Upper Columbia Spring Chinook Salmon and Steelhead Juvenile and Adult Abundance, Productivity, and Spatial Structure Monitoring

BPA Project Number 2010-034-00

Report covers work performed under BPA contract #(s) 65731, 65556, 69402, 69526

Report was completed under BPA contract #_69402__

Report covers work performed from: January, 2015 – December, 2015

Benjamin L. Truscott, Andrew R. Murdoch, Jeremy M. Cram

Washington Department of Fish and Wildlife, Wenatchee, Washington

Kevin See, Quantitative Consultants Inc., Boise, Idaho

Report Created: March, 2016

"This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA."

Contents

Abstract

Refinement of the methodology used to estimate steelhead abundance in the Upper Columbia River basin has been greatly improved and include estimates of uncertainty. Using passive integrated tags (PIT) tags and instream PIT tag detection sites located throughout the Upper Columbia River basin, estimates of hatchery and wild steelhead abundance have been generated for five years with estimates of uncertainty at or near the recommended level of precision for monitoring salmon and steelhead in the Columbia River basin. The same methodology has also been used to estimates steelhead spawner abundance in tributaries. Following the completion of a radio telemetry study to independently validate some aspects of the new PIT tag based approach, the new methodology and revised estimates will be adopted by the WDFW and co-managers, representing a new standard for status and trend monitoring. In addition, progress in developing methodologies to estimate spring Chinook egg to fry survival and the distribution and habitat utilization of subyearling parr in non-wadable rivers shows great progress towards incorporating these life stages and important rearing areas into life cycle models.

Introduction

Despite the incredible amount of resources devoted to salmon and steelhead recovery, most ESA-listed populations in the Upper Columbia River basin (UCR) are not meeting delisting criteria. Collective efforts to date have not shown habitat restoration and hatchery supplementation, as currently applied, to be effective recovery tools (Ford, 2011; Maier, 2014). This project seeks to develop and implement a process that builds upon and augments data from existing monitoring and evaluation (M&E) programs to identify factors limiting desired performance (e.g., productivity, abundance) and efficiently inform the recovery actions directed at salmon and steelhead populations.

A unique, well-coordinated and standardized M&E effort exists in the UCR. Adult and smolt monitoring of all primary populations in the UCR has been ongoing for several years. M&E programs are currently being funded by BPA (ISEMP, OBMEP), and Chelan, Douglas, and Grant County Public Utility Districts. Activities under the M&E programs are being conducted by various Federal, State, Tribal, and County agencies and private contractors. A high degree of coordination and cooperation among programs and contractors has allowed for standardization of metrics and methodologies throughout much of the UCR. Despite the comprehensive nature of these programs, uncertainty exists regarding the accuracy and precision of both juvenile and adult abundance estimates. This status and trend project seeks to estimate the accuracy and precision of several of the current methodologies used in the ongoing monitoring programs, and where applicable, revise methodologies in order to meet accuracy and precision recommendations for monitoring viable salmonid population (VSP) parameters (Crawford and Rumsey 2009).

The objectives of this project address in part or fully the critical uncertainties identified under Supplementation in the Columbia River Basin Research Plan and steelhead population characteristics (abundance, productivity, and ratio of hatchery fish) under the Fish and Wildlife Program. Additionally, these objectives address many of the reasonable and prudent alternatives (RPAs) for the Federal Columbia River Power System Biological Opinion. Washington Department of Fish and Wildlife (WDFW) is the lead agency for the project in the Wenatchee and Methow subbasins. In the Okanogan subbasin, the Colville Confederated Tribes is the lead agency. Many of the components of the project are dependent upon each other and will be implemented over several years in a specific sequence to maximize efficiency and results.

The remaining and/or ongoing objectives of the project are to (1) utilize a PIT tag based model to estimate escapement of natural and hatchery origin steelhead in each primary population of the upper Columbia River basin (Wenatchee, Entiat, Methow, Okanogan), and the number of those fish that reach tributary spawning grounds; (2) conduct a steelhead radio telemetry study to independently validate adult escapement estimates generated from the PIT tag based model, and estimate steelhead population characteristics; (3) estimate the egg to fry survival in spring Chinook throughout major spawning areas and (4) describe reach specific juvenile spring Chinook Salmon overwinter habitat utilization in the mainstem Wenatchee River. Completed objectives of the project previously reported on include: evaluating the accuracy of the steelhead spawning ground survey design, estimating the precision of redd counts for both steelhead and spring Chinook Salmon, developing analytical tools to automate and standardize the analysis of PIT tag data from instream PIT tag detection sites (IPTDS) and evaluating the precision and accuracy of the smolt monitoring methodology for both steelhead and spring Chinook Salmon.

Methods

Steelhead Stock Assessment

A key component to estimating UCR steelhead populations is the steelhead stock assessment work at Priest Rapids Dam (PRD) during which a representative sample of steelhead are sampled and PIT tagged. Escapement estimates of wild steelhead in 2011 and 2012 suggested that a greater tag rate at PRD was needed to reduce uncertainty in the PIT tag based escapement estimates generated. In response, the sampling rate was increased from 2 days per week to 3 days per week in 2013 and beyond with the goal of obtaining a 15% tag rate. Methods conducted in 2015 are consistent with the methods described in Monitoring Methods protocol 235, http://www.monitoringmethods.org/Protocol/Details/235.

PIT Tag Based Steelhead Abundance Model

Development of the UCR steelhead PIT tag escapement model has been ongoing since 2010. Quantitative Consultants Inc. (QCI) has been subcontracted under this project to lead the development of the model, with assistance from WDFW. The methodology employed was originally developed by QCI to estimate adult steelhead abundance for Snake River basin populations and has been adapted to address the conditions present in the UCR. The model is updated annually to include newly installed IPTDS. However, the process is consistent with the methods described in See, 2014, and in Monitoring Methods protocol 504, http://www.monitoringmethods.org/Protocol/Details/504.

Inherent in the PIT tag escapement estimation is the operation and maintenance of IPTDS in the UCR. All UCR IPTDS are operated consistent with protocols and guidelines developed by NOAA under the ISEMP project (BPA contract 2003-017-00). The maintenance protocols include:

1. Respond to alarms/notifications generated from QCI server on a daily or as needed basis. Follow up with site visit to troubleshoot as necessary. At times requires logging into QCI server to check reports and troubleshoot likely causes; i.e., antenna unplugged or low voltage due to switcher/timer. Contact QCI staff as necessary to turn alarms on or off.

2. Weekly site visits (or monthly for sites with data loggers and modems that can be monitored remotely) to conduct routine maintenance and visual inspection of antennas. Removal of debris as necessary. Cycle through transceiver settings and document errors. Record site conditions in log book for reporting to PTAGIS. Troubleshoot malfunctions and fix as necessary and able (i.e., reconnect cables, restart MUX, verify battery voltage, etc.)

3. Quarterly visits (as flow allows) to inspect strapping on each anchor for wear and replace as needed. Inspect communication cables and connection points. Replace zip ties at each connection point. Tune each individual antenna. Inspect batteries and other equipment in power supply/transceiver box. Notify NOAA Electronic Technician if repair or equipment is needed. Submit site event logs to PTAGIS.

4. Annual site visits to conduct routine maintenance to replace all straps in early spring prior to high flows.

5. Scheduling repairs/assistance beyond scope of WDFW contract on an as needed basis. Contact NOAA Electronic Technician when equipment failure is experienced beyond the scope of WDFW routine maintenance, such as antenna replacement, transceiver software troubleshooting, updating firmware, communication failures and fixing power supply failures.

Steelhead Radio Telemetry

Adult steelhead were radio tagged (tags inserted gastrically) at PRD during annual stock assessment activities. A target of 500 radio tagged fish was selected in order to maximize sample size for statistical analysis while remaining within permitted limits. A set tagging rate was determined preseason (based on run size projections) in order to ensure the radio tagged fish were equally dispersed amongst the entire population and representative of the entire UCR run. Fixed detection sites were installed at key locations throughout the UCR, including at mainstem Columbia River dam sites, near the mouths of major tributaries, and at the upper extent of suspected overwinter holding areas. Fixed sites were downloaded at two week intervals. Mobile tracking of the entire UCR was conducted during winter months to identify overwinter holding locations. Methods for tagging and tracking are consistent with the methods described in Monitoring Methods protocol 323, http://www.monitoringmethods.org/Protocol/Details/323.

Egg to Fry Survival

Spring Chinook Salmon eggs were collected from excess hatchery origin spring Chinook Salmon from the Eastbank Hatchery program. Egg boxes with 100 fertilized eggs are placed in all study sites weekly through the duration of natural spawning activity within the target watershed. Boxes are recovered the following winter and spring, after having accumulated approximately 1000 thermal units (ATU). Generally, a minimum of three weeks are required to place boxes with fertilized gametes into the selected study sites. Weekly box placements are intended to provide some temporal context to the design over the rage of natural spawning, primarily seasonal drops in water temperature which may differ spatially throughout the spawning range. Boxes are generally recovered over a period of four to five months the following spring, dependent upon temperature accumulation rates. Methods conducted in 2015 are consistent with the methods described in Monitoring Methods protocol 2103, http://www.monitoringmethods.org/Protocol/Details/2103 and in Johnson et al. (2012).

Parr Distribution and Habitat Utilization

In an effort to describe reach specific juvenile spring Chinook Salmon overwinter habitat utilization, a combination of floating and walking surveys with mobile PIT tag detection equipment were conducted throughout the mainstem Wenatchee River. In addition, a spatially continuous edge habitat survey was conducted. Individual edge habitat units were mapped throughout the mainstem Wenatchee River from the outlet of Lake Wenatchee to the confluence with the Columbia River. Beechie et al. (2005) suggested that in large rivers (i.e., > 10 m bankfull width) suitable juvenile salmonid habitat is primarily located along the stream margins. Edge habitat units were identified visually as natural bank edge, rip-rap bank edge, bar edge, backwater or rapids (Beamer and Henderson 1998; Beechie et al. 2005). In addition to the above edge habitat types, side channels were also mapped as they are known to be productive habitat for rearing juveniles (Martens and Connolly 2014). Edge types identified as rapids were not sampled as water velocity in rapids exceeds known suitable holding velocities for juvenile salmonids (Beechie et al. 2005). Individual edge habitat units were mapped using ArcPad on a tablet PC equipped with a GPS. Along with edge type, individual units were visually evaluated for dominant cover type, depth, water velocity, and dominant substrate size.

Floating surveys were conducted throughout the entirety of the Wenatchee River, aside from the Tumwater Canyon reach. Boat surveys were not feasible in Tumwater Canyon due to Class IV and V rapids present during normal flows. Walking surveys were conducted in the Tumwater Canyon reach. Floating surveys consisted of two rafts (lead and follow) equipped with PIT tag detection equipment, surveying in series downstream along the river margins. The follow raft trailed approximately 100m behind the lead raft, following the same route as the lead raft. Individual PIT tag detections on each boat were recorded on a tablet PC and georeferenced using a GPS, allowing for detections to be associated with an edge habitat classification type.

Paired surveys throughout the entirety of Tumwater Canyon were not possible due to time and staffing constraints. As such, a two-pass subsampling design was developed for Tumwater Canyon. Individual edge habitat units and accompanying cover, depth, velocity, and substrate data were organized into groups using principal components analysis (PCA). PCA yielded five groups of edge types; the group dominated by rapids was removed from consideration and the remaining habitat units were randomized by group for sampling priority. Tumwater Canyon edge habitat units from each PCA group were subsampled at 25% of the total length available of each type. Side channel habitat units were sampled completely. Fish sampling within each edge unit required two surveys conducted by separate surveyors within 48 hours of each other. Surveyors systematically sampled the entirety of the edge habitat unit working in the upstream direction. For habitat units where edge habitat extended more than 5m from the wetted edge of the river, only the first 5m were sampled. Side channel habitats outside of Tumwater Canyon that could not be surveyed during the floating surveys were subsequently sampled with single pass walking surveys. Methods conducted in 2015 are consistent with the methods described in Monitoring Methods protocol 2105, http://www.monitoringmethods.org/Protocol/Details/2105.

Results

Steelhead Stock Assessment

The 2015 steelhead sampling (brood year 2016) at Priest Rapids Dam began 6 July and concluded 12 November. Sampling consisted of operating the Priest Rapids Off Ladder Adult Fish Trap (OLAFT), located on the left bank of Priest Rapids Dam, 8 hours per day, three days per week (typically Monday, Wednesday and Friday), for a total of 59 sampling days. Steelhead were trapped, handled and released in accordance with Section 2.1 and 2.2.1 of the National Marine Fisheries Service Biological Opinion for ESA Permit 1395.

WDFW technicians sampled 2,778 steelhead of the 2015/2016 run-cycle passing PRD, totaling an estimated 14,363 steelhead (based on a 99.1% cumulative passage when trapping ended; M. Tonseth, personal communication, 11 March 2016), for an overall sampling rate of 19.34%. Of the steelhead sampled, 1,860 (67.0%) were hatchery origin and 918 (33.0%) were wild origin. Of those fish sampled, 2,634 steelhead were PIT tagged at PRD and 142 steelhead that were previously PIT tagged at another location, either as an adult or juvenile, were recaptured during sampling (Table 1). Three steelhead mortalities were observed post sampling, with one fish having been radio tagged. Examination of the radio tagged fish showed that the tag had perforated the stomach cavity. Run and spawning escapement estimates for 2015 sampling (brood year 2016) are not completed and will be reported in the following annual report.

Table 1. Summary of annual Upper Columbia River steelhead DPS stock assessment sampling at Priest Rapids Dam (H = hatchery; W = wild).

Brood year	Escapement		PIT Tagged		Tag Rate	
	H	W	H	W	H	W
2011	18,784	7,647	1,566	638	0.0834	0.0834
2012	15,911	4,895	2,083	642	0.1309	0.1311
2013	13,906	3,286	1,868	440	0.1343	0.1339
2014	9,464	5,468	1,370	792	0.1448	0.1448
2015	12,974	6,685	2,260	1,166	0.1742	0.1744
2016	9,617	4,746	1,858	918	0.1932	0.1943

PIT Tag Based Steelhead Abundance Model

The escapement model for brood year 2015 was run in two stages. Initially, all tagged fish were used (hatchery and wild) to estimate the probabilities of detection for the detection infrastructure. Then the posteriors distribution of those detection probabilities were used as priors in the second stage of the model, which was ran using only wild fish (n = 1,166), and then using only hatchery fish (n = 2,260). The probabilities of where the wild fish went were used to estimate wild escapement. To generate escapement estimates, the probability of a fish moving to any particular area was multiplied by the number of wild fish estimated to have crossed Priest Rapids Dam. The same process was then applied to the model run using hatchery fish. The total number of steelhead that crossed Priest Rapids Dam in the 2014/2015 run year was 19,659. For the escapement estimate model, the hatchery to wild ratio was assumed to be known without error. Sampling distributions were based on this ratio and the total number of steelhead in order to incorporate an estimate of uncertainty in how many hatchery and wild steelhead crossed Priest Rapids Dam. Run escapement estimates were generated for each primary population in the UCR steelhead DPS (Table 2) and spawning escapement estimates to the tributaries within each population (Table 3) for brood year 2015.

Table 2. PIT tag based run escapement estimates for primary populations of the Upper Columbia River steelhead DPS, brood year 2015.

Population	Population Run Escapement Estimate					
	Hatchery			Wild		
	Estimate	SE	CV	Estimate	SE	CV
Wenatchee River	1,507	9	0.059	1,323	73	0.056
Entiat River	61	19	0.302	631	55	0.093
Methow River	2,258	104	0.045	1,069	70	0.065
Okanogan River	1,045	73	0.071	444	49	0.105

WDFW operated and maintained 16 permanent IPTDS and two seasonal IPTDS in the Wenatchee and Methow River basins in 2015. The Colville Confederated Tribes (CCT) operated and maintained 7 permanent IPTDS and 13 seasonal IPTDS in the Okanogan River basin. An additional 8 permanent sites and two seasonal sites, operated and maintained through other funding sources, were utilized to develop the PIT based escapement estimates (Figure 1). All sites were maintained consistent with established protocols. All interrogation data collected by WDFW and CCT was uploaded to PTAGIS and all events affecting array performance (e.g., outages, maintenance, reduced detection range) were detailed in event logs submitted to PTAGIS (http://ptagis.org/services/event-logs/view-event-logs). WDFW installed and assumed operation and maintenance responsibilities for one new permanent site on Icicle Creek (Wenatchee River basin) in 2015 (site code ICM, http://ptagis.org/sites/interrogation-site-metadata?IntSiteCode=ICM). Funding to construct and install the site was provided through the Priest Rapids Coordinating Committee Hatchery Subcommittee as part of the Icicle Creek Boulder Field project. This permanent IPTDS will provide recapture data to improve PIT based escapement estimates in Icicle Creek, along with distribution and timing data to investigate passage at a major known barrier.

Table 3. PIT tag based steelhead spawner escapement estimates for tributaries within primary populations of the upper Columbia River steelhead DPS, brood year 2015.

Tributary/Reach	Tributary Spawning Escapement Estimate					
	Hatchery			Wild		
	Estimate	SE	CV	Estimate	SE	CV
			Wenatchee River			
Mission Creek	16	11	0.491	71	20	0.28
Peshastin Creek	33	15	0.370	204	33	0.158
Chumstick Creek	0	-	-	33	15	0.395
Icicle Creek	48	17	0.321	75	21	0.253
Chiwaukum Creek	8	9	0.717	44	16	0.335
Chiwawa River	164	39	0.229	157	35	0.208
Nason Creek	55	20	0.288	233	35	0.146
Little Wenatchee R.	0	-	-	0	-	-
White River	0	-	-	0	-	-
Colockum Creek[1]	0	-	-	40	14	0.403
			Entiat River			
Lower Entiat River	10	10	0.526	88	24	0.234
Mad River	9	8.5	0.567	216	34	0.157
Upper Entiat River[2]	23	13	0.429	270	38	0.141
			Methow River			
Gold Creek	68	37	0.417	101	64	0.454
Libby Creek	21	12	0.443	13	11	0.519
Beaver Creek	47	19	0.332	103	25	0.237
Twisp River	393	48	0.118	236	35	0.150
Upper Methow River[3]	241	55	0.200	153	31	0.199
Chewuch River	73	25	0.299	227	36	0.166
			Okanogan River			
Loup Loup Creek	0	-	-	13	10	0.606
Salmon Creek	64	19	0.288	24	12	0.450
Omak Creek	373	46	0.125	170	31	0.178
Wanacut Creek	0	-	-	0	-	-
Johnson Creek	21	13	0.45	10	9	0.593
Tunk Creek	26	13	0.45	3	7	0.71
Aeneas Creek	0	-	-	0	-	-
Bonaparte Creek	72	21	0.267	51	17	0.300
Antoine Creek	6	9	0.733	0	-	-
Wildhorse Sp. Ck.	0	-	-	0	-	-
Above Zosel Dam	88	24	0.238	88	20	0.245
Foster Creek[4]	10	10	0.571	6	8	0.709

[1] Colockum Creek is a tributary of the Columbia River, but is included in the Wenatchee population
[2] Entiat River above confluence of Mad River
[3] Methow River above confluence of Chewuch River
[4] Foster Creek is a tributary of the Columbia River, but is included in the Okanogan population

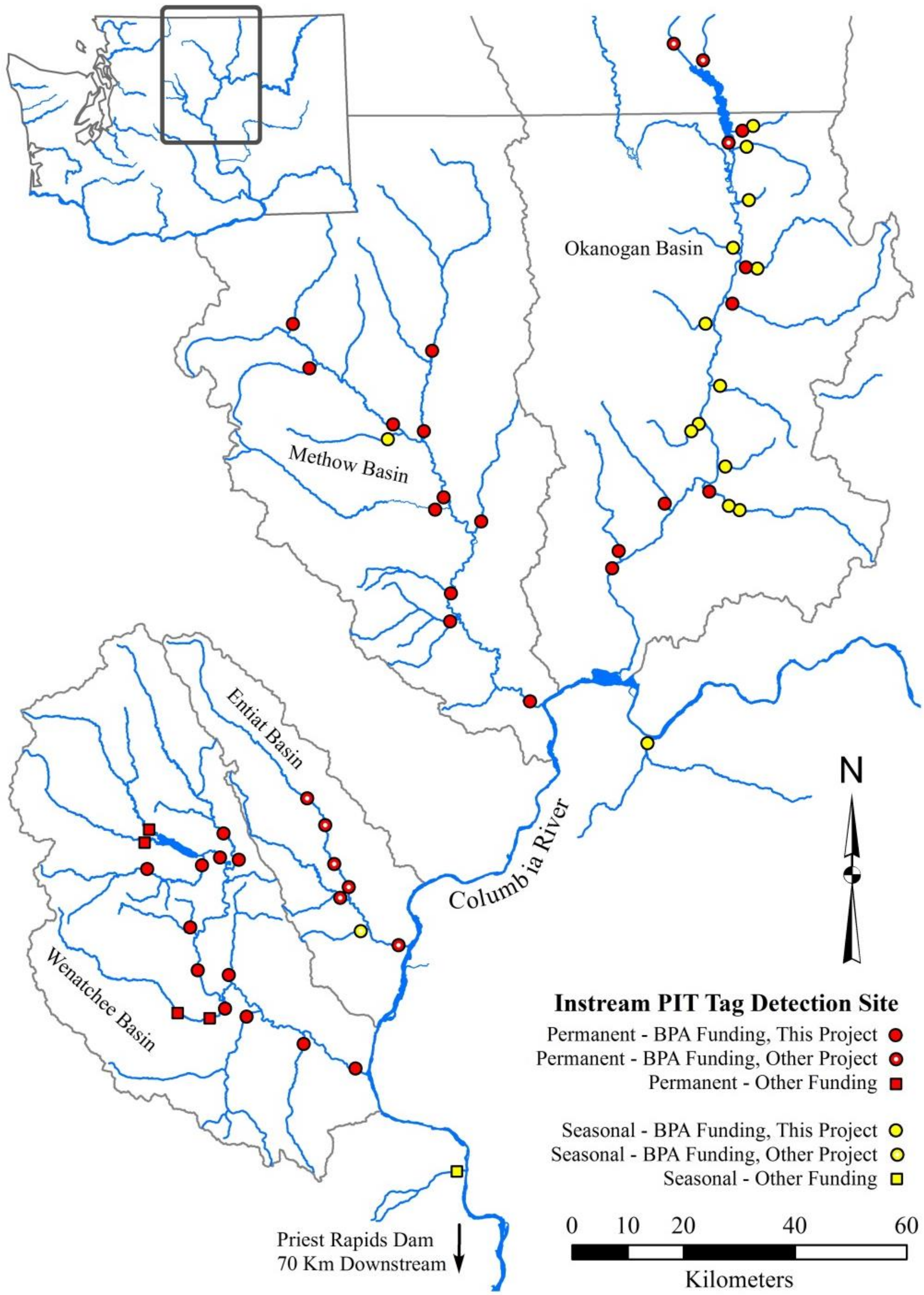


Figure 1. Location of instream PIT tag detection sites utilized for generating PIT tag based escapement estimates for brood year 2015 Upper Columbia River steelhead.

Steelhead Radio Telemetry

Fixed radio tag detection sites were installed along the Columbia River and at key locations throughout the main tributaries of UCR in June and July. Fixed site locations were selected to inform key project objectives of overwinter survival (by mainstem Columbia River and/or tributary reach) and escapement of hatchery and wild fish into each of the four main UCR populations. A total of 21 fixed sites were installed. At some sites two receivers were installed to provide directional movement data (Table 4). Fixed sites consisted of a Lotek SRX 400 receiver with 4- or 6-element yagi antenna mounted to a mast and supported by a free standing tripod or affixed to a tree, and powered by grid or solar power. Fixed sites were downloaded at two week intervals beginning in July when tagging commenced. The University of Idaho was subcontracted under this project to assist WDFW in the installation of the fixed sites, downloading receivers, and data management and analysis.

Table 4. Location of fixed radio telemetry monitoring sites in the Upper Columbia River basin in 2015.

Waterbody	Location	Number of Sites	Directional Movement
Columbia River	Priest Rapids Dam Tailrace	1	
Columbia River	Priest Rapids Dam Forebay	3	
Columbia River	Wanapum Dam Tailrace	1	
Columbia River	Rock Island Dam Tailrace	1	
Columbia River	Rock Island Dam Forebay	3	
Columbia River	Chief Joseph Dam Tailrace	1	X
Wenatchee River	Mouth	1	X
Wenatchee River	Below Tumwater Canyon	1	
Entiat River	Mouth	1	X
Entiat River	Mad River Confluence	1	
Methow River	Mouth	1	X
Methow River	Chewuch River Confluence	2	
Okanogan River	Mouth	2	X
Okanogan River	Eyhott Island Complex	1	
Similkameen River	Mouth	1	

Radio tagging was conducted by WDFW concurrent with stock assessment and PIT tagging activities. A systematic random sample (1 out 7; 14.3%) was selected based on preseason run projections. A total of 400 steelhead (268 hatchery and 132 wild) were radio tagged as the actual run was approximately 20% less than the projected run. An additional 20 steelhead (8 hatchery and 12 wild) were tagged at Tumwater Dam (Wenatchee River basin) in the fall in order to increase sample size for the secondary objective of determining the number of redds constructed per female. WDFW intends use the remaining tags at Tumwater Dam and the Twisp River weir in the spring of 2016 in order to increase sample size available to investigate the number of redds constructed per female.

Egg to Fry Survival (2014 Brood Year)

A total of 22 sites (12 NOAA funded; 10 funded by this contract) were installed during fall of 2014 in the White River, Little Wenatchee River, Nason Creek, and the mainstem Wenatchee River, four of the five major spring Chinook Salmon spawning areas in the upper Wenatchee River basin (Figure 2). Two egg boxes were placed at each site for two consecutive weeks (N = 4) for a total of 88 egg boxes. Temperature probes and gravel scour chains were installed at each site. Water temperature was monitored with HOBO temperature probes at each site and egg boxes were recovered when the accumulated thermal units (ATUs) reached 1000 degrees Celsius. Egg boxes were recovered from 21 October, 2014 to 9 April, 2015. Gamete survival for the 2014 brood year (BY) is presented in Table 5.

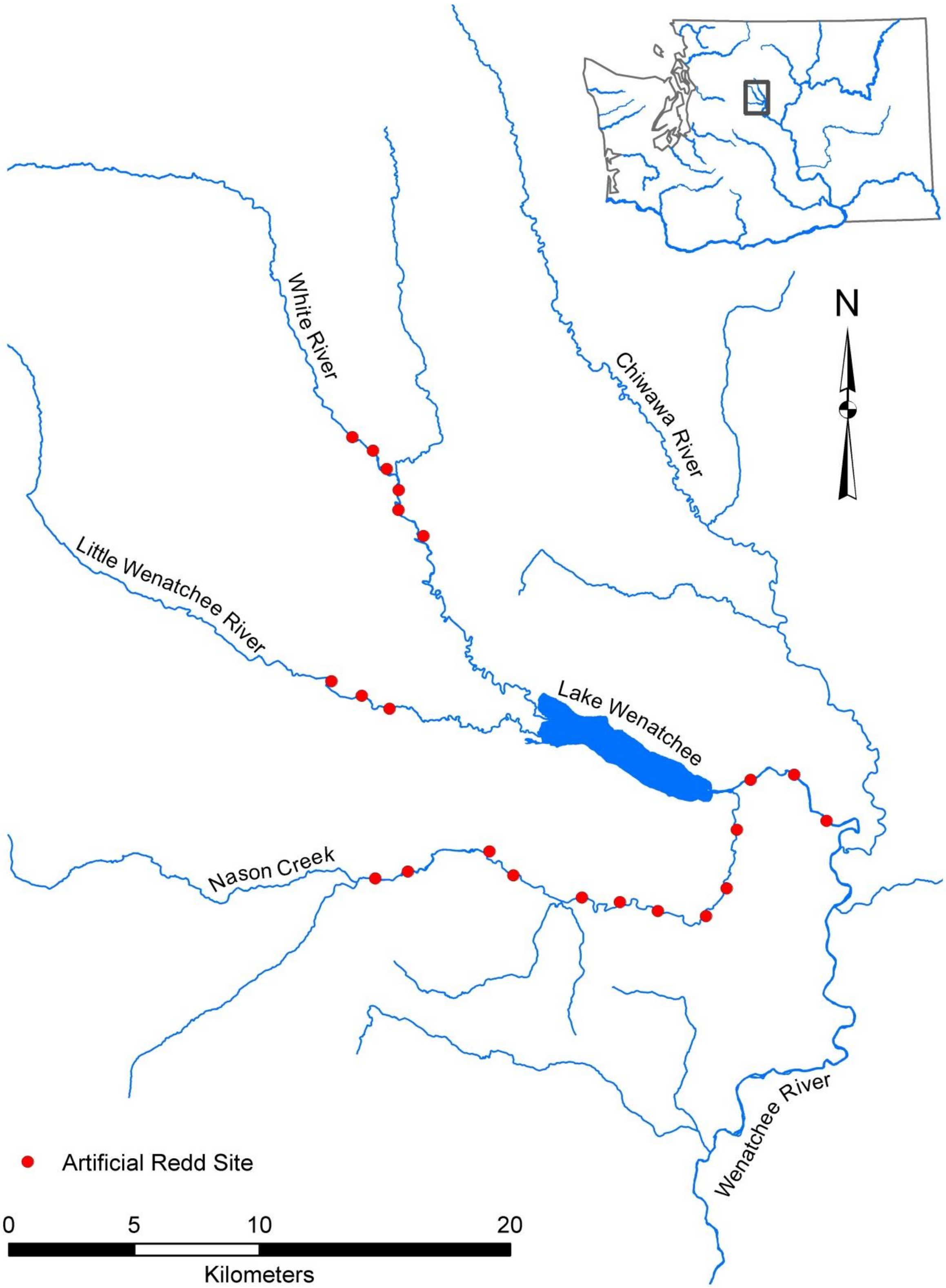


Figure 2. Site locations of egg boxes intended to assess spawning habitat quality for the Wenatchee River spring Chinook Salmon population.

Table 5. Estimates of spring Chinook Salmon survival from egg to hatch in egg boxes installed in the Wenatchee River basin for brood year 2014.

River/Reach	Reach length (km)	Number of sites	Number of egg boxes	Percent Survival
Upper Nason Creek	12.6	5	20	50.7
Lower Nason Creek	13.3	5	20	19.5
Little Wenatchee	13.9	3	12	8.0
Mainstem Wenatchee	9.3	3	12	0.0
Upper White River	12.6	3	12	46.0
Lower White River	10.4	3	12	27.6
Total	72.1	22	88	27.1

Egg to Fry Survival (2015 Brood Year)

Study design for BY 2015 replicated the 2014-2015 study with 22 sites (12 NOAA funded and 10 by this contract) in the White River, Little Wenatchee River, Nason Creek, and the mainstem Wenatchee River. Two egg boxes were placed at each site for two consecutive weeks. This year, a third week of egg boxes were placed in the mainstem Wenatchee River because the previous years' gametes were exposed to extremely high water temperatures and was thought to be the leading cause of complete mortality observed in BY 2014.

As of 31 December 2015, all boxes in the mainstem Wenatchee River had been recovered, while no other sites had yet reached the target temperature of 1000 ATUs (Table 6). River discharge peaked over 185 m^3/s in the first three months of incubation for BY 2015 compared to once over the entire incubation period for BY 2014 (Figure 3). Considerable scour and deposition has been observed at study sites. Egg boxes have been lost due to scour and more egg boxes are expected to be lost with a difficult recovery season compared to BY 2014. The snow water equivalency for BY 2015 is more than twice as much as the previous years' total. At current ATU accumulation rate, all egg boxes should be recovered by mid May 2016.

Table 6. Preliminary estimates of spring Chinook Salmon survival from egg to hatch in egg boxes installed in the Wenatchee River basin for brood year 2015.

River	Reach length (km)	Number of sites	Number of egg boxes	Percent Survival
Upper Nason Creek	12.6	5	20	N/A
Lower Nason Creek	13.3	5	20	N/A
Little Wenatchee	13.9	3	12	N/A
Mainstem Wenatchee	9.3	3	18	41.6
Upper White River	12.6	3	12	N/A
Lower White River	10.4	3	12	N/A
Total	72.1	22	94	

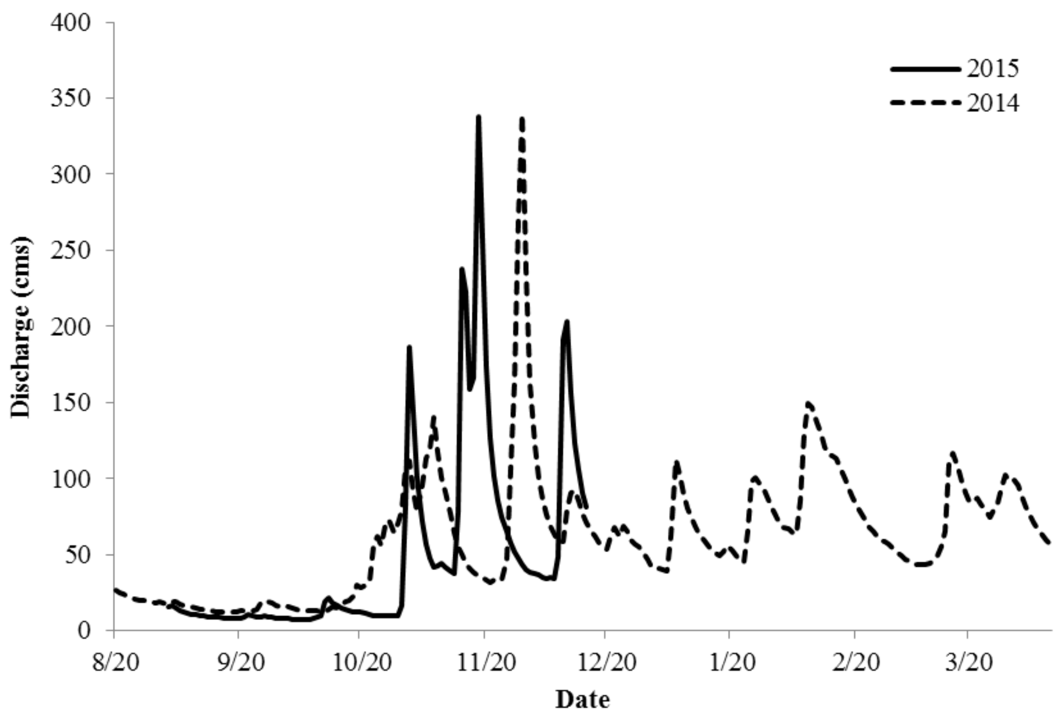


Figure 3. Mean discharge throughout the incubation period for brood year 2014, and to mid December 2015. Flow data acquired from the USGS mainstem Wenatchee River gauge station 12457000.

Parr Distribution and Habitat Utilization

During 2015, mobile PIT tag detection surveys were conducted in the early spring and late fall. Surveys in early spring (26 February – 5 March) covered the Wenatchee River from Lake Wenatchee to the top of Tumwater Canyon. Spring surveys were intended to investigate the efficacy of developing an expansion rate based on detection efficiency from paired surveys. A total of six paired surveys were conducted in the spring. Fall surveys consisted of 12 days of paired float surveys, 19 days of walking surveys and 9 days of edge habitat mapping (30 November 2015 – 15 January 2016). The entire Wenatchee River mainstem was surveyed in the fall, from Lake Wenatchee to the confluence with the Columbia River to include all wadable side channels. Some side channels were not surveyed due to lack of surface water or non-wadable conditions. Only results from fall surveys are presented, as spring surveys were only utilized to investigate and improve survey methods.

Raw detections of spring Chinook Salmon PIT tags were processed in order to identify each as live or dead, according to individual release dates. Most of the live wild-origin spring Chinook Salmon juveniles that were available for mobile detections in this study were tagged during emigration at rotary screw traps in the Chiwawa River and Nason Creek. Only fish tagged since late summer 2015 were assumed to be alive. Georeferenced live and dead detections were then joined to individual line segments in a GIS in order to summarize patterns in fish habitat utilization by edge habitat type. Within Tumwater Canyon, it was assumed that winter fish habitat utilization within sampled edge units represented unsampled units. Raw fish detections were expanded by length of PCA group to estimate a total number of PIT-tagged fish in the canyon. An expansion rate was also estimated for both floating and walking surveys. In each case the proportion of tags (live and dead) that was detected on both passes relative to the total number of unique tags detected at that site was used as the efficiency. Survey detection efficiencies for floating and walking surveys ranged from 12-28% and 35-48%, respectively.

Expanded live PIT tagged juvenile spring Chinook Salmon densities in the mainstem Wenatchee River were highest in the upper Wenatchee River (Lake Wenatchee to the top of Tumwater Canyon) and middle Wenatchee River (Tumwater Canyon) segments. Expanded live PIT tagged juvenile spring Chinook Salmon density in the lower mainstem Wenatchee River segment was much lower than either the upper or middle segments (Table 7). Analysis of off-channel density and detections by edge habitat segment is ongoing and will be presented in the following report.

Table 7. Density of live PIT tagged juvenile spring Chinook Salmon in the mainstem Wenatchee River in December 2015.

Reach	Length (km)	Raw Chinook/km	Expansion Rate	Expanded Chinook/km
		Upper Wenatchee River		
W7	8.1	0.6	0.249	2.5
W6	8.8	6.9	0.120	57.8
W5	13.4	4.9	0.194	25.4
Total	30.3	4.2	0.188	28.5
		Middle Wenatchee River/Tumwater Canyon		
W4	14.7	12.1	0.432	28.0
		Lower Wenatchee River		
W3	14.4	1.2	0.174	6.8
W2	13.7	0.3	0.125	2.3
W1	13.8	0.9	0.283	3.1
Total	41.9	0.8	0.194	4.1

Discussion/Conclusion

While this project funds several distinct deliverables, the ultimate goal of the project is to improve the accuracy and precision of status and trend monitoring. Through annual steelhead stock assessment activities at PRD and the development of a PIT tag based steelhead abundance model, unbiased population estimates of all UCR steelhead populations with associated uncertainty are now generated annually. Improvements to the PIT based abundance model are ongoing, with future modifications including a revised estimate of escapement past PRD that accounts for fallbacks and passage during non-counting periods.

The ongoing radio telemetry study will provide independent validation of the PIT based abundance model and provide of estimates of overwinter survival and the number of redds constructed per female. The current radio telemetry based UCR steelhead population estimation method based on results from English et al. (2001, 2003) will continue to be used for reporting purposes until the ongoing radio telemetry study is completed and the stated modifications to the PIT based model are incorporated. However, in the current form, the PIT based model represents a significant improvement from the current population estimates that hold the fraction of fish over PRD constant through time and lack any estimate of uncertainty.

The outputs from the PIT based model can also be combined with observer efficiency adjusted redd counts (methodology developed previously under this project) to generate spawner escapement estimates with uncertainty for each of the populations in the UCR. This work in currently being conducted in the Wenatchee River basin, funded annually under the Chelan County Public Utility District’s monitoring and evaluation program. Wenatchee River basin spawner escapement estimates for BY 2015 are included in Appendix A.1. Population level spawner escapement estimates are critical for evaluating restoration and recovery actions, as recovery metrics and thresholds all require an unbiased and precise estimate of spawners (UCSRB 2007).

Egg to Fry Survival

Reach specific differences in egg to fry survival has been observed in the Wenatchee River basin. These data will be collected for three years (2014-2016) in the Wenatchee River basin and subsequently effort will be shifted to another ESA listed population if warranted. While survival rates using a standardized method are positively biased (i.e., fish are not allowed to emerge naturally), the relative comparisons within or between spawning areas is the primary interest. Discussions have been initiated with NOAA and others to include these data and corresponding environmental and habitat data to potentially develop fish – habitat relationships for a critically important life stage. When developed, these relationships can be used in a life cycle modeling framework to identify, prioritize and estimate fish response to habitat restoration or climate change scenarios.

Parr Distribution and Habitat Utilization

Spring Chinook Salmon in the Wenatchee River basin primarily spawn in the Chiwawa River and Nason Creek. However, in an average adult escapement year, approximately 50% of spring Chinook Salmon parr in the Chiwawa River and 80% of spring Chinook Salmon parr in Nason Creek exhibit downstream rearing (DSR) life histories, emigrating from their natal stream and overwintering in the Wenatchee River (Jeremy Cram, WDFW, unpublished data). For many spring or stream type Chinook populations in the Columbia River basin, non-wadable river reaches may be the primary overwintering area (Copeland et al. 2014). The distribution data suggest that these DSR parr migrate to the upper and middle Wenatchee River segments for overwintering habitat. The distribution, habitat preference, capacity and survival of juvenile salmonids in non-wadable rivers are major data gaps. This project has made some progress in the development of the methodology that could be used to fill these data gaps, but much more work is needed. Estimates of fish density and survival coupled with habitat data are needed to develop fish – habitat relationships for non-wadable rivers. Without these relationships, habitat restoration projects may be misguided as to the habitat attributes most important in creating greater capacity or increasing survival.

Juvenile spring Chinook Salmon parr distribution during fall surveys in 2015 was similar to that observed in 2014. Based on observations during surveys, it was expected that detection efficiency of floating surveys, and to a lesser degree during walking surveys, could be significantly impacted by changes in habitat complexity. Thus, habitat specific detection probabilities may be necessary in order to compare different reaches with various levels of habitat complexity. The current method for calculating detection efficiency was developed to address this issue. However, the assumptions necessary to calculate detection efficiency in the current methodology are likely not being reasonably met. The detection efficiency calculation requires the assumptions that paired surveys are conducted with equal effort and that both surveys sample identical paths. The assumption of equal effort is likely being met, as detection range is measured daily and adjustments are made if necessary to ensure that PIT tag detection equipment is functioning equally amongst the two surveyors. However, it is difficult in the environmental conditions present during surveys to identically replicate the path of the lead surveyor, especially in the floating surveys. PIT tag detection range during floating surveys averaged 0.75 m, so even a diversion of <1 m from the lead boat path could appreciably impact calculated detection efficiency. As the detection efficiency calculation is based on shared detections between surveyors, the greater the diversion from identical paths results in greater reduction of calculated detection efficiency. PIT tag densities were reported both raw and expanded by detection efficiency. However, expanded densities should be considered preliminary until the issues with the detection efficiency calculation can be addressed. Additional work is ongoing in order to address this issue.

Adaptive Management & Lessons Learned

Improvements to status and trend methodologies were the primary focus of this project at its inception in 2010. Many of these improvements have not been officially adopted by WDFW or the co-managers, but will be soon and included in the Hatchery M & E program funded by the PUDs. As a result of this project, NOAA may need to completely reanalyze UCR steelhead population viability as part of their next 5 year status review as large differences exist between the two approaches used to estimate adult abundance. Furthermore, while population level estimates of steelhead spawners have been generated as part of this project, it is too early to determine the relationship between PIT tag based run escapement and spawning escapement estimates. Assuming a robust relationship does exist, the data time series will need to be further refined and status reassessed.

The project has evolved as original objectives have been completed. The current and future focus of the project will be the development of life cycle models (i.e., egg to fry and parr distribution objectives) to identify population bottlenecks and prioritize recovery/restoration actions. Given the distribution of juvenile spring Chinook Salmon parr in the Wenatchee River basin, restoration actions designed for improving overwinter survival should be targeted in the upper and middle Wenatchee River segments. While off-channel and high flow refugia projects in the lower Wenatchee River segment likely provide positive impacts during outmigration periods, the residence time of juvenile spring Chinook in the lower Wenatchee River segment is much shorter compared to the middle and upper segments, where the vast majority of overwintering has been documented. Similarly, restoration efforts in the spring Chinook spawning areas have not explicitly focused on the earliest of life stages (i.e., egg incubation). Given the observed juvenile life history strategies, a shift in focus may be warranted. When completed, the Wenatchee spring Chinook Salmon life cycle model will be able to prioritize survival gaps by life stage at a spatial scale relevant for habitat restoration practioners.

References

Beamer, E., and R. Henderson. 1998. Juvenile salmonid use of natural and hydromodified stream bank habitat in the mainstem Skagit River, northwest Washington. Skagit River System Cooperative, La Conner, Washington.

Beechie, T. J., M. Liermann, E. M. Beamer, R. Henderson. 2005. A Classification of Habitat Types in a Large River and Their Use by Juvenile Salmonids. Transactions of the American Fisheries Society 134(3):717-729. DOI: 10.1577/T04-062.1

Crawford, B.A., and S. Rumsey. 2009. Guidance for monitoring recovery of salmon and steelhead. NOAA Fisheries Service, Northwest Region, Portland, Oregon.

English, K.K., C. Sliwinski, B. Nass, and J.R. Stevenson. 2001. Assessment of adult steeled migration through the mid-Columbia River using radio-telemetry techniques, 1999-2000. Mid – Columbia PUDS, Wenatchee, WA.

English, K.K., C. Sliwinski, B. Nass, and J.R. Stevenson. 2003. Assessment of adult steeled migration through the mid-Columbia River using radio-telemetry techniques, 2001-2002. Mid – Columbia PUDS, Wenatchee, WA.

Ford, M.J. (ed.). 2011. Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Pacific Northwest. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-113, 281 p.

Johnson, C. L., P. Roni, G. R. Pess. 2012. Parental effect as a primary factor limiting egg-to-fry survival of spring Chinook salmon in the upper Yakima River basin. Transactions of the American Fisheries Society 141(5): 1295-1309

Maier, G. 2014. Integrated Recovery Program Habitat Report. Upper Columbia Salmon Recovery Board.

Martens, K. D., and P. J. Connolly. 2014. Juvenile anadromous salmonid production in Upper Columbia River side channels with different levels of hydrological connection. Transactions of the American Fisheries Society 143:757-767.

See, K. 2014. Upper Columbia Brood Year 2014 Steelhead PIT Tag Escapement Modeling

UCSRB 2007. Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan. http://www.ucsrb.com/UCSRP%20Final%209-13-2007.pdf

Appendix A.1

Estimates of Wenatchee Steelhead Spawners in 2015

Kevin See

March 15, 2016

Introduction

Redd counts are an established method to provide an index of adult spawners (Gallagher et al. 2007). In the Wenatchee and Methow subbasins, index reaches are surveyed weekly during the steelhead spawning season (Mar 09, 2015 - May 28, 2015) and non-index reaches are surveyed once during the peak spawning period. The goal of this work is to:

- Predict observer net error, based on a model developed with data from steelhead redd surveys in the Methow, similar to that described in Murdoch et al. (2014).
- Use estimates of observer net error rates and the mean survey interval to estimate the number of redds in each index reach, using a Gaussian area under the curve (GAUC) technique described in Millar et al. (2012).
- Estimate the total number of redds in the non-index reaches by adjusting the observed counts with the estimated net error.
- Convert these estimates of redds in the mainstem areas (surveyed for redds) into estimates of spawners.
- Use PIT-tag based estimates of escapement for all tributaries in the Wenatchee, and combine those estimates with the redd-based estimates of spawners in the mainstem areas to estimate the total number of spawners in the Wenatchee.

Methods

Mainstem areas

The model for observer net error (observed redd counts / true number of redds) is a model averaging of the two best models that were fit to 43 data points in the Methow. Both models contained covariates of observed redd density (redds / m) and mean thalweg CV as a proxy for channel complexity. One model also contained discharge while the other also contained total redd survey experience as an additional covariate. Predictions were made using model averaged coefficients (based on AICc model weights) and the 2015 steelhead data. From these survey specific estimates of net error, a mean and standard error of net error was calculated for each reach. The standard deviation was calculated by taking the square root of the sum of the squared standard errors for all predictions within a reach.

Estimates of total redds were made for each index reach using the GAUC model described in Millar et al. (2012). The GAUC model was developed with spawner counts in mind. As it is usually infeasible to mark every individual spawner, only total spawner counts can be used, and an estimate of average stream life must be utilized to translate total spawner days to total unique spawners. However, in adapting this for redd surveys, two modification could be used. The first would fit GAUC models to data showing all visible redds at each survey, and use an estimate of redd life as the equivalent of spawner stream life. However, because conditions led to many redds not disappearing before the end of the survey season, the estimates of redd life are biased low for this year. The second method relies on the fact that individual redds can be marked, and therefore the GAUC model can be fit to new redds only. The equivalent of stream life thus became the mean and standard deviation of the survey interval. We utilized the second method for this analysis.

For non-index reaches, which were surveyed only once during peak spawning, the estimate of total redds was calculated by dividing the observed redds by the estimate of net error associated with that survey. This assumes that no redds were washed out before the non-index survey, and that no new redds appeared after that survey. As the number of redds observed in the non-index reaches ranged from 0 to 5, any violoation of this assumption should not affect the overall estimates very much. Based on the peak spawning time for the associated index reaches, the surveys in the non-index reaches were conducted either at peak spawning, or within 10 days after peak spawning (Figure 2}).

To convert estimates of total redds into estimates of natural and hatchery spawners, total redds were multiplied by a fish per redd (FpR) estimate and then by the proportion of hatchery or wild fish. The fish per redd estimate was based on PIT tags from the branching patch-occupany model (see below) observed to move into the lower or upper Wenatchee (below or above Tumwater dam). FpR was calculated as the ratio of male to female fish, plus 1. This was 1.78 above Tumwater dam, and 1.73 below Tumwater. Reaches W1 - W7 are below Tumwater, while reaches W8 - W10 are above Tumwater. Similarly, the proportion of hatchery and natural origin fish was calculated from the same group of PIT tags for areas above and below Tumwater. The proportion of hatchery origin fish was 0.6 above Tumwater dam, and 0.34 below Tumwater (Table 2).

Tributary areas

Esimates of escapement to various tributaries in the Wenatchee were made using a branching patch-occupancy model (***Need citation***) based on PIT tag observations of fish tagged at Priest Rapids dam. All fish that escaped to the various tributaries were assumed to be spawners (i.e. pre-spawn mortality only occurs in the mainstem).

Total spawners

When summing spawner estimates from index reaches to obtain estimates of total spawners in the Wenatchee, an attempt was made to incorporate the fact that the reaches within a stream are not independent. Estimates of correlation between the reaches within a stream were made based on weekly observed redds. Because correlations are often quite high between reaches, this is a better alternative than to naively assume the standard errors between reaches are independent of one another. These estimates of correlation were combined with estimates of standard error for each index reach to calculate a covariance matrix for the Wenatchee index reaches (W2, W6, W8, W9, W10), which was used when summing estimates of spawners to estimate the total standard error. Failure to incorporate the correlations between reaches would result in an underestimate of standard error at the population scale. Non-index reaches were only surveyed once, so it is impossible to estimate a correlation coefficient between non-index reaches and index reaches. Therefore, they were assumed to be independent from the index reachs when summing the estimates of spawners. Because the estimates of tributary spawners were made separately (see above), they were also treated as independent when summing spawner estimates. The uncertainty in each step was carried through the entire analysis via the delta method (Casella and Berger 2002).

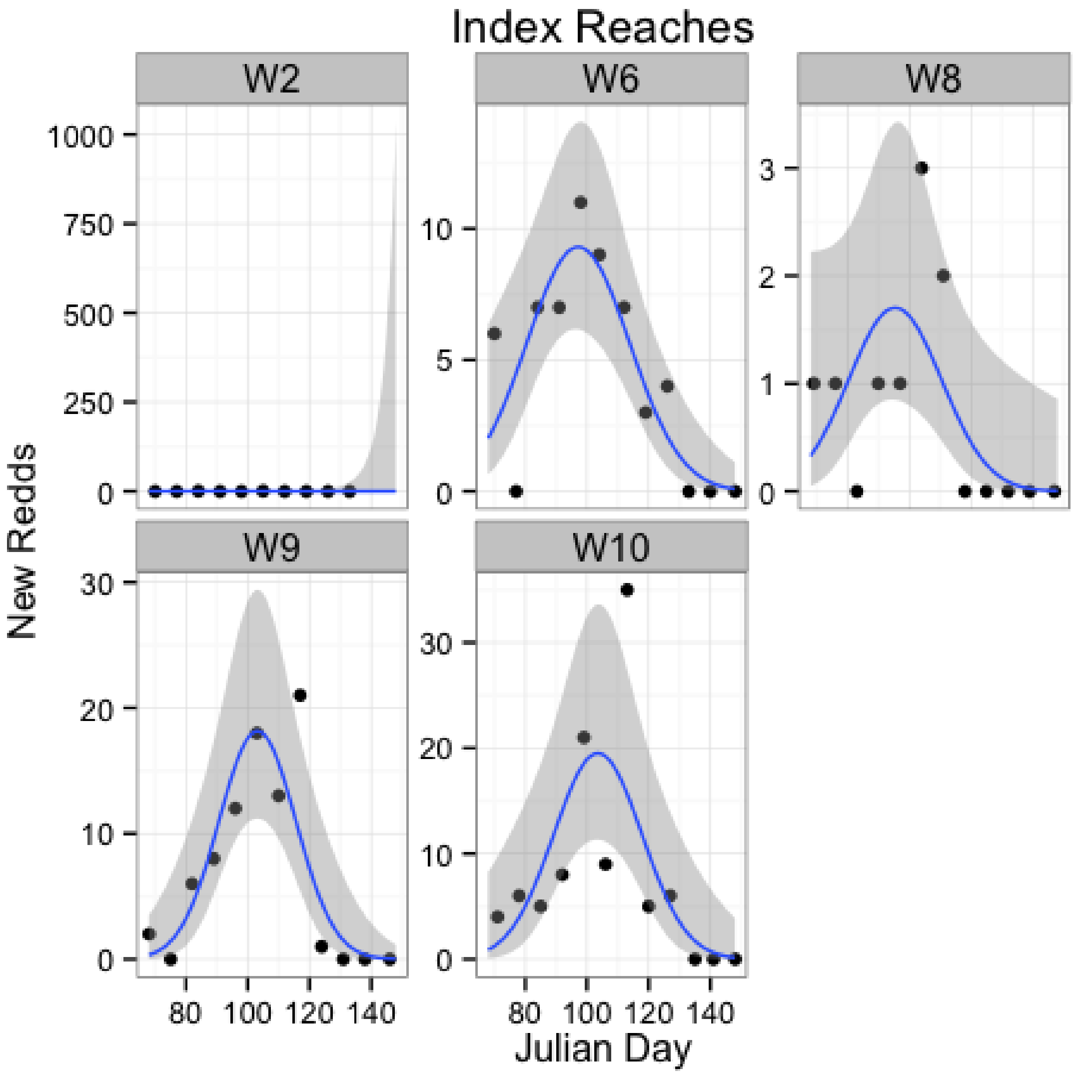
Results

Redd estimates

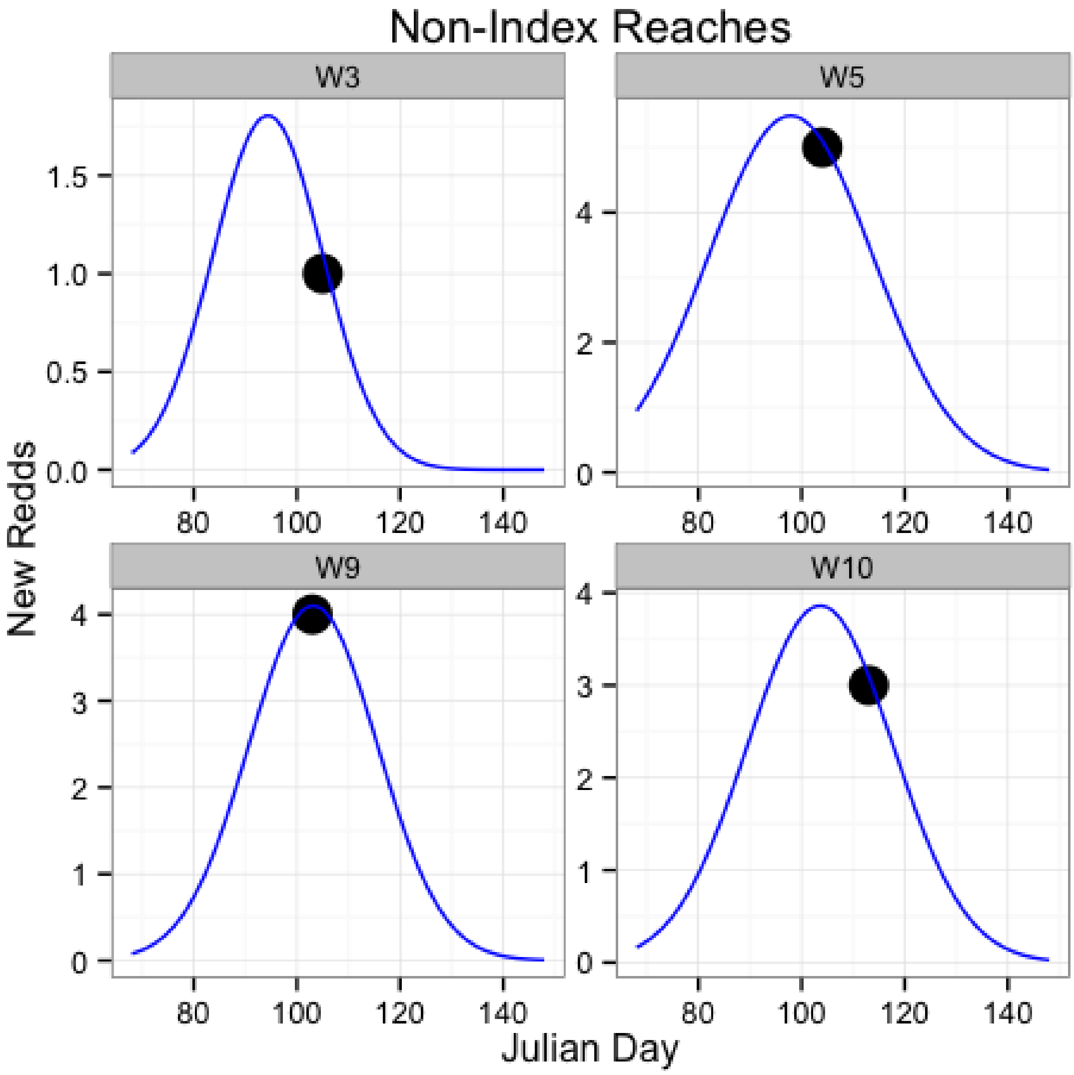
It should be noted that the GAUC parameters from index reaches were not used to estimate total redds in the associated non-index reaches. Figure 4 does illustrate that the non-index reach surveys were conducted close to the period of peak spawning (as determined by the associated index reaches), thus helping to validate the assumptions that go into estimating total redds in non-index reaches.

Table 1: Estimates of mean net error and total redds for each reach.

Reach	Type	Index Reach	Net Error	Net Error CV	Redds Counted	Redds Est	Redds CV
W1	Non-Index	W2	0.55	0.24	0	0	NA
W2	Index	-	0.59	1.40	2	3	1.50
W3	Non-Index	W2	0.44	0.30	1	2	0.30
W4	Non-Index	W6	0.46	0.23	0	0	NA
W5	Non-Index	W6	0.50	0.22	5	10	0.22
W6	Index	-	0.99	0.85	54	53	0.88
W6	Non-Index	W6	0.46	0.15	0	0	NA
W8	Index	-	0.92	0.90	9	10	0.95
W9	Index	-	0.79	0.89	81	102	0.91
W9	Non-Index	W9	0.63	0.15	4	6	0.15
W10	Index	-	0.83	0.61	99	120	0.65
W10	Non-Index	W10	0.59	0.13	3	5	0.13
Total		NA	NA	NA	258	311	0.63



Plots of observed redd counts (black dots) through time for each index reach, and the fitted curve from the GAUC model (blue line) with associated uncertainty (gray).



Observed redd counts for non-index reaches with non-zero peak redd counts. The blue curve shows the GAUC estimated spawning curve, demonstrating how close to peak spawning the non-index surveys were conducted.

Spawner estimates

Table 2: Fish per redd and hatchery / natural origin proportion estimates.

Area	Fish / redd	FpR Std. Error	Prop. Hatchery	Prop Std. Error
Above TUF	1.777	0.059	0.599	0.026
Below TUF	1.728	0.089	0.343	0.040

Table 3: Estimates (CV) of spawners by area and origin.

Area	Type	Hatchery	Natural
W1	Non-Index	0 (--)	0 (--)
W2	Index	2 (1.51)	4 (1.51)
W3	Non-Index	1 (0.32)	3 (0.31)
W4	Non-Index	0 (--)	0 (--)
W5	Non-Index	6 (0.25)	11 (0.23)
W6	Index	32 (0.89)	60 (0.88)
W6	Non-Index	0 (--)	0 (--)
W8	Index	10 (0.95)	7 (0.95)
W9	Index	108 (0.92)	73 (0.92)
W9	Non-Index	7 (0.16)	5 (0.16)
W10	Index	127 (0.65)	85 (0.66)
W10	Non-Index	5 (0.14)	4 (0.15)
Icicle	Trib	52 (0.32)	83 (0.25)
Peshastin	Trib	40 (0.37)	206 (0.16)
Mission	Trib	23 (0.49)	71 (0.28)
Chumstick	Trib	0 (--)	38 (0.39)
Chiwaukum	Trib	12 (0.72)	48 (0.34)
Chiwawa	Trib	168 (0.23)	168 (0.21)
Nason	Trib	68 (0.29)	237 (0.15)
Little Wenatchee	Trib	0 (--)	0 (--)
White River	Trib	0 (--)	0 (--)
Total		661 (0.45)	1103 (0.3)

Discussion

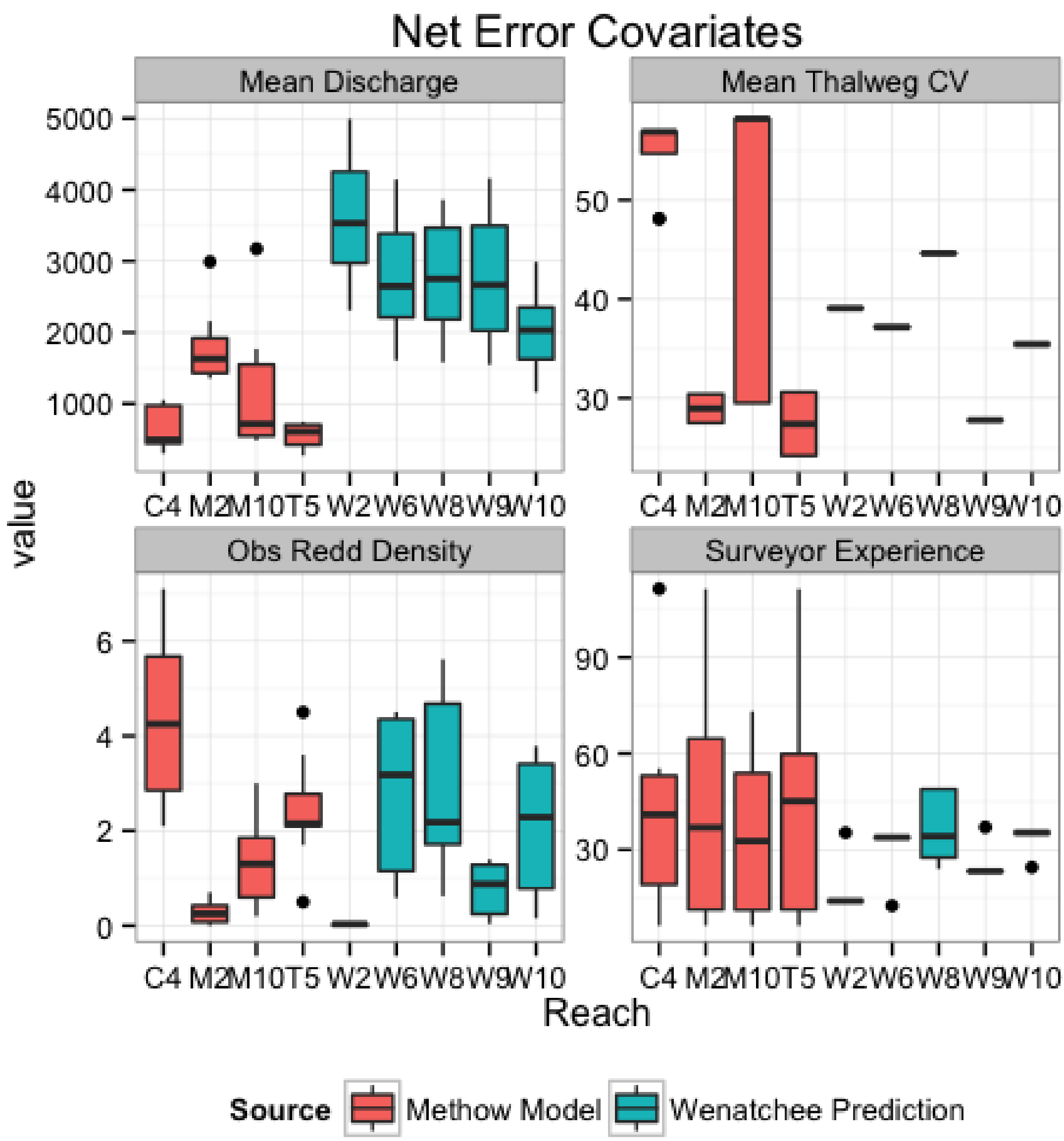
We have estimated the number of steelhead redds based on redd surveys, while incorporating potential observation error. After translating these to estimates of spawners by origin, we can then compare the spawner estimates to escapement estimates made using PIT tags, and estimate a prespawn mortality rate (Table 4). Taking the total PIT-tag based escapement estimate to the Wenatchee (after substracting the number of hatchery fish removed at Tumwater), and subtracting the total estimate of spawners, including the tributaries, then dividing by the total escapement estimate provides an estimate of pre-spawn mortality across the entire Wenatchee population. We did this for natural and hatchery origin fish, and found that hatchery fish had a higher pre-spawn mortality rate, although the difference is not statistically significant.

Table 4: Wenatchee pre-spawn mortality rates.

Origin	Prespawn_Mort	CV
Hatchery	0.25	0.0016
Natural	0.16	0.0013

Caveats

The predictions of surveyor net error were made using a model that had been fit to data in the Methow. Most covariates in the Wenatchee were within the range of values in the Methow study, but mean discharge was higher in all reaches in the Wenatchee than in the modeled reaches in the Methow (Figure 3). The mean discharge in the Methow study was 1069.2, while it was 2680 in the Wenatchee reaches in 2015. That difference alone would change net error predictions by 0.29, not an insignificant amount. However, the observed covariate values in the Wenatchee did not lead to unrealistic estimates of net error. The ranges of net error estimates for the Methow study and the Wenatchee in 2015 were very similar.



Net error covariate values from the study in the Methow and the predicted reaches in the Wenatchee.

References

Casella, G., and R. L. Berger. 2002. Statistical inference. Duxbury Pacific Grove, CA.

Gallagher, S., P. Hahn, and D. Johnson. 2007. Redd counts. Salmonid field protocols handbook: Techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, Maryland:197–234.

Millar, R., S. McKechnie, and C. Jordan. 2012. Simple estimators of salmonid escapement and its variance using a new area-under-the-curve method. Canadian Journal of Fisheries and Aquatic Sciences 69:1002–1015.

Murdoch, A. R., C. J. Herring, K. E. See, and C. E. Jordan. 2014. Incorporating observer error in estimates of steelhead redd abundance in the Wenatchee River basin.