Colville Tribes, Fish & Wildlife Department

2013 Okanogan Subbasin Steelhead Escapement and Spawning Distribution

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Executive Summary

OBMEP monitored adult Viable Salmonid Population (VSP) abundance attributes (McElhany et al. 2000) within the subbasin for Okanogan River summer steelhead (*Oncorhynchus mykiss*). Adult monitoring was conducted through redd surveys, underwater video counts, and Passive Integrated Transponder (PIT) tag expansion estimates. Figure ES1 summarizes the total summer Steelhead spawning estimates in the Okanogan subbasin, from 2005 through 2013. Abundance of spawners can be compared to recovery goals, as outlined by the Interior Columbia Basin Technical Recovery Team (ICBTRT). The Upper Columbia Spring Chinook and Steelhead Recovery Plan states that 500 naturally produced Steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

Results from Steelhead adult enumeration efforts in the Okanogan subbasin indicate that the number of spawning Steelhead in the Okanogan River, both hatchery and naturally produced, continued to increase since OBMEP began collecting data in 2005. The slope of the trend line from 2005 to 2013 abundance estimates suggests that the number of total Steelhead spawning in the Okanogan subbasin increased at an average rate of 187 fish per year and the number of naturally produced spawners increased at an average rate of 29 fish per year. Spawning occurred throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities. Steelhead spawning was documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning is largely influenced by stocking location because juvenile hatchery Steelhead were scatter-planted in Omak Creek, Salmon Creek, and the Similkameen River acclimation site.

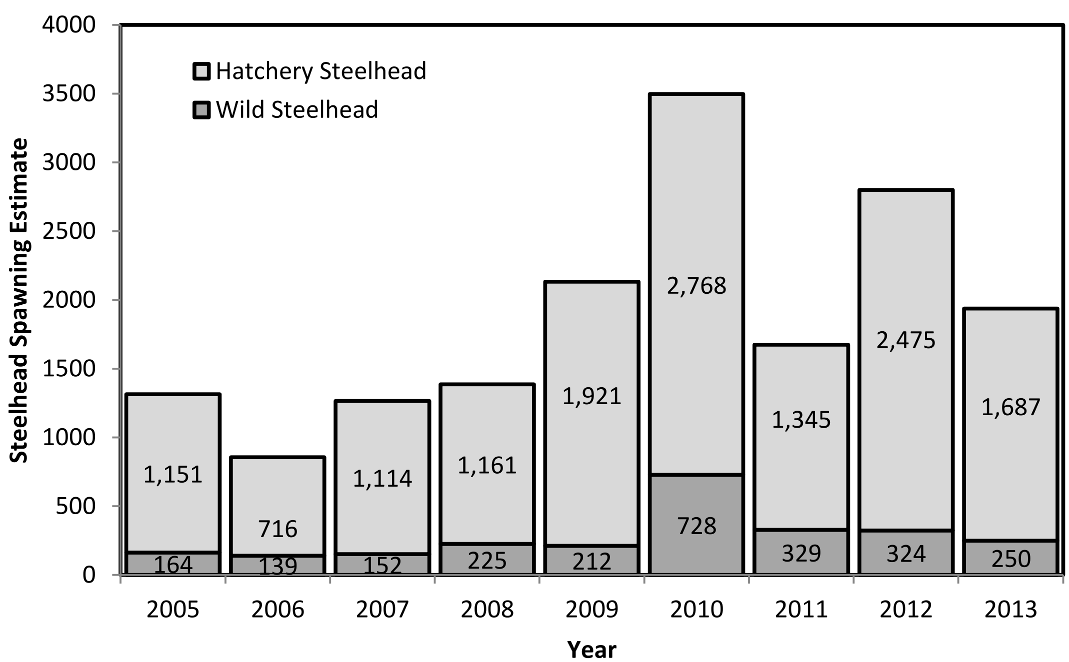

Figure ES1. Spawning estimates for the Okanogan subbasin from 2005 through 2013, as determined by OBMEP.

Steelhead redd surveys can provide a reasonable depiction of spawning distribution and an estimate of escapement on years when spring runoff occurs post-spawning. Defining the physical location of redds informs managers about which, and to what extent, habitats are being used for spawning and allow for tracking of spatial status and trends through time. However, modeling distribution and abundance of spawning on years with early runoff is less objective. Since OBMEP began collecting Steelhead spawning data in 2005, the importance of not relying solely on redd surveys for abundance estimates has become evident. Implementation of an Upper Columbia Basin-wide PIT tag interrogation systems (Project # 2010-034-00), coupled with the representative marking of returning adults at Priest Rapids Dam, allowed managers an additional means to estimate abundance on years with poor water visibility, to validate redd survey efficiency, and describe spatial distribution and upstream extent of spawning, where previously unknown. The Fish and Wildlife Program should consider continuing these efforts to allow managers to more accurately describe the spatial extent of spawning in tributaries, to monitor effectiveness of migration barrier removal, and better define escapement estimates.

Acknowledgements

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Introduction

Within the Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. Summer steelhead (*Oncorhynchus mykiss*) are listed as threatened in the Upper Columbia Evolutionarily Significant Unit (ESU) under the Endangered Species Act (ESA) (NMFS 2009). To recover this ESU requires that all four populations (Wenatchee, Entitat, Methow, and Okanogan) meet minimum adult abundance thresholds, have positive population growth rates, and each population must be widely distributed within respective basins (UCSRB 2007). Within the Okanogan River subbasin, the Okanogan Basin Monitoring and Evaluation Program (OBMEP) monitors adult abundance attributes. Since 2004, OBMEP developed protocols derived from the Upper Columbia Strategy (Hillman 2004) that called for a complete census of all spawning. Preliminary methodologies for implementing redd surveys were developed in 2005 and these methods were later revised in 2007 (Arterburn et al. 2007). In addition to redd surveys, adult weir traps, Passive Integrated Transponder (PIT) tag arrays, and underwater video counting were combined to improve escapement estimates and coordinate with other on-going data collection efforts. In cooperation with the Washington Department of Fish and Wildlife (WDFW), OBMEP expanded the use of PIT tag arrays to enhance monitoring adult summer steelhead use of small tributaries to the Okanogan River.

This document builds upon knowledge and information gained from preceding years' surveys. A literature review of historic spawning information related to the Okanogan River subbasin can be found in Arterburn et al. 2005. Previous years' data and reports can be accessed at: www.colvilletribes.com/obmep.php.

Methods

OBMEP - Adult Abundance - Redd Surveys (ID:192)
https://www.monitoringmethods.org/Protocol/Details/192
OBMEP - Adult Abundance - Adult Weir and Video Array (ID:6)
https://www.monitoringmethods.org/Protocol/Details/6
Estimate the abundance and origin of Upper Columbia steelhead (2010-034-00) v1.0 (ID:235)
https://www.monitoringmethods.org/Protocol/Details/235

The Okanogan River flows from the northern headwaters near Vernon, BC to the confluence with the Columbia River near Brewster, WA (Figure 1). Counts of summer steelhead spawning downstream of anadromous fish migration barriers in the mainstem and all accessible tributaries of the Okanogan and Similkameen River drainages were conducted within the United States (Arterburn et al. 2007, Walsh and Long 2006). Adult weir traps, PIT tag arrays, and underwater video enumeration were used at locations where habitat was extensive or difficult for surveys to be performed on foot.

Summer steelhead were enumerated in all remaining spawning habitats following the OBMEP redd survey protocol. The area of the Okanogan River downstream from Chiliwist Creek is inundated by the Columbia River (Wells Pool/Lake Pateros). Consequently, this lower reach (~23 km) of the Okanogan River was excluded from surveys because it lacks appropriate velocity and substrate needed for summer steelhead to spawn. Designated mainstem and tributary redd survey reaches are listed in Table 1. The Okanogan River was divided into seven survey reaches and the Similkameen River was surveyed as two reaches. Survey reaches were determined by access points along the river and directly related to the EDT reach layer, used in habitat monitoring. Discharge data, air and water temperature, and local knowledge of fish movements collected from previous years were used to determine when to begin surveys on the mainstem. Mainstem surveys were conducted from rafts and on foot in a downstream progression. All island sections or other mainstem areas that could not be floated due to limited access and/or obstacles (e.g. wood debris, braided channels, and diversions) were surveyed on foot. Raft surveys were conducted by a minimum of two people using 10' catarafts. Small tributaries were surveyed on foot, walking in an upstream direction.

Geographic position of redds were collected with a Trimble GeoXT™ GPS unit and downloaded into GPS Pathfinder® after each survey. The GIS data were reviewed and differentially corrected. To avoid recounting, redds were marked by flagging tied to bushes or trees adjacent to the area where they were observed. Individual flags were marked with the survey date, direction and distance from the redd(s), consecutive flag number, total number of redds represented by the flag, and surveyor initials. Incomplete redds or test pits were not flagged or counted.

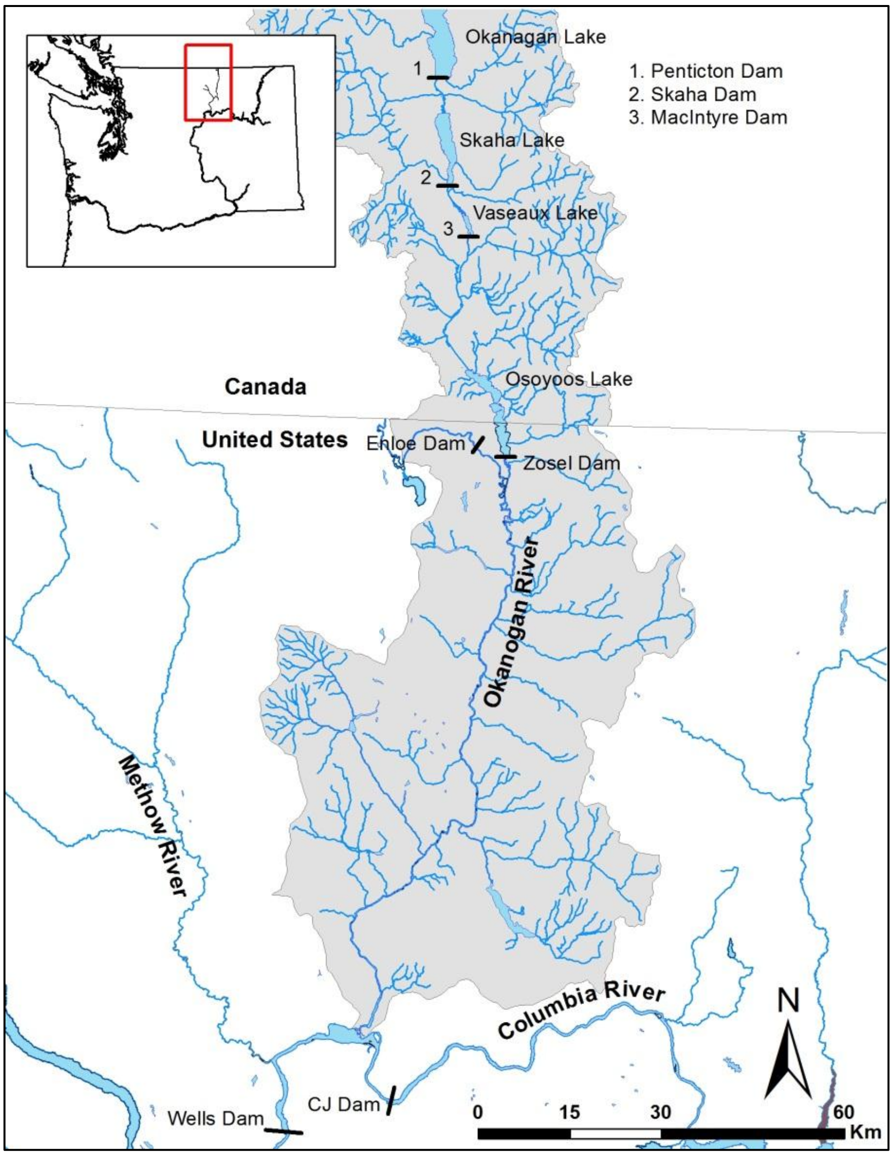

Figure 1. Study area, the Okanogan River subbasin in north-central Washington State and southern British Columbia.

Table 1. Okanogan subbasin redd survey reaches.

Redd Survey Reach	Location and Description	Reach Length (km)
Okanogan River 1	Okanogan River at Loup Loup Creek (26.7) to Salmon Creek (41.4)	14.7
Okanogan River 2	Okanogan River at Salmon Creek (41.4) to the office (52.3)	10.9
Okanogan River 3	Okanogan River at the office (52.3) to Riverside (66.1)	13.8
Okanogan River 4	Okanogan River at Riverside (66.1) to Janis Bridge (84.6)	18.5
Okanogan River 5	Okanogan River at Janis Bridge (84.6) to Tonasket Park (91.4)	6.8
Okanogan River 6	Ok. R. at Horseshoe Lake (112.4) to confluence with Sim. R. (119.5)	7.1
Okanogan River 7	Okanogan River at Sim. confluence (119.5) to Zosel Dam (127.0)	7.5
Similkameen River 1	Similkameen/Okanogan Confluence (0) to sewer plant (6.6)	6.6
Similkameen River 2	Similkameen from sewer plant (6.6) Enloe Dam (14.6)	8.0
Loup Loup Cr	Loup Loup Creek/Ok. R. confluence to Loup Loup Creek diversion (2.3)	2.3
Salmon Cr	Salmon Creek/Okanogan River confluence (0) to OID diversion (7.2)	7.2
Omak Cr	Omak Creek/Ok. R. Confluence (0) to Omak Creek trap site (1.5)	1.5
Wanacut Cr	Wanacut Creek/Okanogan River confluence (0) to the falls (2.5)	2.5
Johnson Cr	Johnson Cr./Ok. R. conf. (0) to PIT tag array above Hwy 97 (0.5)	0.5
Tunk Cr	Tunk Creek/Okanogan River confluence (0) to the falls (1)	1.0
Aeneas Cr	Aeneas Creek/Okanogan River confluence (0) to the barrier (0.4)	0.4
Bonaparte Cr	Bonaparte Creek/Ok. River confluence (0) to Bonaparte Falls (1.6)	1.6
Antoine Cr	Antoine Creek/Okanogan River confluence (0) to video weir (1.3)	1.3
Wildhorse Spring Cr	Wild Horse Spring Creek/Okanogan River Confluence to barrier (1.1)	1.1
Tonasket Cr	Tonasket Creek/Okanogan River confluence (0) to Tonasket Falls (3.5)	3.5
Ninemile Cr	Ninemile Creek from Lake Osoyoos (0) to PIT tag array (0.7)	0.7
Foster Cr	Foster Creek/Columbia River confluence (0) to barrier (1.7)	1.7

Sex Ratio and Number of Fish Per Redd

OBMEP employed the method currently used by Washington Department of Fish and Wildlife in the Upper Columbia Basin to extrapolate escapement estimates from redd counts using the sex ratio fish collected randomly over the run at Wells Dam (Andrew Murdoch, WDFW, pers. comm.). A sample of 584 summer steelhead, including 218 males (185 hatchery, 33 wild) and 366 females (327 hatchery, 39 wild), were sexed at Wells Dam during the 2012 upstream migration by WDFW personnel (Charles Frady, WDFW, pers. comm.). Adjusted proportionally for the run, the WDFW calculated a sex ratio of 0.603 males per female or 1.603 fish per redd (FPR). This value was used to expand redd counts on the mainstem Okanogan River into steelhead spawning estimates. All calculations using sex ratio multipliers assume that each female will produce only one redd.

Percent-Wild

The WDFW estimated that the proportion of wild fish bound for the Okanogan River was 168 out of a total of 1,890 steelhead, or 8.9% (Charles Frady, WDFW, pers. comm.). This value was based on ad-present steelhead counts, PIT tags, coded wire tags, scale analysis, harvest, broodstock collection, radio telemetry data, and stray rates estimated at Wells Dam. The wild percentage was applied to all mainstem Okanogan River reaches to estimate the number of wild steelhead that spawned in mainstem habitats.

PIT Tag Expansion Estimates

Permanent and temporary PIT tag arrays were operated near the mouth of all tributaries to the Okanogan River known to contain steelhead spawning, throughout the spring of 2013. Population estimates derived from PIT tag detections were calculated following Murdoch et al. 2011. A random representative sample of steelhead were captured at Priest Rapids Dam, two days per week over the course of the run, from July through November. A proportion of fish, approximately 13.4%, were tagged and released above Priest Rapids Dam (Ben Truscott, WDFW, pers. comm.). The mark-rate was used to expand the number of detections into escapement estimates for tributaries with PIT tag arrays. For example, if three hatchery and two wild steelhead were detected at a given creek in the Okanogan subbasin, the escapement estimate would be 22 hatchery and 15 wild steelhead, calculated from the mark-rate at Priest Rapids. This method assumes pre-spawn mortality is negligible. Based on the relatively few numbers of detections at many locations, particularly at smaller tributaries, escapement estimates derived from PIT tag detections may be variable and should be considered a general estimate. In addition to fish tagged at Priest Rapids, steelhead may have also received PIT tags at other locations (such as out-migrating juveniles, adults returning to Bonneville Dam, Wells Dam, among others); however, marking at those locations were not consistent across the run. Therefore, any extrapolations from PIT tag detections to an escapement estimate were derived only from the Priest Rapids release group. Detections from fish tagged at other locations may be mentioned anecdotally in this report.

Results

Steelhead Spawning Estimates: Okanogan and Similkameen River Mainstem

Redd surveys were largely unsuccessful at documenting the spawning activity of steelhead in the Okanogan River mainstem reaches in the spring of 2013. Due to an early onset of runoff in the Okanogan and Similkameen Rivers, only one preliminary survey could be completed on most mainstem reaches. Although a number of redds were documented in Okanogan River Reach 7 and Similkameen River Reach 2 (Table 2), it is unknown what proportion of the population they represented. Flows remained high through the end of July, when spawning had long since concluded and steelhead redds were indistinguishable.

Although redd surveys were unable to capture the complete spawning activity of summer steelhead, an estimate of mainstem spawning for 2013 was determined as follows. Assuming that the ratio of mainstem spawning remained comparable to previous years' surveys, spawner estimates for 2013 were calculated by combining data from previous years' redd distributions and Wells Dam count estimates generated by WDFW. The average proportion of spawning that occurred in each reach (from 2005-2011) was multiplied by the WDFW total spawning estimate for the Okanogan Basin in 2013. The estimated number of summer steelhead spawning in mainstem reaches is provided in Table 3.

Table 2. Redd survey and steelhead spawning estimates for mainstem reaches, 2013. Observed redds were multiplied by the WDFW fish per redd value (1.603) for a total steelhead estimate. The total steelhead estimate was multiplied by the proportion of ad-present steelhead (0.089) to calculate a mainstem wild steelhead estimate.

Redd Survey Reach	A. GPS'd Steelhead Redds	B. Total Steelhead Estimate (B=A*1.603)	C. Wild Steelhead Estimate (C=B*.089)	D. Hatchery Steelhead Estimate (D=B-C)	Complete Redd Counts?
Okanogan River 1	0	0	0	0	No
Okanogan River 2	0	0	0	0	No
Okanogan River 3	0	0	0	0	No
Okanogan River 4	0	0	0	0	No
Okanogan River 5	0	0	0	0	No
Okanogan River 6	0	0	0	0	No
Okanogan River 7	68	109	10	99	No
Similkameen River 1	0	0	0	0	No
Similkameen River 2	5	8	1	7	No
Mainstem Total	73	117	11	106	

Table 3. Modeled estimate of mainstem steelhead spawning, 2013. The WDFW Okanogan population estimate (1,890) was multiplied by the average proportion from previous spawning years in each reach. The total estimate was multiplied by the proportion of ad-present steelhead (0.089) to calculate a mainstem wild steelhead estimate.

Mainstem Survey Reach	A. Avg. Proportion of Spawning by Reach (2005-2011)	B. 2013 Total Estimate (B=A*1,890)	C. 2013 Wild Steelhead (C=B*.089)	D. 2013 Hatchery Steelhead (D=B-C)
Okanogan River 1	0.009	17	2	15
Okanogan River 2	0.033	63	6	57
Okanogan River 3	0.007	13	1	12
Okanogan River 4	0.028	53	5	48
Okanogan River 5	0.045	84	7	77
Okanogan River 6	0.012	22	2	20
Okanogan River 7	0.289	546	49	497
Similkameen River 1	0.098	184	16	168
Similkameen River 2	0.074	139	12	127
Mainstem Total	0.595	1,121	100	1,021

Steelhead Spawning Estimates: Tributaries to the Okanogan River

Tributary surveys were more successful at documenting locations of spawning steelhead when compared to the mainstem in 2013. Redd survey efforts on tributaries were occasionally limited by localized high water events from snow melt and precipitation. Some tributaries were successfully surveyed across the entire spawning period, while others were unable to be surveyed when water visibility remained poor. Steelhead redd surveys within tributary habitats occurred from March 18 through June 7. The upstream extent of each survey was limited by either a natural fish passage barrier or access to private land. Above-normal precipitation and discharge in 2013 allowed adult steelhead to access many of the small tributaries which are frequently inaccessible due to low flows or dry creek beds. However, increased flows frequently resulted in reduced water clarity, which at times, limited the effectiveness of redd surveys on many small tributaries. Results from redd surveys on tributaries to the Okanogan River are presented in Table 4.

PIT tag interrogation sites were installed and operated on 12 tributaries to the Okanogan River in 2013. Detections of steelhead marked and released at Priest Rapids Dam (PRD) were expanded by a tag rate of 0.1339 for wild steelhead and 0.1343 for hatchery steelhead, as described in the methods section. The number of tags detected at discrete locations and the expanded summer steelhead spawning estimates are presented in Table 5. Although redd surveys were not able to capture complete spawning activity of summer steelhead on multiple streams, due to poor water visibility, PIT tag antennas were in place to produce an estimate of spawning abundance. In the following paragraphs, we provide a summary of spawning estimates for steelhead in tributaries to the Okanogan River, given both methods.

Loup Loup Creek

Two redds were documented in Loup Loup Creek on May 14, but poor visibility prevented redd surveys from occurring during the primary spawning time period, from early-April through mid-May. PIT tag detections at site LLC suggested that a total of 74 steelhead likely spawned in Loup Loup creek, including 22 wild and 52 hatchery steelhead.

Salmon Creek

A total of 17 redds were documented from the confluence of Salmon Creek with the Okanogan River to the upstream irrigation diversion. These redds were expanded by 1.603 FPR for a total estimate of 28 spawning steelhead. At the diversion, an underwater video monitoring site captured a total of 98 upstream migrants (26 adipose fin-present and 72 hatchery steelhead). The combined estimate from downstream redd surveys and video counts above the diversion was 126 steelhead. The PIT tag array (SA1) documented 14 PRD PIT tags of hatchery origin, which was expanded to 104 hatchery steelhead. No wild PRD tags were detected at this site. Because 26 adipose fin-intact steelhead were documented passing at the video site, a combined estimate of 104 hatchery and 26 wild steelhead, from the PIT expansion and video monitoring, represented the best estimate for Salmon Creek in 2013.

Omak Creek

No redd surveys occurred on Omak Creek, from the confluence with the Okanogan River to the adult weir trap due to turbid water and high flows. Although the weir (operated by the Colville Tribe's Broodstock Acclimation Program, funded by Grant County PUD) was down for a period of time, an estimated 35 wild and 264 hatchery steelhead were estimated to have passed that point, based upon weir captures, tag detections, and marked and unmarked kelts recovered (Wesley Tibbits, CCT, unpublished data). At the PIT tag array (OMK), an estimated 37 wild and 238 hatchery spawned in Omak Creek, which were derived from PRD tag detections. Although the two estimates are comparable, the weir estimate was selected due to counting of actual fish in hand and to maintain agency consistency between the two monitoring operations.

Wanacut Creek

Wanacut Creek was successfully surveyed across the 2013 spring spawning period. A total of 5 redds were documented for a total estimate of 8 steelhead, 7 hatchery and 1 wild. No PRD tags were detected at the PIT tag antenna and the subsequent PIT tag derived estimate was zero steelhead. However, one hatchery steelhead not from the PRD mark-release group was detected in Wanacut Creek. Because 5 redds were found and there was an additional hatchery PIT tagged steelhead detected in the creek, it was estimated that 8 steelhead likely spawned in this Wanacut Creek.

Table 4. Redd survey and steelhead spawning estimates for tributary reaches, 2013. Observed redds were multiplied by the WDFW fish per redd value (1.603) for a total steelhead estimate. The total steelhead estimate was multiplied by the proportion of ad-present steelhead (0.089) to calculate a wild steelhead estimate.

Redd Survey Reach	A. GPS'd Steelhead Redds	B. Total Steelhead Estimate (B=A*1.603)	C. Wild Steelhead Estimate (C=B*.089)	D. Hatchery Steelhead Estimate (D=B-C)	Complete Redd Counts?
Loup Loup Cr	2	3	0	3	No
Salmon Cr, below PIT tag array	1	2	0	2	No
Salmon Cr, above array/below diversion	16	26	2	24	No
Omak Cr	0	0	0	0	No
Wanacut Cr	5	8	1	7	Yes
Johnson Cr	11	18	2	16	Yes
Tunk Cr	3	5	0	5	No
Aeneas Cr	0	0	0	0	Yes
Bonaparte Cr	0	0	0	0	No
Antoine Cr	0	0	0	0	No
Wildhorse Spring Cr	43	69	6	63	Yes
Tonasket Cr	8	13	1	12	No
Ninemile Cr	1	2	0	2	No
Tributary Total	90	146	12	134	

Table 5. PIT tag expansion estimates at detection sites in the Okanogan subbasin, 2013. PIT tag detections in tributaries were divided by the proportion of wild (0.1339) or hatchery (0.1343) steelhead observed in the PRD mark group.

Creek (Interrogation Site)	A. PRD Wild PIT Tags	B. PRD Hatchery PIT Tags	C. Expanded Wild (C=A/0.1339)	D. Expanded Hatchery (D=B/0.1343)	E. Expanded Total (E=C+D)
Loup Loup Cr (LLC)	3	7	22	52	74
Salmon Cr (SA1)	0	14	0	104	104
Omak Cr (OMK)	5	32	37	238	275
Wanacut Cr (WAN)	0	0	0	0	0
Johnson Cr (JOH)	0	3	0	22	22
Tunk Cr (TNK)	0	2	0	15	15
Aeneas Cr (AEN)	0	0	0	0	0
Bonaparte Cr (BPC)	3	8	22	60	82
Antoine Cr (ANT)	0	0	0	0	0
Wildhorse Spring Cr (WHS)	2	6	15	45	60
Tonasket Cr (TON)	1	8	7	60	67
Ninemile Cr (NMC)	1	3	7	22	29
Total	15	83	110	618	728

Johnson Creek

Redd surveys occurred in Johnson Creek throughout the spring of 2013, due to clear water conditions and relatively stable water flows. Eleven redds were documented, representing 18 total steelhead, 16 hatchery and two wild. Three PIT tags from the PRD mark-release group were detected in Johnson Creek, which were expanded to 22 hatchery steelhead. Although a total of 5 PIT tags were detected near the mouth of Johnson Creek, only one tag was detected upstream of the rock weir structure above Hwy 97, suggesting that it may pose a significant barrier to adult passage. On April 18, six adult steelhead were observed in Johnson Creek, attempting to jump into the Hwy 97 culvert; none were visually observed above this point.

Tunk Creek

In Tunk Creek, one early redd survey was conducted in late March and subsequently, elevated flows prevented surveys from occurring from April through May. No redds were observed. Detections from the PIT tag antenna (TNK) suggested that 15 hatchery and no wild steelhead spawned in Tunk Creek.

Aeneas Creek

Water conditions remained favorable in Aeneas Creek throughout the spring of 2013 and zero redds were found. Additionally, no tags were detected, suggesting that Aeneas Creek was not utilized for spawning during the spring of 2013. This was consistent across previous years' surveys.

Bonaparte Creek

Only one survey was conducted on Bonaparte Creek, in late March, before water conditions became unfavorable through May. No redds were found in Bonaparte Creek in 2013. PIT tag detections suggested that Bonaparte Creek was used for spawning by a large number of steelhead, even given its relatively short extent from the mouth to the upstream natural barrier (approximately 1.6 km). A total of 82 steelhead, 60 hatchery and 22 wild, were estimated to have spawned in Bonaparte Creek, based on expanded PRD PIT tag detections.

Antoine Creek

Zero redds were documented in Antoine Creek in 2013, although water conditions remained turbid during the month of April. Additionally, no adult steelhead were observed on an underwater video monitoring system. No PRD PIT tag detections occurred in 2013, however, one hatchery steelhead, not from the PRD mark-release group, was detected in Antoine Creek. It is possible that turbid water conditions precluded video observation during a short timeframe and passed undetected. Nonetheless, very few steelhead have utilized Antoine Creek for spawning in 2013 and in previous years. A barrier upstream of the video and PIT tag monitoring site was removed after the 2013 spawning period, which potentially opened 11 km of upstream habitat in Antoine Creek.

Wildhorse Spring Creek

In 2013, Wildhorse Spring Creek was surveyed successfully through the spring spawning period. A total of 43 redds were documented, leading to a total estimate of 69 steelhead, which were divided into 63 hatchery and 6 wild. Two wild and six hatchery PRD tagged steelhead were detected on Wildhorse Spring Creek, rendering 15 wild and 45 hatchery steelhead, for a total estimate of 60 spawning steelhead. Due to the fact that this small system largely dries up annually by early summer, the redd count estimate of 6 wild steelhead, rather than 15, is likely a more realistic value.

Tonasket Creek

Eight redds were observed in Tonasket Creek in May of 2013, although poor water visibility limited surveys prior to that date, during March and April. An unknown number of redds may have been missed during that timeframe. One wild and 8 hatchery PIT tagged steelhead were detected on Tonasket Creek from the PRD mark-release group. These detections led to an estimate of 7 wild and 60 hatchery steelhead, for a total of 67 spawning adults. The PIT tag derived estimate likely captured a more accurate value, when compared to the incomplete redd survey count.

Ninemile Creek

One redd was found in the lower reaches on Ninemile Creek before high flows occurred in April, which precluded further redd surveys and forced removal of an underwater video weir. One wild and three hatchery

PRD PIT tagged steelhead were detected on the PIT tag array (NMC), which was operable throughout the season. This provided a total estimate of 29 steelhead, 7 wild and 22 hatchery. The upstream extent of spawning in Ninemile Creek is currently unknown.

Zosel Dam and Upstream Locations

At Zosel Dam, both video monitoring and PIT tag antennas documented steelhead passage through the fishways in 2013. At high flows, spillways were opened and fish bypassed the fishways, passing upstream undetected. Underwater video captured the passage of 240 steelhead (151 hatchery, 89 ad-present) through May, at which time, the spillgates were opened. During that same timeframe, 27 hatchery and 4 wild PRD PIT tag mark-released steelhead passed in the fishways, for an estimate of 231 steelhead (201 hatchery and 30 wild). Both methods rendered similar total counts, albeit each likely underestimated the total count due to the spillways opening in May. The PIT tag counts likely better represented the adipose fin-intact hatchery steelhead count, so that method likely generated a more accurate count to date.

Zosel Dam is located immediately above Okanogan River Reach 7, the largest spawning area in the Okanogan subbasin, and the downstream end of Osoyoos Lake. Above this point are Tonasket and Ninemile Creek in the Washington State portion of the subbasin, which both have PIT tag detection capability. In the upriver British Columbia portion of the subbasin are the mainstem Okanagan (detection site OKC at VDS3, just upstream from Lake Osoyoos), Inkaneep Creek (no adult monitoring in 2013), and very small perennial streams. Three wild steelhead from the PRD mark-release group were detected at OKC, which represented approximately 22 wild steelhead. Two additional hatchery steelhead and one wild, not from the PRD mark-release group, were also detected at this location. From all upstream monitoring sites (Tonasket, Ninemile, OKC), approximately 120 steelhead were accounted for from Zosel Dam counts. The remainder leaves approximately 110 steelhead unaccounted for. These fish may have entered Inkaneep Creek, past OKC undetected, been caught in the Osoyoos Lake recreational fishery, or may have fallen back over Zosel Dam to downstream locations. The fall back rate at Zosel Dam is currently unknown, but may be relatively large, due to heavily utilized spawning habitat available in Okanogan Reach 7 immediately downstream and the inundated Lake Osoyoos directly upstream.

In the Canadian portion, above Lake Osoyoos (upstream of OKC at VDS3), steelhead have access up to the dam at the outlet of Okanagan Lake at Penticton, British Columbia. Between Lake Osoyoos and Okanagan Lake are thirteen Vertical Drop Structures, as well as, two more lakes (Skaha Lake and Vaseux Lake), both with outlet dams. The outlet dam at Vaseux Lake (McIntyre Dam) was the upstream barrier for anadromous salmonids up until 2009 and the outlet dam at Skaha Lake was still undergoing improvements for fish passage in 2013. The majority of the Canadian portion of the mainstem Okanagan River is characterized as being straightened and channelized. The main tributaries to the mainstem Okanagan River include Shingle Creek, Ellis Creek, McLean Creek, Shuttleworth Creek, Vaseux Creek and a number of small perennial streams. In 2013, no adult steelhead monitoring was performed through OBMEP above the OKC site at VDS3.

Foster Creek (located outside the Okanogan subbasin)

Although Foster Creek is not located within the Okanogan subbasin, OBMEP installed a PIT tag antenna and conducted redd surveys in 2013 to further describe the spatial extent of Upper Columbia River steelhead. Foster Creek was successfully surveyed across the entire 2013 spawning period, due to clear water and stable flows. A total of 19 steelhead redds were observed for an estimated total of 30 steelhead, divided into 3 wild and 27 hatchery. The PIT tag antenna detected 2 wild and 3 hatchery PIT tagged steelhead from the PRD mark-release group, which led to an estimated 15 wild and 22 hatchery steelhead, or a total of 37. Because no juveniles were observed during adult surveys, we reverted to the more conservative estimate of 3 wild and 27 hatchery steelhead. Either method considered, a comparable total number of steelhead entered and spawned in Foster Creek in 2013.

Okanogan Subbasin Steelhead Spawning Distribution and Trends

A summary of the estimated adult steelhead population in the Okanogan subbasin, distributed by mainstem survey reach and individual tributaries, is presented in Table 6. Table 7 and Table 8 contain a summary of total and wild steelhead spawning estimates, as determined by WDFW and OBMEP from 2005 through 2013.

Table 6. Estimated number of total and wild spawning steelhead for each sub-watershed or assessment unit in 2013. The total Okanogan River population is presented with subtotals for tributary and mainstem habitat types in Washington State. The estimates are based on combinations of PIT tag detections, video counts, and observed redds.

Distribution of Steelhead Spawning in the Okanogan Basin, 2013

Category	Description/location	Estimated Total # Spawners	Estimated Total # Wild
WA Mainstem	Okanogan River 1	17	2
WA Mainstem	Okanogan River 2	63	6
WA Mainstem	Okanogan River 3	13	1
WA Mainstem	Okanogan River 4	53	5
WA Mainstem	Okanogan River 5	84	7
WA Mainstem	Okanogan River 6	22	2
WA Mainstem	Okanogan River 7	546	49
WA Mainstem	Similkameen River 1	184	16
WA Mainstem	Similkameen River 2	139	12
WA Tributary	Loup Loup Creek	74	22
WA Tributary	Salmon Creek	130	26
WA Tributary	Omak Creek	299	35
WA Tributary	Wanacut Creek	8	1
WA Tributary	Johnson Creek	18	2
WA Tributary	Tunk Creek	15	0
WA Tributary	Aeneas Creek	0	0
WA Tributary	Bonaparte Creek	82	22
WA Tributary	Antoine Creek	1	0
WA Tributary	Wild Horse Spring Creek	69	6
Zosel Dam	**Observed Passing Zosel Dam**	231	30
WA Tributary	Tonasket Creek	67	7
WA Tributary	Ninemile Creek	29	7
Subtotals	**Adult escapement into WA mainstem**	**1,121**	**100**
Subtotals	**Adult escapement into WA tributaries**	**792**	**128**
Subtotals	**Adult escapement into BC**	**24**	**22**
Grand total		**1,937**	**250**

Table 7. Total escapement of summer steelhead for the Okanogan River, 2005 - 2013, including combined hatchery and natural-origin summer steelhead estimates.

Okanogan River summer steelhead spawner population trend data				
Year	**WDFW escapement estimate** [b]	**OBMEP spawner survey estimate**		
		Low	Estimate	High
2005	2,233	1,147	1,315[c]	1,482
2006	1,602	779	855[c]	930
2007	1,921	1,234	1,266[d]	1,280
2008	1,755	1,341	1,386	1,436
2009	2,211	2,020	2,133	2,198
2010	3,920	3,236	3,496	3,596
2011	2,497	1,479	1,674	1,687
2012	2,784		2,799[c]	
2013	1,890		1,937[c]	

[b] WDFW revised previous escapement estimates from previous years in 2010.
[c] Estimated mainstem reach data rather than empirical data, as in other years.
[d] Only a low and high value was reported, so a simple arithmetic mean was computed.

Table 8. Natural origin summer steelhead estimates for the Okanogan River, 2005 - 2013.

Okanogan River wild summer steelhead spawner population trend data				
Year	**WDFW escapement estimate** [e]	**OBMEP spawner survey estimate**		
		Low	Estimate	High
2005	153	143	164[f]	185
2006	130	127	139[f]	151
2007	110	148	152[g]	155
2008	227	213	225	266
2009	202	178	212	241
2010	352	630	728	853
2011	338	307	329	339
2012	261		324[h]	
2013	168		250[h]	

[e] WDFW revised escapement estimates from previous years in 2010.
[f] The Okanogan mainstem percent wild was applied across all reaches.
[g] Only a low and high value was reported, so a simple arithmetic mean was computed.
[h] Estimated mainstem reach data rather than empirical data, as in other years.

Discussion

Okanogan Subbasin Adult Steelhead Trends

In the United States, summer steelhead are currently listed as "threatened" under the Endangered Species Act in the Upper Columbia River ESU (NMFS 2009). OBMEP monitored adult Viable Salmonid Population (VSP) abundance attributes (McElhany et al. 2000) within the subbasin for Okanogan River summer steelhead. Adult monitoring was conducted through redd surveys, underwater video counts, and Passive Integrated Transponder (PIT) tag expansion estimates. Detailed percent-wild information has been provided annually and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. However, these data should be used with caution, as it is difficult to define natal origin through visual observation alone (i.e. intact adipose fin). Values presented in this document represent our best scientific estimate from available information, but the variability surrounding point estimates are currently undefined.

A summary of spawning estimates in the Okanogan subbasin from 2005 through 2013, for both hatchery and wild Steelhead is presented in Figure 2. Estimates were compared with recovery goals outlined by the Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007). The Upper Columbia Spring Chinook and Steelhead Recovery Plan stated that 500 naturally produced Steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin; if the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

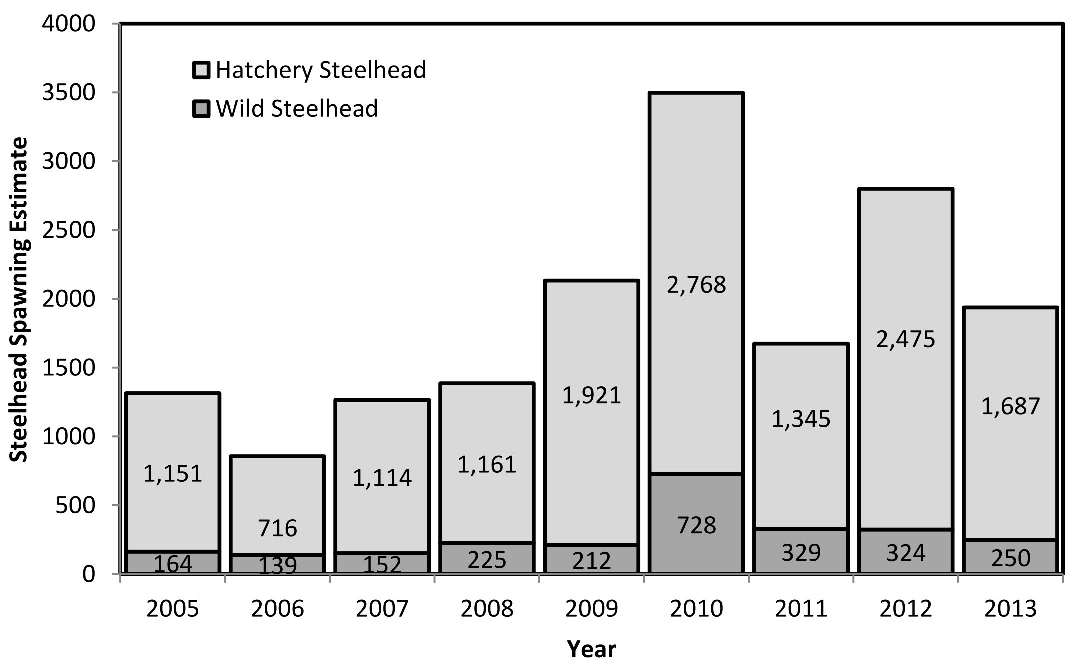

Figure 2. Spawning estimates for the Okanogan subbasin from 2005 through 2013, as determined by OBMEP.

Results from steelhead adult enumeration efforts indicate that the number of spawning steelhead in the Okanogan River subbasin, both hatchery and naturally produced, continued to increase since OBMEP began collecting data in 2005. The slope of the 2005 through 2013 trend line suggests that the number of total steelhead spawning in the Okanogan subbasin increased at an average rate of 187 fish per year (Figure 3) and the number of naturally produced spawners increased at an average rate of 29 fish per year (Figure 4). Spawning occurs throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning is largely influenced by stocking location because juvenile hatchery steelhead were scatter-planted in the Similkameen River, Omak Creek, and Salmon Creek.

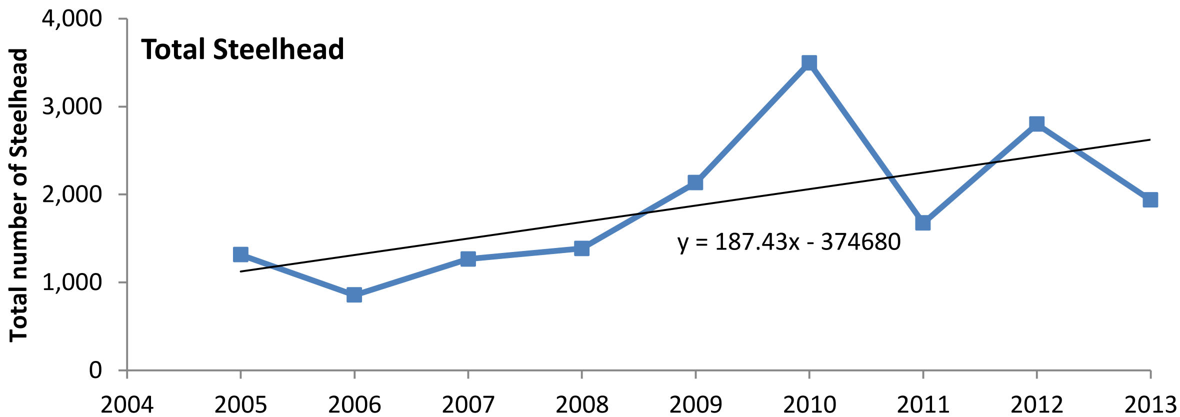

Figure 3. Trend in the estimated total number of summer steelhead spawning in the Okanogan River subbasin, 2005 - 2013.

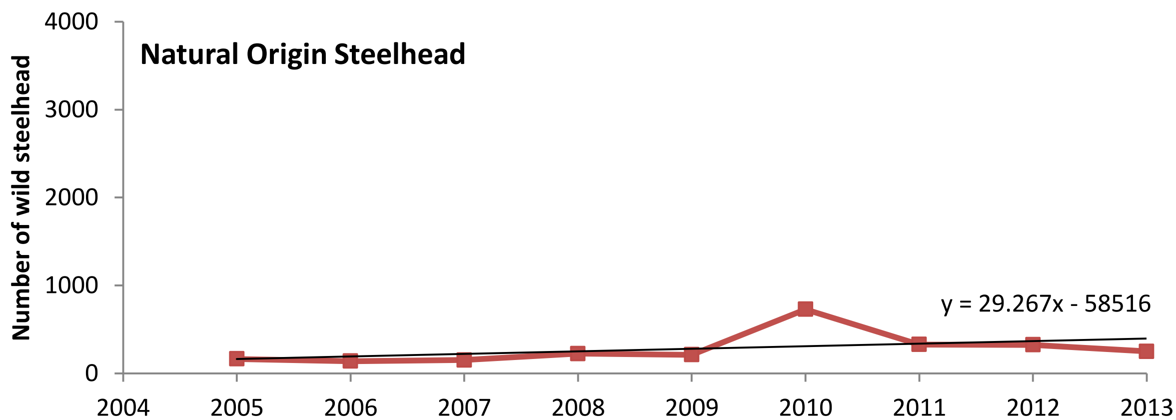

Figure 4. Trend in the estimated number of natural origin summer steelhead spawning in the Okanogan River subbasin, 2005 - 2013.

Large variations in estimates exist in many reaches from year to year, but often, these accurately reflect real-world situations rather than survey bias or calculation error. Small creeks may have extremely low flows for two years, blocking access with no spawning occurring, and then experience a large run of fish the following year when sufficient flows exist (e.g. Loup Loup Creek escapement of 0, 0, and 125 for 2008, 2009, and 2010, respectively). This irregular nature of small scale population data frequently results in data being scattered loosely around a linear trend line. Numerous methods have been described in the literature for analyzing complex fisheries data. When more years of data become available, additional detailed data analysis methods may be employed. We have made every effort to ensure that the reported values are as accurate as possible, including using multiple data collection methods for validation, comprehensive on the ground surveys, and best scientific judgment based on extensive local experience with the subbasin.

Annual variations of environmental factors can profoundly impact redd distributions in small tributaries to the Okanogan River. Changes in summer steelhead spawning distribution within tributaries appear to be driven by the following four factors: 1) Discharge and elevation of the Okanogan River, 2) discharge of the tributary streams, 3) timing of runoff in relation to run timing of steelhead, and 4) stocking location of hatchery smolts. The first three factors are largely based upon natural environmental conditions, which can be altered dramatically by such things as water releases from dams, irrigation withdrawals, and climate change. Years such as 2006, 2008, and 2009 clearly show how low tributary discharge can dramatically alter spawning location and reduce the available tributary habitat for steelhead to utilize (Figure 5). Habitat alterations at the mouths of key spawning tributaries may improve access, provided that sufficient discharge is available.

In 2010, 2011, and 2012, water availability in the Okanogan subbasin was above normal and subsequently, a larger proportion of steelhead spawned in tributaries than documented in previous years. Approximately 41% and 43% of steelhead were estimated to have spawned in tributaries to the Okanogan in 2010 and 2011, respectively. Because mainstem values were largely calculated and not directly counted for 2007, 2012, and 2013, no certain conclusions can be drawn for those survey years. Summer steelhead that spawn in tributary habitats of the Okanogan subbasin are more likely to find suitable environmental conditions and rearing habitats than those spawning in mainstem habitats. Therefore, the Fish and Wildlife Program should consider continuing restoration projects that address adequate flow in tributaries to the Okanogan River and providing access to additional kilometers of tributary streams.

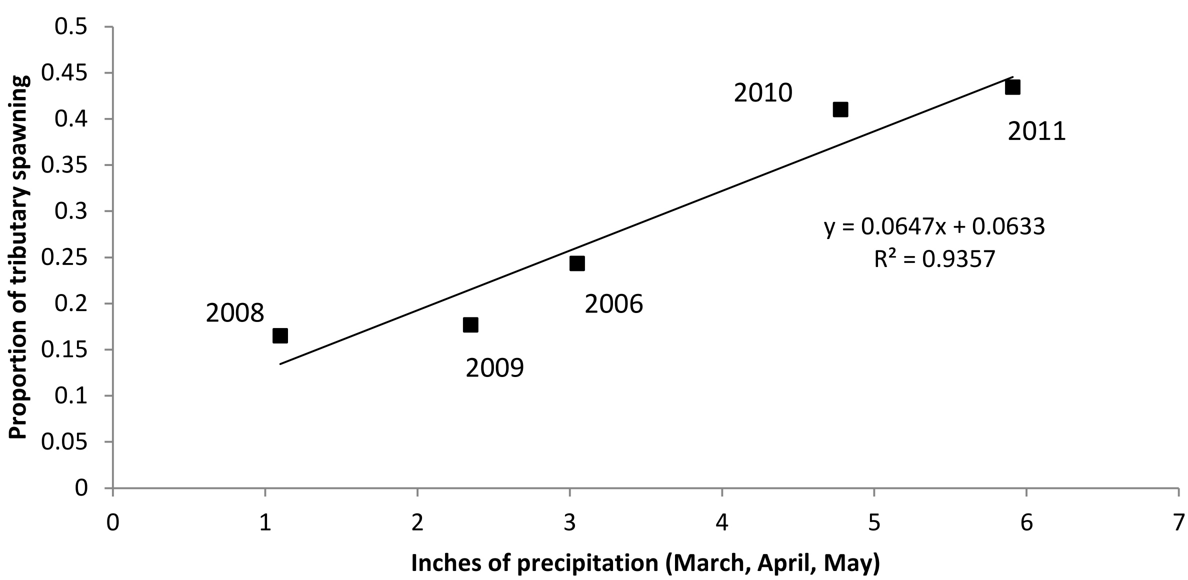

Figure 5. Correlation between precipitation occurring during March, April, and May and the proportion of summer steelhead spawning in tributaries to the Okanogan River in Washington State.

Comparison of PRD PIT Tag Expansion and 'On-the-Ground' Survey Estimates

Summer steelhead redd surveys, underwater video, and weir counts can provide a reasonable depiction of spawning distribution and an estimate of escapement on years when spring runoff occurs post-steelhead spawning. However, using these methods to determine distribution and abundance of spawning on years with early runoff is less objective. Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on redd surveys for abundance estimates has become evident. Implementation of an Upper Columbia Basin-wide PIT tag interrogation systems (Project # 2010-034-00), coupled with the representative marking of returning adults at Priest Rapids Dam, allowed managers an additional means to estimate abundance on years with poor water visibility, to validate redd survey efficiency, and describe spatial distribution and upstream extent of spawning where previously unknown.

In 2013, steelhead spawning estimates could not be determined for many tributaries through the use of redd surveys alone, including Loup Loup, Tunk, Bonaparte, Antoine, Tonasket, and Ninemile Creeks. In these systems, an estimate would not have been able to be produced, if not for PIT tag detection and expansion to a total estimate. It is useful to compare the traditional methods that OBMEP has used to calculate spawning estimates (defined as: expanding redd counts by FPR values, using underwater video counts, and weir traps) to PRD PIT tag expansion estimations. In the example below, PRD PIT tag expansion estimates were compared in systems where redd counts, video, and/or weir traps (referred to here-on as 'on-the-ground' estimates) were successful at monitoring adult steelhead. Any locations where on-the-ground estimates were unachievable were omitted in this analysis, and it is useful to note that PIT tag expansion was feasible in systems where redd surveys could not occur.

The total count of steelhead using on-the-ground estimates were compared to the PRD PIT tag expansion estimate (Table 9) and further analyzed by hatchery and wild steelhead (Table 10). Steelhead estimates were compared by linear regression analysis (Figure 6). Preliminary results from data from 2013 suggest that both methods provide highly correlated estimates for total steelhead ($p < 0.001$, Figure 6a.) and for hatchery steelhead ($p < 0.001$, Figure 6b.). The independent estimates of wild steelhead were noticeably less correlated ($p = 0.130$, Figure 6c.).

Multiple factors may lend clues to discrepancies between the two methods for wild steelhead. For on-the-ground counts, estimates were loosely determined from an applied general percent-wild rate, calculated from expanding observed redds to fish, and further dividing the calculated total fish to wild and hatchery. Video counts used the observation of an adipose fin alone to differentiate between wild from hatchery steelhead. This assumption may be over estimating the number of wild steelhead, due to a number of hatchery steelhead only being marked with a coded wire tag and not a fin clip. Although great efforts are made to differentiate hatchery from wild steelhead when PIT tagging occurred at PRD, relatively few detections of PIT tagged wild steelhead in small watersheds had a significant influence on the total estimate for wild steelhead, based on PIT tag detections alone. It is interesting to note that in one case, Omak Creek, both estimates produced a similar estimate of 35 and 37 wild steelhead (Table 10). This is likely due to the operation of a weir trap and a larger number of wild PIT tagged steelhead detected (Table 5) when compared with smaller sites.

From these initial analyses, we felt confident expanding PIT tag expansion estimates, for total and hatchery steelhead, to creeks where redd surveys and underwater video observations failed to document the spawning activity. However, determining the number of wild steelhead in small discrete watersheds continued to be a challenging task for both methods. Prospective solutions to aid monitoring programs in better defining an accurate estimate of spawning wild steelhead in the Okanogan subbasin include: 1) mark all hatchery steelhead with a visual mark, 2) increase the percent of tagged wild steelhead at PRD, 3) determine the feasibility of using the number of PIT tags detected at Wells Dam, and the total passage count, to determine the tag rate passing above that facility for use in expansion estimates, and 4) potentially implement a similar representative PIT tagging program at Wells Dam during the adult migration period. Continuing these adult steelhead monitoring efforts will allow managers to more accurately describe the spatial extent of steelhead spawning in the Okanogan River subbasin and define spawning estimates when redd surveys cannot be conducted.

Table 9. Comparison of 'On-the-Ground' and PIT Tag Expansion total estimates from 2013.

Location	'On-the-Ground' Total Steelhead	PRD PIT Tag Expansion Total Steelhead
Salmon Creek	126	104
Omak Creek	299	276
Wanacut Creek	8	0
Johnson Creek	18	22
Wildhorse Spring Creek	69	60
Zosel Dam	240	231
Foster Creek	30	37

Table 10. Comparison of 'On-the-Ground' and PIT Tag Expansion hatchery and wild steelhead estimates from 2013.

	'On-the-Ground'		PRD PIT Tag Expansion	
Location	Hatchery Steelhead	*Wild Steelhead*	Hatchery Steelhead	*Wild Steelhead*
Salmon Creek	98	*28*	104	*0*
Omak Creek	264	*35*	238	*37*
Wanacut Creek	7	*1*	0	*0*
Johnson Creek	16	*2*	22	*0*
Wildhorse Spring Creek	63	*6*	45	*15*
Zosel Dam	151	*89*	201	*30*
Foster Creek	27	*3*	22	*15*

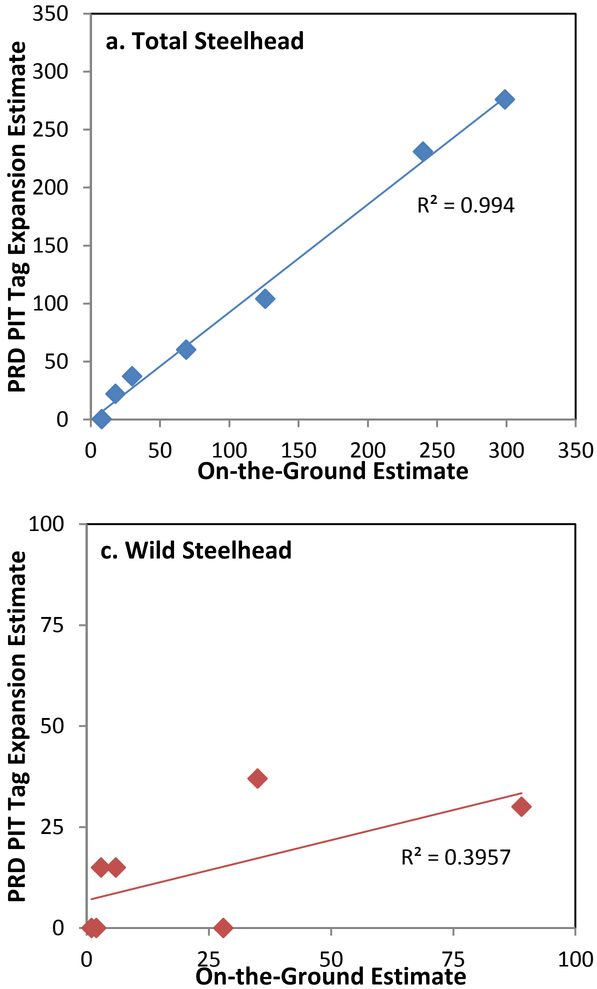

Figure 6. Linear regression analysis of PRD PIT tag expansion and 'On-the-Ground' spawning estimates, for a. total steelhead, b. hatchery steelhead, and c. wild steelhead.

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