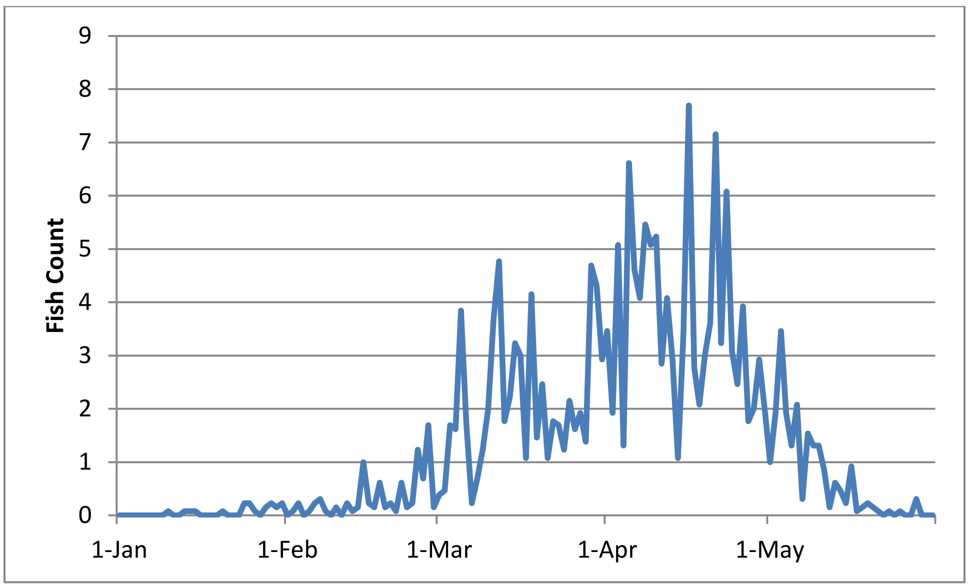

Figure 12. Average Daily Adult Steelhead Passage at Roza Dam, 2001 – 2013.

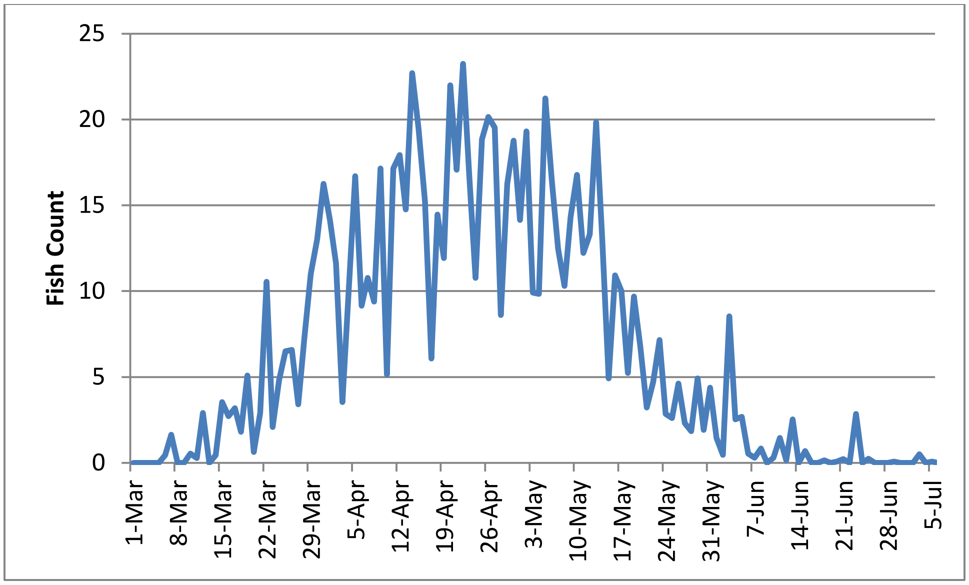

Figure 13. Average arrival timing of downstream migrating, post-spawned kelt steelhead at the Chandler Fish Monitoring Facility (Prosser Dam), 2001-2013.

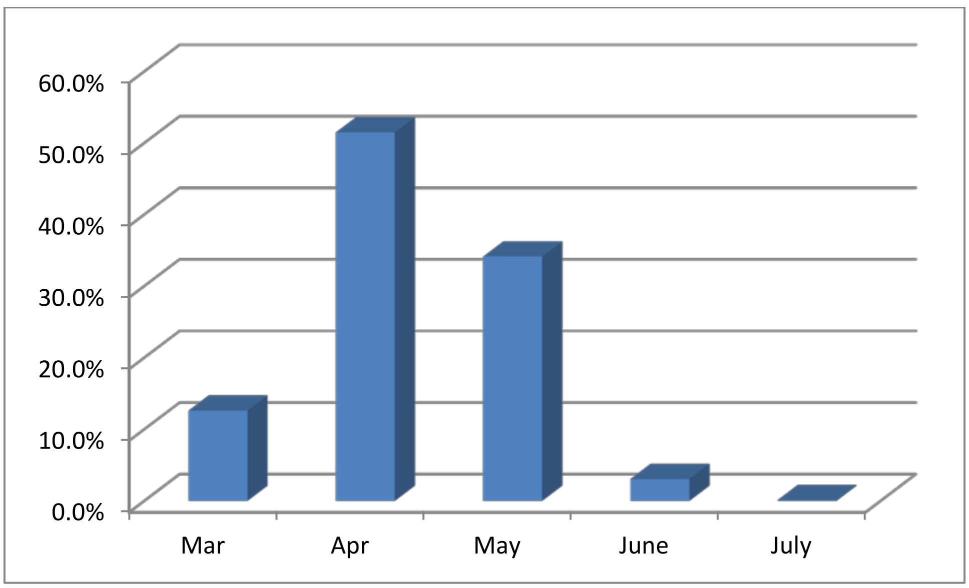

Figure 14. Average Kelt Steelhead Passage Proportions by Month at Chandler, 2001-2013.

Table 4. Sex ratio of upstream migrating wild steelhead sampled at the Prosser Dam right bank denil ladder and fish trap[1], 2002-2013.

Run Year	Sample Size F	Sample Size M	Female%	Sample Date Range First	Sample Date Range Last
2002-03	144	29	83.2%	09/09/02	11/25/02
2003-04	388	185	67.7%	09/11/03	11/24/03
2004-05	617	356	63.4%	09/06/04	12/02/04
2005-06	274	81	77.2%	09/11/05	11/20/05
2006-07	152	40	79.2%	09/14/06	11/20/06
2007-08	205	67	75.4%	09/11/07	11/20/07
2008-09	165	76	68.5%	09/10/08	12/07/08
2009-10	473	289	62.1%	09/08/09	03/18/10
2010-11	247	109	69.4%	09/08/10	11/17/10
2011-12	455	231	66.3%	09/14/11	05/08/12
2012-13	553	272	67.0%	09/07/12	04/25/13
2013-14	647	279	69.9%	09/16/13	05/01/14
		Mean	70.8%		

[1] July 1-June 30 run year. Excludes any fish with a previously-inserted PIT tag to exclude reconditioned kelts which would skew sex ratios even further toward females. 2013-14 data are preliminary.

Table 5. Sample size (N), mean fork and mid-eye to hypural plate (MEH) lengths (cm), and weights (pounds) of upstream migrating wild steelhead sampled at the Prosser Dam right bank denil ladder and fish trap[1], 2002-2013.

Run	Females				Males			
Year	N	Fork	MEH	Weight	N	Fork	MEH	Weight
2002-03	143	68.0	56.1	6.9	29	67.2	53.9	6.6
2003-04	388	60.0	49.4	4.8	185	60.3	48.8	4.8
2004-05	617	62.3	52.1	5.2	356	61.0	50.1	4.7
2005-06	274	65.9	54.6	6.3	81	66.0	54.0	6.2
2006-07	152	64.0	53.0	5.9	40	66.7	54.9	6.4
2007-08	205	61.1	48.7	5.1	67	63.3	49.2	5.3
2008-09	164	64.0	52.2	6.4	76	62.6	51.2	6.0
2009-10	473	62.9	48.7	5.4	289	63.3	48.2	5.7
2010-11	247	65.0	52.1	6.3	109	64.4	50.4	6.0
2011-12	455	65.8	54.3	5.9	230	64.9	52.3	5.6
2012-13	553	65.8	52.2	6.1	272	65.7	51.2	6.0
2013-14	646	62.4	50.5	5.1	279	62.4	50.1	4.9
Mean		63.9	52.0	5.8		64.0	51.2	5.7

[1] July 1-June 30 run year. Excludes any fish with a previously-inserted PIT tag to exclude reconditioned kelts which could skew means. 2013-14 data are preliminary.

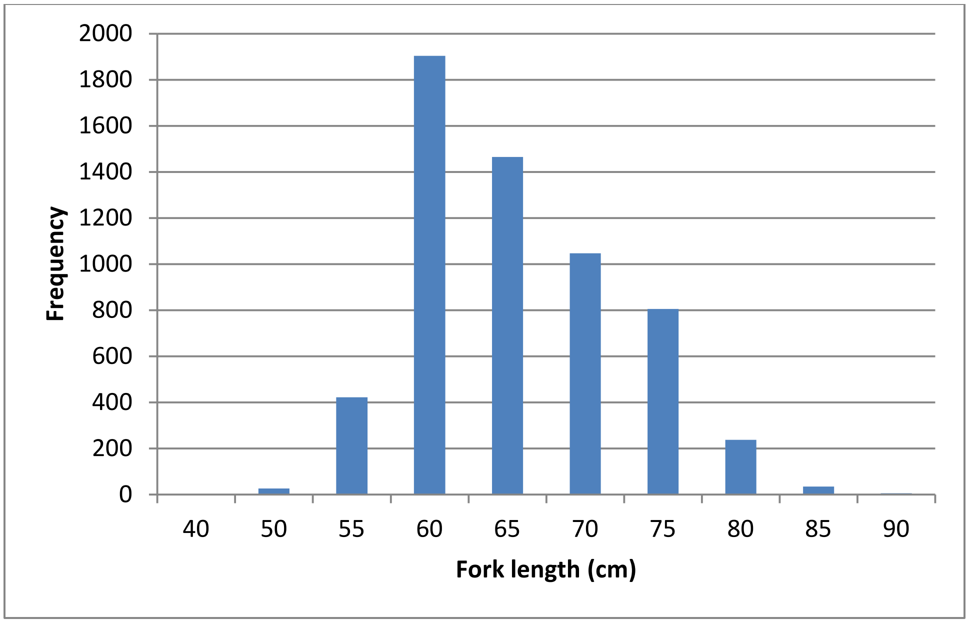

Figure 15. Frequency histogram of fork lengths (cm) for all upstream migrating wild steelhead sampled at the Prosser Dam right bank denil ladder and fish trap, 2002-2013. Excludes any fish with a previously-inserted PIT tag to exclude reconditioned kelts which could skew the data.

Table 6. Sex ratio of upstream migrating steelhead sampled at the Roza Dam adult fish trap[1], 2002-2013.

Run Year	Sample Size F	M	Female%	Sample Date Range First	Last
2001-02	155	59	72.4%	01/10/02	05/15/02
2002-03	109	20	84.5%	11/18/02	05/13/03
2003-04	148	55	72.9%	07/24/03	06/24/04
2004-05	159	39	80.3%	01/24/05	06/02/05
2005-06	76	38	66.7%	01/13/06	05/15/06
2006-07	42	16	72.4%	02/13/07	05/14/07
2007-08	123	46	72.8%	09/13/07	05/16/08
2008-09	147	44	77.0%	02/25/09	06/03/09
2009-10	220	84	72.4%	07/25/09	06/29/10
2010-11	259	74	77.8%	07/10/10	05/23/11
2011-12	282	72	79.7%	07/10/11	06/19/12
2012-13	151	69	68.6%	09/07/12	05/10/13
		Mean	74.8%		

[1] July 1-June 30 run year. Excludes any fish with a previously-inserted PIT tag to exclude reconditioned kelts which would skew sex ratios even further toward females.

Table 7. Sample size (N), mean fork and post-eye to hypural plate (POH) lengths (cm), and weights (pounds) of upstream migrating steelhead sampled at the Roza Dam adult fish trap[1], 2002-2013.

Run	Females				Males			
Year	N	Fork	POH	Weight	N	Fork	POH	Weight
2001-02	155	65.5	53.8	6.2	59	66.6	53.5	6.3
2002-03	109	69.3	57.1	7.4	20	71.3	57.0	7.6
2003-04	148	60.9	50.0	5.1	55	62.7	49.7	5.2
2004-05	159	66.9	55.4	6.4	39	68.9	55.5	6.7
2005-06	76	66.3	55.0	6.3	38	70.8	57.5	7.4
2006-07	42	64.4	53.6	4.1	16	67.2	54.2	4.7
2007-08	123	61.9	51.5	5.4	46	64.3	51.9	5.6
2008-09	147	65.3	54.1	6.2	44	66.2	53.3	6.2
2009-10	220	62.1	51.6	5.1	84	62.7	50.5	5.1
2010-11	259	66.3	55.3	6.3	74	67.5	54.5	6.5
2011-12	282	63.3	52.9	6.3	72	63.5	51.8	6.3
2012-13	151	63.6	53.3	6.4	69	64.9	52.7	6.8
Mean		64.7	53.6	5.9		66.4	53.5	6.2

[1] July 1-June 30 run year. Excludes any fish with a previously-inserted PIT tag to exclude reconditioned kelts which could skew means.

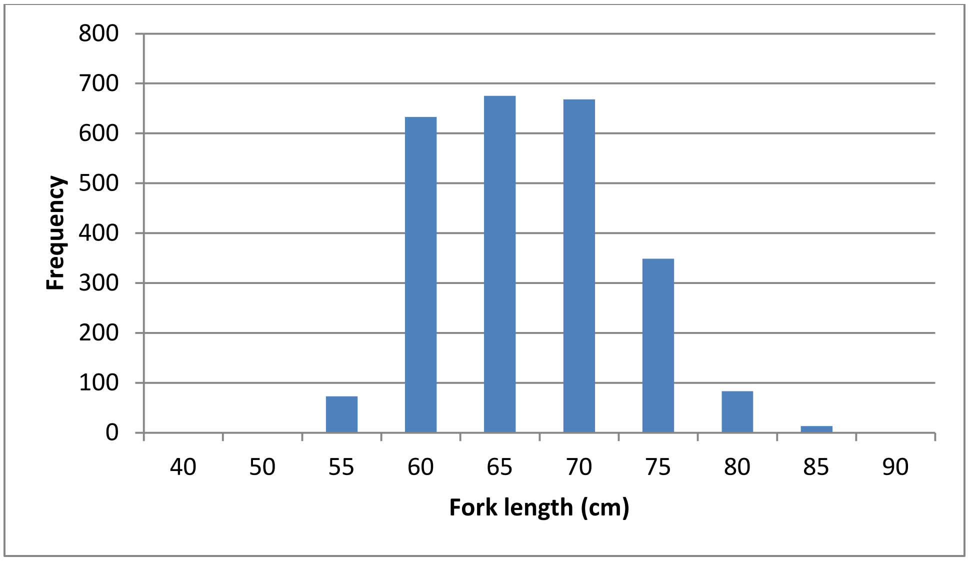

Figure 16. Frequency histogram of fork lengths (cm) for all upstream migrating steelhead sampled at the Roza Dam adult fish trap, 2002-2013. Excludes any fish with a previously-inserted PIT tag to exclude reconditioned kelts which could skew the data.

Discussion:

Steelhead residing in the Yakima Basin are classified as summer-run based on their July-September run timing at Bonneville Dam (ODFW/WDFW 2014). Adult run timing into the Yakima Basin typically begins in late August or early September, and extends into May of the following year (Figures 10 and 11). After crossing Prosser Dam, the majority of fall migrants overwinter in mainstem areas near the tributary mouths of Satus and Toppenish Creeks. Part of the run will continue upstream, and overwinter in mainstem areas extending up to, and above Roza Dam. Steelhead will typically move upriver and into tributaries when spawning begins the following spring (Figure 12; tributary array PIT detection data). Post-spawned (kelt) and juvenile steelhead downstream passage at Prosser Dam is similar, generally occurring from March-June (Figures 9, 13, and 14). Adult steelhead migrants to the Yakima River Basin are predominantly female, with mean annual percentage female rates ranging from 62-83% (pooled mean 70.8%) at Prosser Dam (Table 4) and from 67-84% (pooled mean 74.8%) at Roza Dam (Table 6) for steelhead sampled from 2002-2013.

Mean annual fork lengths of wild adult steelhead sampled at Prosser Dam ranged from about 60-68 centimeters (cm) from 2002-2013 and averaged 63.9 cm for females and 64.0 cm for males (Table 5). Nearly 90% of all wild steelhead sampled at Prosser Dam from 2002 to 2013 were between 55.1cm and 75.0cm fork length (Figure 13; range 32-92cm, median 62 cm). Mean annual fork lengths of adult steelhead sampled at Roza Dam ranged from about 61-71 centimeters (cm) from 2002-2013 and averaged 64.7 cm for females and 66.4 cm for males (Table 7). Over 93% of all wild steelhead sampled at Roza Dam from 2002 to 2013 were between 55.1cm and 75.0cm fork length (Figure 14; range 38-86 cm, median 64 cm). Thus, the vast majority (about 95%) of MPG steelhead returning to the Yakima River Basin are in the "Group A" size management range (< 78cm fork length) which is used for fishery management purposes in the Columbia River Basin (ODFW/WDFW 2014).

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Appendix A: Use of Data & Products

All data and findings should be considered preliminary until results are published in the peer-reviewed literature.

Where will you post or publish the data your project generates?

Fish Passage Center
Yakama Nation Fisheries website
DART - Data Access in Real Time
RMIS - Regional Mark Information System
Yakima-Klickitat Fisheries Project website
BPA Pisces
StreamNet Database
BPA Fish and Wildlife publication page
PTAGIS Website

Describe the accessibility of the data and what the requirements are to access them?

- Automated integration of Prosser and Roza dam daily count data with Data Access in Real-Time (DART)
- Integration of PIT and CWT release and recovery data with PTAGIS, RMIS, and Fish Passage Center databases
- Production and support of data bases necessary to support BPA quarterly and annual reports (available via PISCES and BPA reports web site)
- Production and support of data bases necessary to support NPCC project proposals (available via CBfish.org)

Additional data for Yakima River steelhead is available on the ykfp.org web site and by email contact through Bill Bosch (bbosch@yakama.com) or Chris Frederiksen (chrisf@yakama.com). Project data managers participated in the Coordinated Assessments process to develop pilot exchange templates for adult and juvenile abundance and productivity parameters. However, as documented in a letter from Phil Rigdon, Director of Natural Resources for the Yakama Nation to Phil Anderson Director of the Washington Department of Fish and Wildlife, dated 7Nov2012, the Yakama Nation would like to see the region develop strong, enforceable data sharing agreements before we can support broad population and unlimited use of and access to these regional databases with data from YN/YKFP projects. We remain concerned about the potential for misuse of project data obtained from existing regional databases.

Appendix B: Detailed Results

Yakima River Steelhead Radio Telemetry Study

(2011-2014)

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Introduction

This is a 3 year study spanning the time frame of September 2011, through the end of June 2014. The study will address the spatial distribution uncertainties for both the Naches and Upper Yakima steelhead populations (Figure 1). In addition, the study will update the radio telemetry study conducted 20 years ago (Hockersmith et al. 1995) that has often been referenced and used for apportioning the Yakima River Major Population Group

(MPG) run size enumerated at Prosser Dam to individual population spawner abundances (ICTRT 2007, YBFWRB 2009). The study will also test alternative methods for apportioning the total run at Prosser Dam for long term status and trends monitoring needs.

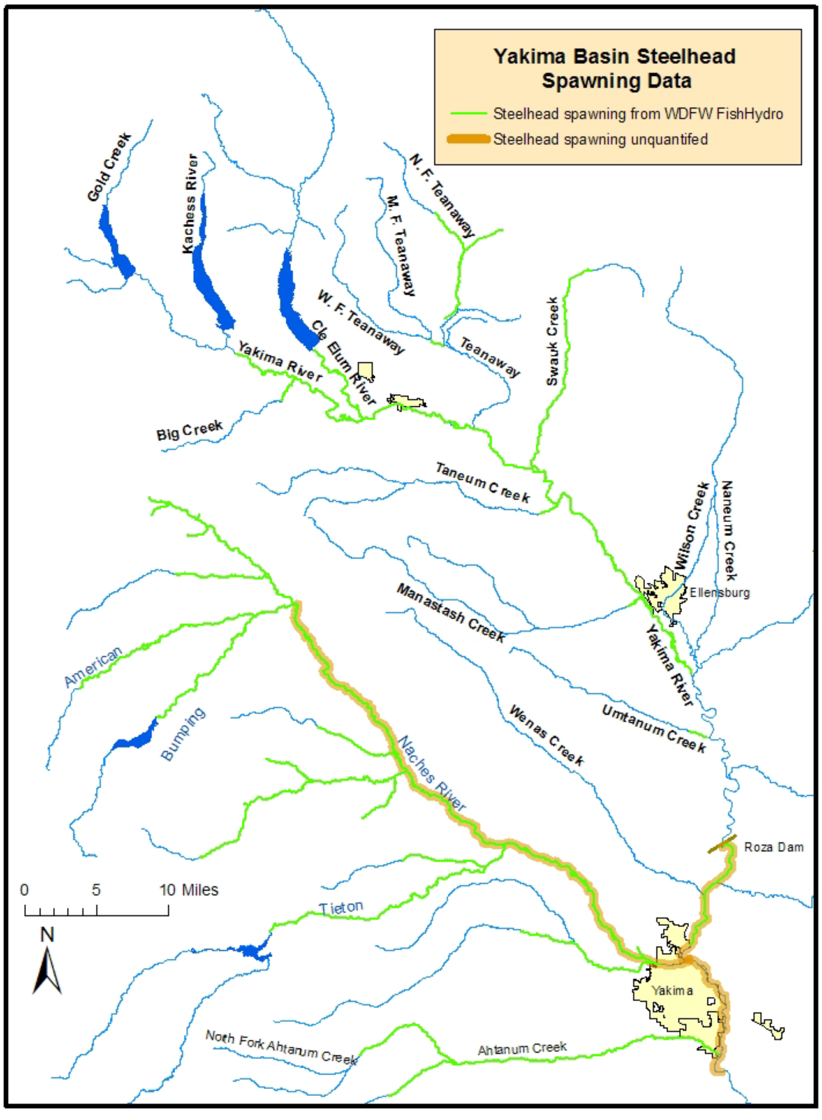


Figure 1. Estimated spawning distributions of Upper Yakima and Naches steelhead populations

Steelhead residing in the Yakima Basin are classified as summer-run. Run timing into the Yakima Basin typically begins in late August or early September, and extends into May of the following year. The large geographic distribution of steelhead in the Yakima Basin results in diverse pre-spawning migration and holding patterns that influence the proportion of fish that survive to spawn. Estimates of run escapement at Prosser Dam (Rkm 75.6) may not accurately reflect spawning escapements due to uncertain pre-spawning mortality rates. Previous abundance estimates have used a generalized rate for the entire MPG. Redd surveys are not reliable for spawner abundance estimates in years and sites when survey efforts are precluded by high flow and low visibility.

The primary objectives of the three year radio telemetry study are to:

1. Better define the Upper Yakima and Naches spawning distributions,
2. Clarify the extent, distribution, and contribution of mainstem spawners,
3. Estimate population specific adult escapement and spawner abundances for each population,
4. Assess, and ground-truth the long-term prospects for using GSI and PIT-tagging techniques for apportioning the total run at Prosser Dam.

The study will also collect other valuable spatial and temporal life history information specific to each population, including:

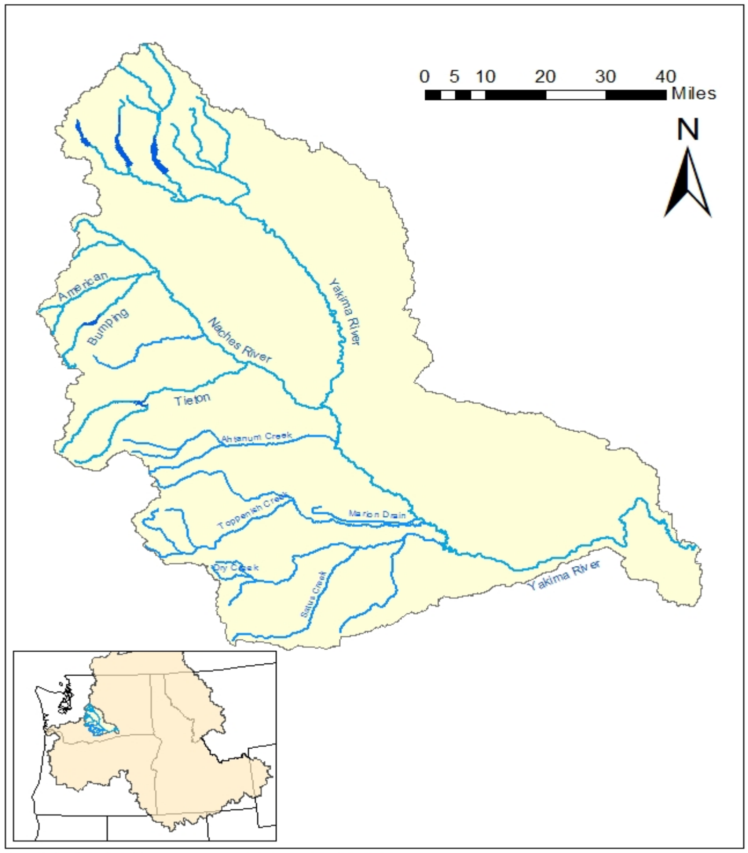
1. Run timing
2. Pre-spawn migration and holding patterns
3. Pre-spawn survival
4. Spawn timing
5. Number of redds constructed per female
6. Age structures (freshwater, ocean and total) and sex ratios
7. Survival to kelting rates

This report appendix is intended to provide annual progress updates for research associated with Biological Objective 1, "Determine spatial distribution and major (MSA) and minor (MiSA) spawning areas of steelhead spawning populations in the Yakima MPG", and for the adult abundance portion of Biological Objective 2 "Estimate juvenile and adult abundance for individual populations" presented in the Yakima Steelhead VSP Project descriptive.

Methods

Study Area

The Yakima Subbasin is located in south-central Washington. It drains an area of 6,155 square miles and contains about 1,900 river miles of perennial streams (Figure 2). The Yakama Indian Reservation is located in the southwest corner of the subbasin just south of the city of Yakima. Major Yakima River tributaries contained within the Reservation include Satus and Toppenish watersheds. The Yakima River originates near the crest of the Cascade Range above Keechelus Lake at an elevation of 6,900 feet and flows 214 miles southeastward to its confluence with the Columbia (RM 335.2). Major tributaries outside the Yakama Indian Reservation include the Kachess, Cle Elum and Teanaway rivers in the northern part of the subbasin, and the Naches River in the west. Six major reservoirs are located in the subbasin. The Yakima River flows out of Keechelus Lake (157,800 acre feet), the Kachess River from Kachess Lake (239,000 acre feet), the Cle Elum River from Cle Elum Lake (436,900 acre feet), the Tieton from Rimrock Lake (198,000 acre feet), and the Bumping from Bumping Lake (33,700 acre feet). Topography in the subbasin is characterized by a series of thrust fault ridges extending eastward from the Cascades. These Ridges divide the Yakima River into several macro floodplain reaches, each unique to its own physical characteristics. Elevations in the subbasin range from about 7,000 feet in the Cascades to about 350 feet at the confluence of the Yakima and Columbia rivers.



Paul Huffman, Yakama Nation Fisheries, 12/13/2011 C:\avdata\subbasin\yak\yakbasin.mxd

Figure 2. Map of the Yakima River Basin and proximity in the Interior Columbia Basin.

Radio tag description

We will be using digitally encoded Lotek MCFT2-3A-M gastric implanted radio tags for the duration of the study. The radio tags are 16x46mm in size, and have an air weight of 16 grams. The tags are outfitted with motion sensors capable of emitting both active and inactive codes. A radio tag implanted in a live swimming fish will continually transmit an active code. In the event the tag has been regurgitated or the fish has been depredated, the tag will emit an inactive code after laying motionless for a 24 hour delay period. The motion sensor feature will greatly assist in determining tag regurgitation rates and depredation events of individual fish.

Tags will use Lotek's 2000 code set, and spread out over 5 different narrowband radio frequencies consisting of 150.680, 150.720, 151.520, 151.720, and 151.800. The motion sensor feature of the radio tags limits the number of tags to 100 per frequency. With an anticipated number of tags ranging from 400-500 per year (see sampling design below), it was necessary to use 5 different frequencies. The use of 5 frequencies will also reduce the incident of emitted signal collisions that compromise the ability of receivers to detect and record individual tag codes. To further alleviate tag collisions within individual frequencies, 4 different burst rates will be used consisting of 3.5, 4.0, 4.5, and 5.0 seconds. The operational life of tags will range from 330 days to 185 days. With tagging efforts spread over an 8 month period, it was necessary to vary the tag life to ensure tags from one year are not emitting signals into the next years study period. As an example, steelhead tagged in September and October will receive a tag with a life expectancy of 330 days, expected to last through August or September of the following year. A steelhead tagged in April will receive a tag with a life expectancy of 185 days, also expected to last through September before termination.

Sample size and distribution of radio tags

A large enough sample size of radio tagged adults will be needed for the following:

1) Population specific adult & spawner escapement- Multiplying the proportion of tagged fish migrating into each of the four independent sub-populations by the total steelhead run size counted at Prosser Dam will generate steelhead abundance levels for each Yakima Basin steelhead sub-population.

2) Population specific life history analysis- Run-timing, adult holding, spawn timing, age structure, sex ratios and kelting rates will be estimated from biological sampling of adults that are radio tagged and partitioned into populations based on spawn location and GSI assignment.

Other important considerations for estimating and selecting an appropriate number of adults to be tagged for the study include: 1) the proportion of run that utilizes the right bank ladder where the denil trap is located, and 2) the strength of annual run size the sample is to be drawn from. Additionally, we used 90% confidence limits (z =1.645) for our estimates in order to keep sample sizes reasonable. Our approach to sampling a finite population is summarized by the following equations:

Equation 1. $p \ +/- \ \ d$

to

Equation 2. $p \ +/- \ \ z * \sqrt{\frac{p*(1-p)}{n} * [1 - \frac{n}{N}]}$

wherein:

z is from a standardized normal-distribution table (z table1)
p is the estimated proportion of a given population in the Prosser adult run size
N is the adult passage at Prosser

n is the sample size at Prosser

In Equation 2, $\frac{p*(1-p)}{n}$ is the usual variance of the sample proportion and $[1-\frac{n}{N}]$ is the adjustment in that variance due to sampling from a finite population.

The sample size is thus estimated by equating from Equations 1 and 2

$$d = z*\sqrt{\frac{p*(1-p)}{n}*[1-\frac{n}{N}]}$$

and then solving for n and using Q = n/N as the proportion sampled,

Equation 4.a $$\mathbf{Q = n/N = \frac{1}{1+\frac{N*d^2}{z^2 p*(1-p)}}}$$

and Equation 4.b. n = Q*N

Three total run sizes were used in the analysis consisting of the recent 5 year mean (3156), min (1523) and max (5793 and still counting) run sizes enumerated at Prosser dam from 2005/06 to 2009/10. The variability across the 5 year period emphasizes the need for evaluating sampling sizes across a fairly broad range of run sizes potentially occurring within the three year study period.

Estimated proportions of individual populations within the run at large were needed for the sample size analysis. We used the 10 year geometric mean abundances estimated by the ICTRT that were derived for stock status assessments for the Yakima River MPG (YBFWRB 2009). We computed population proportions by dividing their respective geometric means by the total sum of 10 year geo-means (Table 1). The largest and smallest populations were both used in the analysis which consisted of the Naches (37.7%) and the Upper Yakima (6.5%). For simplicity, the Naches proportion was rounded to 40% and the Upper Yakima was rounded to 10%. The 6.5% is based on the abundance of adults enumerated at Roza dam and does not include any mainstem spawning activity below the dam. Therefore, we felt the use of 10% was adequate for this analysis.

Table 1. 1995-2004 Geometric means of spawner abundance for Yakima MPG populations (ICTRT 2007).

Yakima River Steelhead Population				
	Satus	Toppenish	Naches	Upper Yakima

1995-2004 Geomean	405	344	505	87
Proportion of total spawners	30.2%	25.6%	37.7%	6.5%

For column E in tables 3 and 4 (below), we set up the confidence limits as:

$$d = r*p$$

where r is the desired +/- value as a proportion of p

A range of r values were initially considered (Table 2) for p = 0.1 (Upper Yakima population receiving 10% of Prosser's passage) and p = 0.4 (Naches population receiving 40% of Prosser's passage).

Table 2. Values of d (for +/-d) across a range of r values for Naches and Upper Yakima populations.

Computed values of d for +/d		
r values	Upper Yakima (p = 0.1)	Naches (p = 0.4)
r = 0.1	0.01	0.04
r = 0.2	0.02	0.08
r = 0.4	0.04	0.16

Using the largest and smallest proportionate populations in the analysis created a lower and upper bound for the +/- d values so it was not necessary to analyze the other two populations based on the assumption that proportions of these populations fall within the range of 10-40%.

Initial estimates of sample sizes using r values ranging from 0.1 – 0.4 for the 5 year min, max and mean run sizes indicated that larger sample sizes were needed for smaller p values (0.1) in order to achieve similar +/- d values to those estimated for larger p values (0.4). This suggests the sample size needed for the radio telemetry study should be based on the acceptable confidence limits computed for the smallest p value of 0.1 (i.e. upper Yakima population at 10% of the total run). The specified confidence limits for a p value of 0.1 using the upper and lower r values (0.1 and 0.4) are summarized in column J. (Table 3). Results for an r value of 0.1 provide a confidence interval of 9.0-11.0% but the sample sizes ranging from 937 to 1714 are not reasonable, cost effective, and require an un-achievable sampling rate that may also have undesired impacts to an ESA listed species. In contrast, results for an r value of 0.4 demonstrate a cost effective sample size ranging from 138 to 148 that requires a small proportion of the run to be tagged. However, there are several concerns and deficiencies with this sample size. A confidence interval of 6.0-14.0% may not provide an accurate estimate for comparison to stock proportion estimates from

GSI techniques. Without an accurate estimate for comparison, our ability to assess and validate the long term usage of GSI for disaggregating the run at large will likely be compromised. In addition, it is doubtful a sample size ranging from 138 to 148 will be of sufficient size for conducting life history analysis when apportioned to each of the four individual steelhead populations.

Table 3. Summary of sample size analysis across an expected range of Yakima River steelhead run sizes for p=0.1 (upper Yakima), and r values of 0.1 and 0.4.

A. Population	B. Prosser adult passage (N)	C. Proportion of Run in Subbasin (p)	D. Desired +/- Value as a proportion (r) of p	E. actual +/- value +/-d = +/-r*p	F. Desired Confidence Interval Percentage	G. Table Z value	H. Proportion of Prosser passage tagged (Q)	I. Number (n) Sampled at Prosser	J. Specified Confidence Limits Summary				
Upper Yakima	1,523.00	0.1	0.1	0.01	90%	1.645	0.62	937	90%	CI=	9.0%	to	11.0%
	3,156.00	0.1	0.1	0.01	90%	1.645	0.44	1,375	90%	CI=	9.0%	to	11.0%
	5,793.00	0.1	0.1	0.01	90%	1.645	0.30	1,714	90%	CI=	9.0%	to	11.0%
Upper Yakima	1,523.00	0.1	0.4	0.04	90%	1.645	0.09	138	90%	CI=	6.0%	to	14.0%
	3,156.00	0.1	0.4	0.04	90%	1.645	0.05	145	90%	CI=	6.0%	to	14.0%
	5,793.00	0.1	0.4	0.04	90%	1.645	0.03	148	90%	CI=	6.0%	to	14.0%

Table 4. Summary of sample size analysis across an expected range of Yakima River steelhead run sizes for p=0.1 (upper Yakima) and p=0.4 (Naches), and respective r values of 0.2 and 0.08.

A. Population	B. Prosser adult passage (N)	C. Proportion of Run in Subbasin (p)	D. Desired +/- Value as a proportion (r) of p	E. actual +/- value +/-d = +/-r*p	F. Desired Confidence Interval Percentage	G. Table Z value	H. Proportion of Prosser passage tagged (Q)	I. Number (n) Sampled at Prosser	J. Specified Confidence Limits Summary				
Upper Yakima	1,523.00	0.1	0.2	0.02	90%	1.645	0.29	435	90%	CI=	8.0%	to	12.0%
	3,156.00	0.1	0.2	0.02	90%	1.645	0.16	510	90%	CI=	8.0%	to	12.0%
	5,793.00	0.1	0.2	0.02	90%	1.645	0.10	551	90%	CI=	8.0%	to	12.0%
Naches	1,523.00	0.4	0.08	0.03	90%	1.645	0.29	435	90%	CI=	36.7%	to	43.3%

3,156.00	0.4	0.08	0.03	90%	1.645	0.16	510	90%	CI=	36.7%	to	43.3%
5,793.00	0.4	0.08	0.03	90%	1.645	0.10	551	90%	CI=	36.7%	to	43.3%

Of the r values considered in the sample size analysis, 0.2 provides a reasonable confidence interval of 8.0-12.0% (upper Yakima population) while keeping the sample size within a cost effective range, and achievable sample rate. The specified confidence limits are summarized in Column J. of Table 4. For run sizes ranging from 1523 to 5793, sample sizes of 435- 551 require approximately 10-29% of the run to be tagged (Table 4, columns I and H). A tagging rate of 10-16% is attainable for mid to larger run sizes but at smaller run sizes, the required tagging rate increases to about 29%. If this circumstance arises, the number of fish tagged will likely range from ~300 to 350 fish at a sample rate of about 19-22%. Run sizes are often difficult to predict, but we anticipate a range from about 2500-5500 adults over the 3 year duration of the study.

Confidence intervals and r values for the Naches population (p=0.4) were calculated using the estimated sample sizes for p=0.1 and r =0.2 over the range of run sizes (Table 4). This was done by inputting the sample size estimates into excel's solver and solving for r (column D). The +/- r values were estimated at 0.08 with a confidence interval of 36.7-43.3%.

The sample rate analysis indicates that reasonable statistics can be achieved with sample sizes ranging from approximately 430-550 and that r values will range from 0.2-0.08, depending on the actual proportions of each individual population. Actual tagging numbers will likely range from 350-500 and will be dependent on the actual run size, and right bank ladder usage where the trap is located.

Distribution of tagging effort

Run timing of steelhead over Prosser Dam (Rkm 75.6) typically begins in late August/ early September, and extends into the latter part of May (Figure 3). Although not apparent from the 10 year mean, the run is characterized by a bi-modal peak with the first occurring in the late October/early November period, and the second generally occurring in the January or February the following year. The Sample efforts will be stratified across the entire run beginning in September and potentially extending into the first part of May. Specifically, historical estimates of the proportion of run passing Prosser dam on a monthly basis will be used to guide the stratified tagging effort based on the 10 year mean.

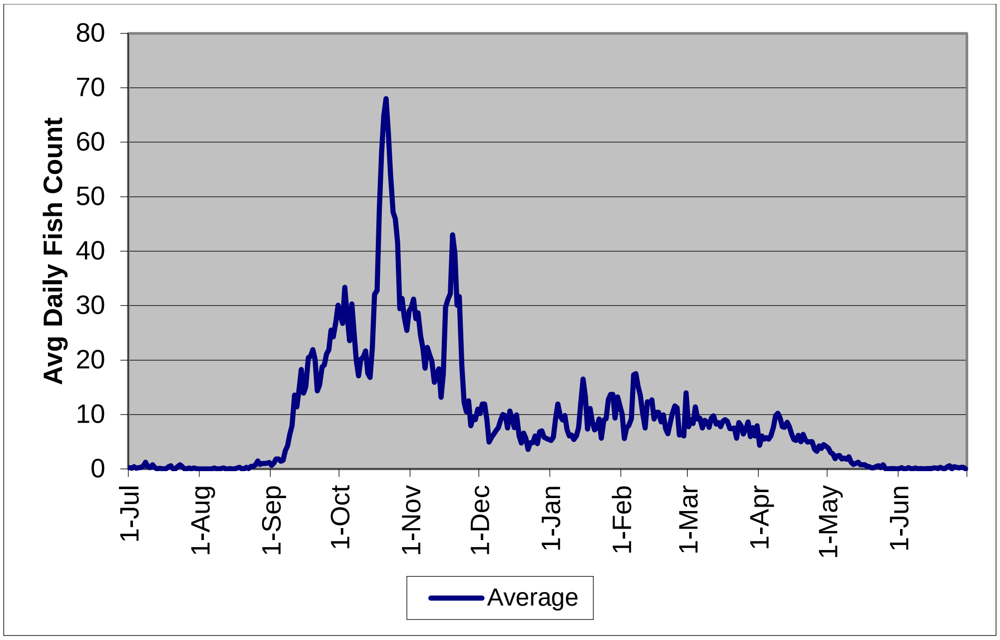


Figure 3. Yakima River summer steelhead run timing at Prosser Dam (RKM 75.6).

Tag application and bio-sampling procedures

Radio tagging operations will be conducted at a denil fish trap located adjacent to the right ladder on the Prosser Dam (Rkm 75.6). During trapping operations, the main ladder is blocked, leading fish up a steep pass before entering one of two chutes. One chute leads to a large holding tank where fish are collected when personnel are not actively working on fish. Fish are then re-directed into a staging tank via a second chute where personnel collect fish using a dip net. Fish identified for sampling and tagging are then transferred into a tank where they are anaesthetized with tricain methanesulphonate (MS-222) prior to sampling and tagging. Upon sedation, scale and DNA (tail fin clips) samples will be collected first while keeping the fish partially submerged. Lengths, weight, and sex information will then be collected prior to scanning the fish for external marks, CWTs, and PIT tags. If an existing PIT-tag is not detected upon interrogation, one will be placed in the dorsal sinus cavity located adjacent to the dorsal fin, or the pelvic girdle, located on the underside of the fish between the pelvic fins. Lotek MCFT2-3A-M (16x46mm in size, 16 grams air weight) radio tags will be placed through the mouth, and into the stomach using a PVC esophageal implant tube. Fish will be placed in an adjacent recover tank and held for approximately 20 minutes or until total equilibrium is regained, and reappearance of avoidance swimming is evident. Upon recovery, fish will be immediately released upstream of Prosser Dam and the denil trap. Radio tags will be spread across the 150-152 Mhz frequency range using 5 different channels. Twelve to 14 month duration radio transmitters will be used 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. These recovered 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 in the resident/anadromous interactions monitoring of the VSP project.

Telemetry Receivers

A combination of Lotek fixed-station radio receivers and ground surveys with mobile receivers will be used to monitor survival, migration patterns, and final spawning locations for each tagged fish. Fixed-stations will consist of Lotek SRX 400 and SRX 600 receivers using 1-3 antennas per site. Mobile tracking will use 2 SRX 400A/SRX 600 receivers with GPS and antennas mounted to vehicles, boats and planes.

This study is being coordinated with a lamprey radio telemetry project in the Yakima Basin under the Yakama Nation's Lamprey Project # 2008-470-00 Yakama Nation Ceded Lands Lamprey Evaluation and Restoration. The total number of fixed site receiver locations provided by the two projects will be approximately 14 (Figure 4).

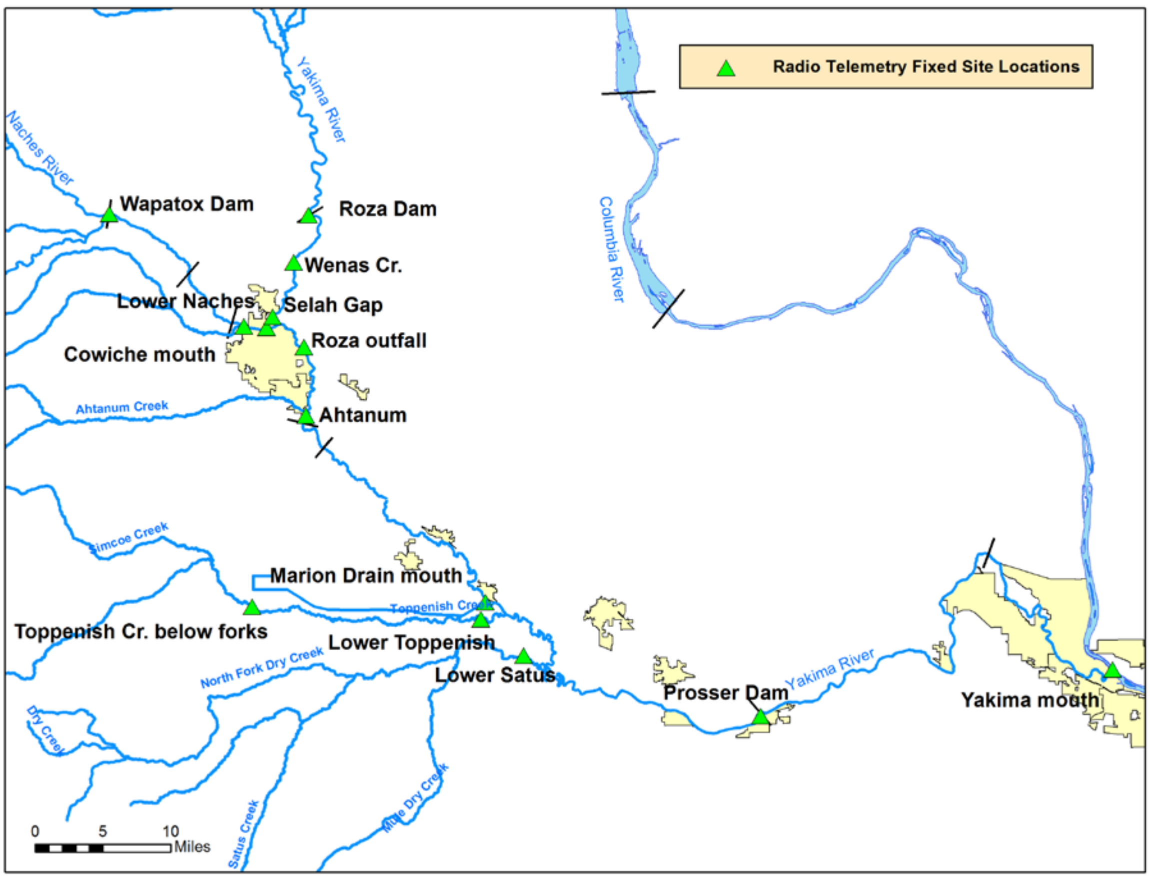


Figure 4. Map of Yakima Subbasin: Radio telemetry fixed site monitoring locations

Installation and Maintenance of Fixed Site Locations

Installation, configuration and maintenance of fixed site receivers and antennas will be conducted by several field technicians from various agencies including the Yakama Nation, U.S. Fish & Wildlife Service, and NOAA Fisheries. the initial installation of fixed sites occurred between July of 2011, and October of 2011. Due to the duration of run-timing, pre-spawn holding and spawn timing, the fixed sites will remain in place for the entire three year period with maintenance trips scheduled as needed. Fixed sites will use a variety of Yagi directional antennas including three, four, and 5 element antennas. Power supply will be site specific, consisting of both grid and solar as power sources. On occasion, battery banks will be swapped out on a weekly basis for areas void of grid power and areas not conducive for use of solar power equipment. A typical solar powered fixed site using two Yagi directional antennas is pictured below (Figure 5).

Figure 5. Typical Solar powered fixed site with two Yagi directional antennas positioned for upstream and downstream detections, upper Toppenish Cr.

Radio Tracking and Data management

Biologists from the lamprey and steelhead radio telemetry projects will collaborate on tracking efforts, routine site check-ups, and weekly data downloads. Raw data will be imported into a telemetry database where data quality control and baseline analysis will be used to check receiver records for known tags released, noise records, and data summaries. Radio telemetry experts with NOAA Fisheries will be contracted to perform all tasks associated with database management. Any problems and malfunctions of the receivers will be immediately reported to the individuals scheduled for fixed site maintenance operations. A summary of unique fish detections from fixed site locations will be provided weekly to field crews in order to assist and guide mobile tracking efforts throughout the monitoring season. Mobile tracking surveys will be used to monitor fish movement and holding patterns between fixed site locations, and to identify individual spawning locations.

Use of Telemetry Study for assessing long-term usage of remote instream PIT-tag detection arrays

One of the objectives of the radio telemetry study is to assess the efficacy of using remote instream PIT-tag detection arrays for estimating population-specific spawner abundance for the indefinite future. The number of unique PIT-tags detected on instream arrays will be used to apportion the total Yakima River steelhead count (enumerated at Prosser Dam, RKM 75.6) into spawner escapement estimates for each of the four individual steelhead populations. Similar to the radio telemetry study methods, the base algorithms will expand the number of unique PIT-tags detected from instream arrays using the sampling and tagging percentage of the total steelhead run enumerated at Prosser Dam. Independent spawner abundance estimates from instream PIT-arrays will be compared to those generated from the radio telemetry study to determine precision and accuracy for three consecutive years.

The remote instream-PIT-detection arrays were installed below the known spawning distributions of the Satus and Toppenish Cr. populations. These monitoring sites are situated on the lower extremities of Satus Cr (Rkm 4.75) and Toppenish Cr (Rkm 1.70), just upstream from their respective confluences with the Yakima River (Figure 5).

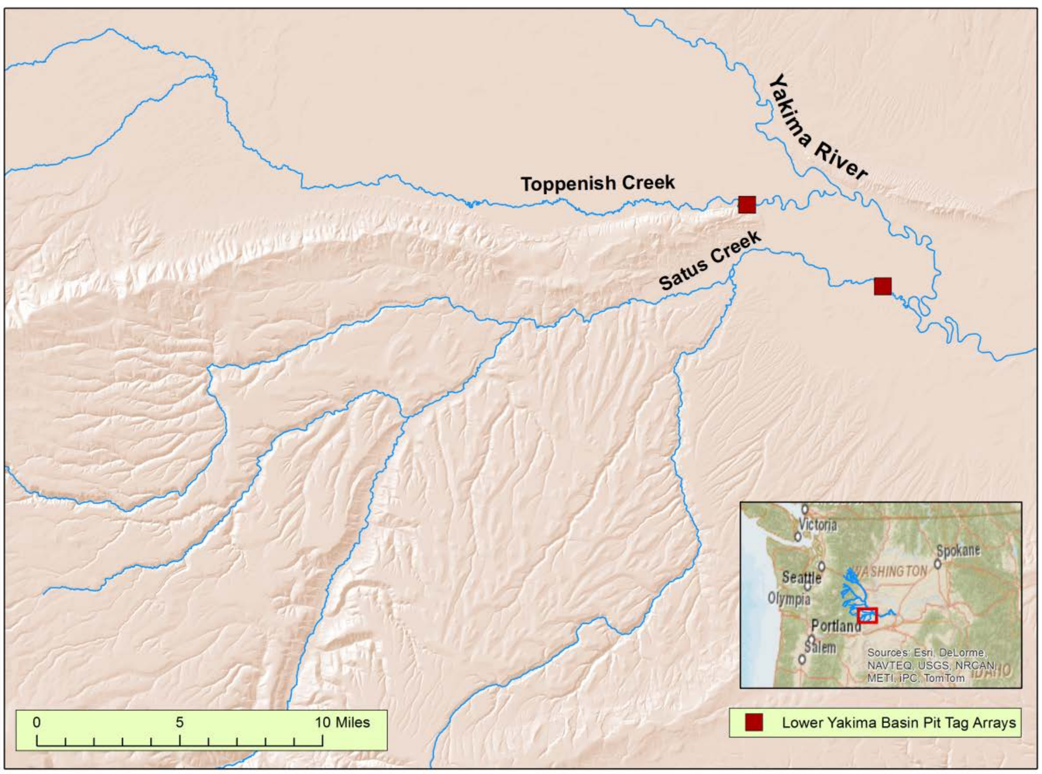


Figure 6. Map illustrating the locations of the Satus Cr. and Toppenish Cr. remote instream PIT-Tag detection arrays.

The assessment of using Remote Instream PIT-tag detection arrays for long term status and trends monitoring of spawner abundance will evaluate several essential elements including:

1) **Adult detection efficiencies of instream-array antennas-** Determination of the array detection efficiency is critical for accurately estimating adult spawner escapement. Detection efficiencies will be evaluated with adult steelhead that are tagged with both PIT-tags, and radio tags. The PIT-array detection efficiency will be calculated using the proportion of PIT-tags detected from the total number of known migrants to have passed over the array. The total number of known migrants will be equal to the number of radio tagged adults that were detected simultaneously, and continued upstream.
2) **Ability to determine directionality of adult movement-** For the purpose of determining upstream and downstream movement patterns of adult steelhead, detections of adults will need to be picked up on both channel spanning antennas (There are 2 antennas at each site). Upstream and downstream movement patterns as determined by the radio telemetry data, will be compared to detection histories and interpretations of directionality from the PIT-detections.
3) **Suitability of location for long-term monitoring of adult spawner escapement-** Based on available data, it is assumed the pre-determined locations of the Satus and Toppenish Instream PIT-arrays are situated below the spawning distributions of their respective populations. This assumption will be tested and looked at with additional spawning information as it comes readily available from the radio telemetry study.
4) **Reliability and longevity of monitoring equipment-** In order to use the Instream PIT-arrays for long term status and trends monitoring of adult abundance, the antennas and equipment must prove somewhat reliable, particularly for the time strata spanning adult movement from November to May. The equipment must demonstrate the ability run continuously without power outages, electrical equipment failure, and also antenna failure.

Results

All results presented below are considered preliminary and are subject to future revisions if deemed necessary. Final results will be available upon the completion and reporting of the synthesized 3 year Telemetry study. Run-timing of steelhead over Prosser Dam typically begins in late August/early September and extends into late April/early May the following year. The 2011-12 total estimated run size of summer run steelhead as enumerated at Prosser Dam was 6,359 consisting of 6208 natural origin, and 151 hatchery origin. Of these, 493 wild fish and 14 hatchery fish were outfitted with both Radio tags and PIT-tags (Table 5). An additional 214 were PIT-tagged only, resulting in a total of 721 PIT-tagged steelhead. Correcting for tagging effects reduced the total effective sample size for Radio tagging from 507 to 484 (23 mortalities), and from 721 to 698 for PIT-tagging. The final fate of radio tagged steelhead were condensed into 3 general categories including steelhead that survived to spawn, left the basin prior to spawning, or presumably died before spawning from a number of causes (Table 5). The total Yakima MPG Spawner escapement was further broke out by individual populations including Satus Cr, Toppenish Cr, Naches R, and Upper Yakima R populations (Table 6). A comparison between the radio telemetry and PIT-tag expanded population adult escapement estimates suggest no significant differences between the methods (Table 7). The instream PIT-tag detection arrays had remarkably high detection efficiencies during the first year of the study, with 100% of the radio tagged fish being detected in the Toppenish Cr PIT-tag array, and 96.9% of the radio tagged fish being detected in Satus Cr PIT-tag array (Table 8).

Table 5. Summary of Yakima steelhead MPG enumeration, sampling rates, and fate of fish.

Yakima River MPG steelhead	**total**		**% of total run**	**# wild**	**# Hatchery**
2011-12 Prosser Dam counts	6359		100%	6206	153
# Radio tagged Steelhead	507		7.97%	493	14
# PIT-tagged Steelhead	721		11.34%	700	21
Fate of steelhead as determined by Radio Telemetry	**total**	**CI (α = .05)**	**% of total run**	**# wild**	**# Hatchery**
Total Yakima MPG Spawner escapement	5274	(+/- 86)	82.9%	5156	119
Non-migrants (left Yakima basin)	270	(+/- 175)	4.3%	238	32
Natural In-river mortalities (All possible sources)	791	(+/- 112)	12.4%	791	0
Tagging Mortalities	23	N/A	0.4%	23	0

Table 6. Radio Telemetry spawner escapement estimates by population

2012 Preliminary Radio Telemetry spawner escapement estimates		
Population	Abundance	CI (α = .05)
Satus Cr	1859	+/- 216
Toppenish Cr (Includes Marion Drain)	694	+/- 167
Naches R	2214	+/- 217
Upper Yakima R	507	+/- 147

Table 7. Expanded PIT-tag spawner escapement estimates and comparisons

Comparison between Radio Tag and PIT tag based escapement estimates			
Method	Population	Abundance	CI (α = .05)
Radio tag (N=484)	Satus Cr	1859	+/- 216
PIT-tag (N=698)	Satus Cr	1906	+/- 212
Radio tag (N=484)	Toppenish Cr*	620	+/- 160
PIT-tag (N=698)	Toppenish Cr	626	+/- 140
PIT-tag array difference	Satus Cr	+2.5%	
	Toppenish Cr	+1.0%	

*For direct comparison to PIT-array estimates, the Toppenish Cr radio telemetry abundance estimate does not include the Marion Drain spawner escapement, and therefore differs from the estimate in Table 1.

Table 8. 2012 Detection efficiencies of Remote Instream PIT-tag detection Arrays

Metric	Satus Cr Instream PIT-Array	Toppenish Cr Instream PIT-Array
Total number of radio+PIT tagged fish migrating over PIT-array	159	48
Total number of PIT-tags detected	154	48
PIT-Array detection efficiency	96.9%	100.0%