Okanogan Basin Monitoring and Evaluation Program

2015 Annual Progress Report

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Abstract

Within the Upper Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous salmonid habitat is found in the Okanogan River. The Okanogan Basin Monitoring and Evaluation Program (OBMEP) conducted status and trend monitoring from 2004 through 2015 to evaluate viable salmonid population (VSP) criteria (abundance, productivity, spatial structure, and diversity) and threats to habitat of salmonids in the Okanogan subbasin. Monitoring efforts primarily focused on summer steelhead *Oncorhynchus mykiss*, which are ESA listed as threatened as part of the Upper Columbia River ESU. In 2015, it was estimated that a total of 1,461 summer steelhead (1,009 hatchery origin and 452 natural origin) spawned in the Okanogan subbasin. Over the past 11 years of monitoring (2005 through 2015), the average number of adult steelhead spawners in the Okanogan subbasin was 1,785 (geomean = 1,658). The average number of natural-origin spawning steelhead was 322 (geomean = 284). Although results indicate that the number of natural-origin steelhead spawning in the Okanogan River subbasin has increased since data collection began in 2005, the NOAA subbasin recovery goal of 1,000 natural origin spawners was not reached. Distribution of adult steelhead spawning within the subbasin has varied by survey reach, subwatershed, origin (natural or hatchery), and year, and was largely influenced by snowpack and spring discharge patterns.

To estimate outmigration, OBMEP operated a rotary screw trap from 2004 through 2011 on the mainstem Okanogan River, however, very few captures of naturally produced steelhead yielded highly variable and unreliable estimates. Challenges to derive meaningful outmigration estimates required a shift in methodology. From 2014 onward, outmigration was calculated from natural-origin juvenile steelhead PIT tagged instream during mark-recapture events and subsequently detected within the subbasin and downriver. An estimated 17,908 (95%CI = 16,449 to 19,367, SE = 744) juvenile steelhead outmigrated during the fall of 2014 through summer of 2015 from sample areas defined within this report. The majority of juvenile steelhead outmigrants were produced in Salmon Creek (62.8%), lower Omak Creek (23.0%), and Loup Loup Creek (11.3%). All remaining streams produced a combined 2.9%. Results from snorkel surveys conducted over the past 11 years are also presented in this document; observed fish abundance varied and general trends were largely site specific.

Habitat monitoring included measurement of habitat metrics including physical habitat, water quality, temperature, discharge, and benthic macroinvertebrates. The program collected annual habitat data at 25 fixed and 25 rotating panel sites. Additional habitat data were evaluated with the rapid assessment protocol, designed to quickly collect the most essential inputs for the Ecosystem Diagnosis and Treatment (EDT) model in reaches that were not covered by the fixed or random sites. The EDT habitat status and trend analysis provided a detailed assessment of steelhead and Chinook habitat potential in the Okanogan subbasin and characterized change in habitat conditions between 4-year monitoring cycles. The most recent 4-year EDT status and trend report was completed in 2015 and includes data collected through 2013. Data collected over the past 10 years have resulted in a list of recommendations for prioritization of habitat protection or potential restoration. An extremely low snowpack from the winter of 2014/2015 combined with above-normal temperatures and below-normal precipitation throughout 2015 resulted in record-low stream flow conditions throughout the Okanogan subbasin. Additionally, large wildfires burned throughout the catchment area of seven tributaries to the Okanogan River. Habitat monitoring sites are well positioned to evaluate potential impacts from these fires on anadromous salmonids moving forward.

The overall outcome of monitoring strategies is to guide natural resource managers' decisions to minimize threats to salmon and steelhead, choose restoration actions that will have the most positive impact, and set measurable salmon and steelhead enhancement objectives over multiple jurisdictions. Salmonid monitoring also includes collecting pertinent data useful for real-time decisions about harvest, hatchery management, and habitat project implementation. As monitoring efforts continue to progress, the Okanogan Basin Monitoring and Evaluation Program expects to continue to deliver practical status and trend monitoring data and to make those data readily available to agencies for use in more comprehensive, broad-scale analysis.

Acknowledgements

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The Okanagan Nation Alliance Fisheries Department would like to acknowledge the Osoyoos Indian Band (OIB), the Penticton Indian Band (PIB), the townships of Oliver, Okanagan Falls and Penticton, the Lezard family (of PIB), the Baptiste family (of OIB), the Thompson family (of OK Falls), The Nature Trust of BC, Elkink Ranch, Bobtail Ranch and the South Okanagan Rehabilitation Center for Owls for access granted to sites of this ongoing study. Acknowledgements also go to J. Squakin, Michael Dunn, Cash Tonasket, Dave Tom, Zoe Eyjolfson, Amanda Stevens, Sheena Hooley, Skyeler Folks, Colette Louie, Kari Alex, Natasha Neumann, Hannah Sungaila, Norm Johnson, Dan Stefanovic, Saul Squakin and Elliot Tonasket (PIB) for providing valuable technical assistance throughout the 2015 study.

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1.0 Introduction

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) conducted status and trend monitoring from 2004 through 2015 to collect and analyze fisheries data corresponding to adult and juvenile abundance, as well as, spatial and temporal distribution throughout the Okanogan[1] subbasin. Much of these efforts specifically focused on Upper Columbia River summer steelhead *Oncorhynchus mykiss*, which are listed as "threatened" under the Endangered Species Act (NMFS 2009). Habitat capacity and productivity monitoring tasks included collecting physical habitat measurements, water quality, temperature, discharge, and benthic macroinvertebrate data. Over the long-term, status data can be used to examine trends, which may indicate if salmon and steelhead populations and respective habitats are improving or degrading. Due to the Washington-British Columbia international boundary intersecting the Okanogan subbasin, the CCT and Okanagan Nation Alliance (ONA) Fisheries Department began coordinating on this project in the Canadian portion of the subbasin in 2005. Continuing effort is put into maintaining consistent sampling programs on both sides of the border through frequent meetings and cross-training to align methodologies for collecting biological and physical field data.

Study Area

Within the Upper Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. The Okanogan subbasin extends south from its headwaters in southern British Columbia through north central Washington State, where it meets the confluence with the Columbia River (Figure 1). The total drainage area of the Okanogan subbasin is roughly 21,000 km^2, more than twice the size of the Methow, Entiat, and Wenatchee subbasins combined (NPCC 2004, Morrison and Smith 2007); however, the total stream kilometers available to anadromous salmonids are limited due to natural falls and man-made barriers. The Okanogan subbasin is comprised of diverse habitat, from high mountain forests to semi-arid shrub-steppe lowlands. Often bordered by steep granite walls, water flows from north to south through a series of large lakes which give way to a low gradient mainstem river before entering the Columbia River near the town of Brewster, WA.

The subbasin supports a population of summer-fall Chinook Salmon (*Oncorhynchus tshawytscha*), a greatly expanding number of Sockeye Salmon (*Oncorhynchus nerka*), a population of summer steelhead, and occasional observations of spring Chinook Salmon and Coho Salmon (*Oncorhynchus kisutch*). During the late summer months, water temperatures in the mainstem Okanogan River frequently exceed 24˚C, representing a challenging environment for salmonids. A number of small, cooler water tributaries to the Okanogan offer additional habitat for steelhead, but access is often limited by insufficient discharge, natural barriers and man-made impediments. Within the Washington State portion of the Okanogan subbasin, the vast majority of land along the river is under private ownership, and landowner cooperation is required for fisheries research activities to occur. Economic activity in the subbasin is centered on fruit crops, ranching, agriculture, tourism, mining, and timber harvest. In this relatively arid environment, a complex system of fisheries and water management requires coordination between

[1] Spelled 'Okanogan' in the U.S. and spelled 'Okanagan' in Canada; may be used interchangeably in this document.

many local stakeholders, state (provincial) agencies, federal agencies, Tribes and First Nations, from both the United States and Canada.

In the Canadian portion of the Okanagan subbasin, man-made barriers are major constraints to current salmonid migrations. Dams exist at the outlets of Canadian Okanagan mainstem lakes including, suwiẇs (Osoyoos Lake), np'əxłpiw' (Vaseux Lake), q̓awstik̓ʷt (Skaha Lake), and kłusxnitkʷ (Okanagan Lake). In 2009, the outlet dam at np'əxłpiw' (Vaseux Lake), known as McIntyre Dam, was refitted to allow limited fish passage. Currently, the kłusxnitkʷ (Okanagan Lake) outlet dam at snpintktn (Penticton) is the upstream barrier for all anadromous salmon species and the q̓awstik̓ʷt (Skaha Lake) outlet underwent improvements for fish passage in 2014. It is known that anadromous salmonids have previously occupied the entire q̓awsitkʷ (Okanagan River) system (Ernst and Vedan 2000).

Goals and Objectives

OBMEP conducted status and trend monitoring in the Okanogan River subbasin to evaluate Upper Columbia River summer steelhead population in support of the following Bonneville Power Administration (BPA) Fish and Wildlife management sub-strategies[2]:

1. Assess the status and trend of natural and hatchery origin abundance of fish populations for various life stages.
2. Assess the status and trend of juvenile abundance and productivity of natural origin fish populations.
3. Assess the status and trend of spatial distribution of fish populations.
4. Assess the status and trend of diversity of natural and hatchery origin fish populations.

This project also conducted status and trends monitoring to evaluate habitat in the Okanogan subbasin used by Endangered Species Act (ESA) Listed Upper Columbia River steelhead and summer/fall Chinook in support of the following BPA Fish and Wildlife sub-strategy[3]:

5. Monitor and evaluate tributary habitat conditions that may be limiting achievement of biological performance objectives.

OBMEP was designed to monitor status and trends of both biological and physical habitat parameters. Protocols were developed to assess viable salmonid population (VSP) criteria (abundance, productivity, diversity, and spatial structure) of adult and juvenile Upper Columbia River summer steelhead in the Okanogan River and its tributaries. Although data and analysis derived from OBMEP may help to address effectiveness of habitat or hatchery projects, identifying causal mechanisms was not the intent of the original program research questions.

[2] Fish Population RM&E https://www.cbfish.org/ProgramStrategy.mvc/Summary/1

[3] Tributary Habitat RM&E https://www.cbfish.org/ProgramStrategy.mvc/Summary/3

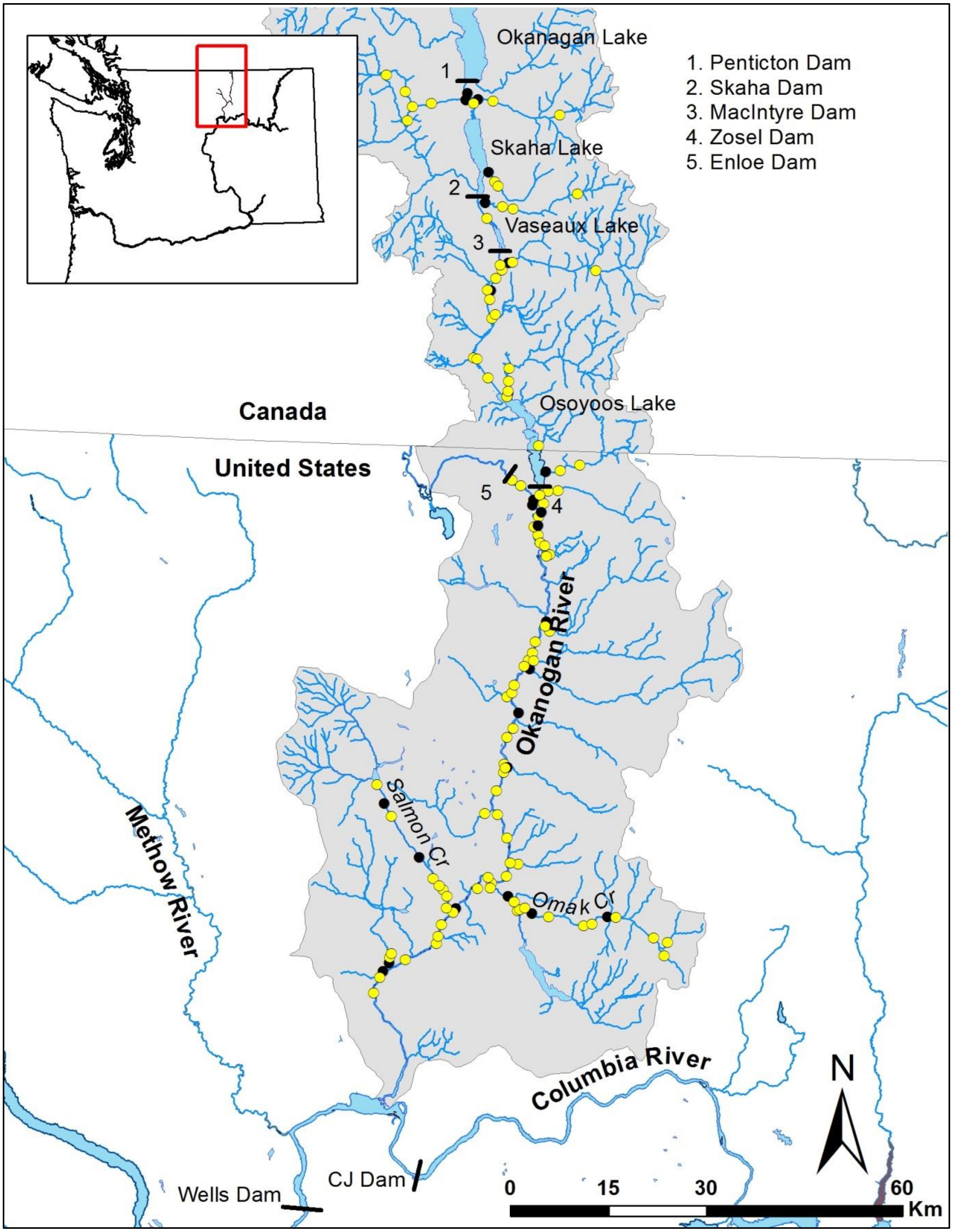

Figure 1. Study area, the Okanogan subbasin in north-central Washington State and southern British Columbia. Markers signify OBMEP habitat monitoring sites; black markers represent annual panel sites sampled every year and yellow markers represent rotating panel sites sampled every four years.

The objectives of OBMEP habitat status and trend monitoring through the Ecosystem Diagnosis and Treatment (EDT) model are to:

1. Provide a platform for organizing habitat status and trends data and translating these data into estimates of change in theoretical habitat capacity for ESA-listed steelhead and Chinook salmon.
2. Track trends in data quality and identify priority data collection needs.
3. Identify priority areas for habitat protection and restoration planning.
4. Provide a platform for evaluating the biological effectiveness of restoration actions as measured by observed habitat response.

2.0 Methods

2.1 Fish Population Status and Trend Monitoring

Adult Steelhead Monitoring

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

A combination of methods have been utilized to derive annual spawner abundance estimates for steelhead in the subbasin, including redd surveys, underwater video observations, Passive Integrated Transponder (PIT) tag interrogation sites, and adult weir traps. Spawner abundance estimates were determined for each unique tributary and mainstem reach. The subbasin-wide estimate was the sum of those individual estimates. Specific methods are detailed in the web links listed above. Enumeration of adult steelhead in the British Columbia portion of the subbasin relied solely on expanded PIT tag detections.

Juvenile Salmonid Monitoring

OBMEP - Juvenile Abundance - Mark-Recapture (ID:194)
https://www.monitoringmethods.org/Protocol/Details/194
OBMEP - Juvenile Abundance - Snorkel surveys (ID:7)
https://www.monitoringmethods.org/Protocol/Details/7

In the recent years of the program, instream juvenile abundance monitoring occurred through the implementation of an Okanogan tributary-focused electrofishing and PIT tag mark-recapture study in the Washington State portion of the subbasin. To estimate outmigration, OBMEP operated a rotary screw trap from 2004 through 2011 on the mainstem Okanogan River, however, very few captures of naturally produced steelhead yielded highly variable and unreliable estimates for that species. Challenges to derive meaningful outmigration estimates required a shift in methodology. From 2014 onward, outmigration was calculated from natural-origin juvenile steelhead PIT tagged instream during mark-recapture events and subsequently detected within the subbasin and downriver. Detailed methods for the juvenile mark-recapture/outmigration project are presented in Appendix B.

Snorkel surveys have been conducted in both Washington State and British Columbia from 2004 through 2015. In this document, snorkel survey metrics have been presented as density of juvenile *O. mykiss*/hectare, which were derived by dividing the observed number of fish by the wetted surface area of the survey site. Wetted surface area was calculated by measuring 22 evenly spaced wetted width measurements during habitat surveys and multiplying the average width by the total survey reach length.

2.2 Habitat Status and Trend Monitoring

OBMEP - Habitat Monitoring (ID:9)
https://www.monitoringmethods.org/Protocol/Details/9
OBMEP – Rapid Habitat Assessment (ID:8)
https://www.monitoringmethods.org/Protocol/Details/8
Method: Ecosystem Diagnosis and Treatment (EDT) v1.0
https://www.monitoringresources.org/Document/Method/Details/3973

Two data collection protocols and a habitat modeling methodology are utilized by OBMEP on a four-year data collection and analysis cycle. The supporting protocols and methods are detailed in the web links listed above. The transect-based OBMEP Habitat Monitoring protocol is applied at 50 habitat monitoring sites (25 annual panel sites, 25 rotating panel sites) per year for the entire Okanogan subbasin and covers 125 sites including 85 reaches in the U.S. portion of the Okanogan subbasin in each four-year sampling cycle. The GIS mapping-based OBMEP Rapid Habitat Assessment protocol is applied at reaches not sampled using the OBMEP Habitat Monitoring protocol and should occur at least once within each four year cycle.

The OBMEP/EDT integration method transforms the extensive and complex body of habitat monitoring data collected by CCT into information that is easier to use in decision making and communication with stakeholders and the public (CCT 2015). EDT integrates quantitative and qualitative OBMEP habitat metric data with empirical observations of species and habitat relationships to provide characterization of habitat status and trends in terms of the change in the ability of the habitat to support a species of interest over time (CCT 2015). This relationship is arranged hierarchically. Higher level indicators (survival factors) of habitat performance are the product of one or more environmental attributes, which are in turn the product of empirically-based transformations of habitat data. Detailed methods describing this hierarchy and the translation of habitat data into EDT environmental attributes are found in Lestelle (2005). Further methods describing linkages between environmental attributes, survival factors, EDT spatial structure and data sources are provided in CCT 2013 and 2015.

3.0 Results

3.1 Fish Population Status and Trend Monitoring

Adult Steelhead Monitoring

OBMEP monitored the status and trend of summer steelhead spawning abundance and distribution within the Okanogan subbasin through a combination of redd surveys, underwater video counts, and PIT tag expansion estimates. In 2015, it was estimated that a total of 1,461 summer steelhead (1,009 hatchery origin and 452 natural origin) spawned in the Okanogan subbasin (Table 1). From 2005-2015, the average estimated number of steelhead spawners in the subbasin was 1,785 (geomean=1,658). The average number of natural-origin spawning steelhead was 322 (geomean=284). Although results indicate that the number of spawning natural-origin steelhead in the Okanogan River subbasin increased since data collection began in 2005, the NOAA recovery goal of 1,000 natural origin spawners for the subbasin was not reached (Figure 2). The proportion of hatchery origin spawners (pHOS) from 2005 through 2013 averaged 0.85, but decreased to 0.65 for 2014 and 2015. A summary of spawning estimates in the Okanogan subbasin from 2005 through 2015 are presented in Table 2.

Table 1. Estimated number of total and natural origin steelhead spawning for each sub-watershed or assessment unit in 2015.

Category	Description/location	Estimated Total Spawner Abundance	Estimated Natural Origin Spawner Abundance
WA Mainstem	Okanogan River 1	7	1
WA Mainstem	Okanogan River 2	26	5
WA Mainstem	Okanogan River 3	6	1
WA Mainstem	Okanogan River 4	23	5
WA Mainstem	Okanogan River 5	36	7
WA Mainstem	Okanogan River 6	10	2
WA Mainstem	Okanogan River 7	233	47
WA Mainstem	Similkameen River 1	79	16
WA Mainstem	Similkameen River 2	59	12
WA Tributary	Loup Loup Creek	12	6
WA Tributary	Salmon Creek	98	29
WA Tributary	Omak Creek	551	172
WA Tributary	Wanacut Creek	0	0
WA Tributary	Johnson Creek	41	12
WA Tributary	Tunk Creek	41	8
WA Tributary	Aeneas Creek	0	0
WA Tributary	Bonaparte Creek	138	63
WA Tributary	Antoine Creek	8	0
WA Tributary	Wild Horse Spring Creek	0	0
WA Tributary	Tonasket Creek	0	0
WA Tributary	Ninemile Creek	2	1
Subtotal	**Adult escapement into WA mainstem**	**479**	**96**
Subtotal	**Adult escapement into WA tributaries**	**891**	**291**
Subtotal	**Adult escapement into BC**	**91**	**26**
Grand total		**1,461**	**452**

*Estimates based on a combination of expanded redd counts, PIT tag detections, and underwater video observations.

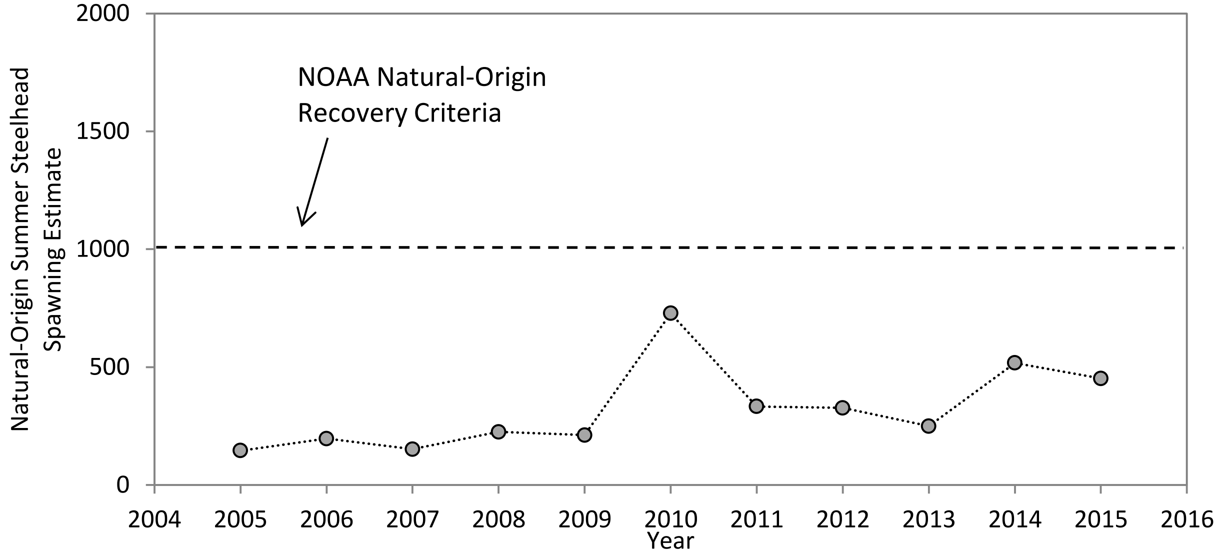

Figure 2. Trend in the estimated number of natural-origin summer steelhead spawning in the Okanogan River subbasin, 2005 - 2015.

Table 2. Estimated summer steelhead spawner abundance in the Okanogan subbasin, 2005-2015.

Year	Hatchery-Origin	Natural-Origin	Total	pHOS
2005	1,080	146	1,226	0.88
2006	702	197	899	0.78
2007	1,116	152	1,268	0.88
2008	1,161	225	1,386	0.84
2009	1,921	212	2,133	0.90
2010	2,768	728	3,496	0.79
2011	1,341	333	1,674	0.80
2012	2,475	327	2,802	0.88
2013	1,687	250	1,937	0.87
2014	838	518	1,356	0.62
2015	1,009	452	1,461	0.69
Mean	1,463	322	1,785	0.82

In the Washington State portion of the subbasin, distribution of adult steelhead spawning varied by survey reach, subwatershed, origin (natural or hatchery), and year. The 11-year (2005-2015) average pHOS was higher for the mainstem Okanogan River (0.89) compared with tributaries (0.76). Summer steelhead spawning has been documented throughout the mainstem Okanogan River, although due to a relatively low gradient, spawning is narrowly focused to distinct areas that contained suitable water velocities and spawning substrate. The proportion of steelhead spawning in many of the tributaries to the Okanogan River appeared to be regulated in part by stream discharge, which in turn was influenced by winter snowpack, spring precipitation in small creeks, timing of runoff in relation to spawn timing of steelhead, and surface water diversions.

Distribution of spawning in the British Columbia portion of the subbasin has remained largely unknown over the past 11 years. Determining total abundance of spawners was also difficult, but improved with the installation of a PIT tag antenna array (OKC) above suwiẁs (Osoyoos Lake) and representative marking of returning adults at Priest Rapids Dam (Project # 2010-034-00). A relatively small proportion of the total adult steelhead pass into British Columbia, averaging 3.5% for the past three years (2013-2015); however, average pHOS was much lower in British Columbia (0.26) than Washington State (0.74) during that timeframe. Given the apparent large amount of potential habitat for anadromous fish in the British Columbia portion of the Okanagan subbasin, continuing to expand the number of PIT tag interrogation sites in British Columbia will help increase knowledge concerning trend in abundance and spatial distribution of summer steelhead in the subbasin.

Juvenile Salmonid Monitoring

Instream Abundance (Electrofishing)

During sampling in the fall of 2015, the majority of juvenile *O. mykiss* were found in Salmon Creek (67.4%), lower Omak Creek (22.5%), and Loup Loup Creek (5.7%). All remaining streams contained a combined 7.4% of juvenile *O. mykiss*. Similar results were found in 2014, the first year of the study (Table 3). While only high-level instream abundance metrics have been presented here, additional details concerning fish abundance by specific reach, length frequency data, and growth rates by tributary, among others, can either be found in Appendix B or could be obtained by contacting OBMEP staff directly. In future years, these sampling techniques may be applied to tributaries in the British Columbia portion of the subbasin.

Table 3. Instream abundance estimates of natural-origin *O. mykiss* (±95% CI) in tributaries to the Okanogan River for 2014 and 2015.

	< 95 mm *O. mykiss*		> 95 mm *O. mykiss*	
Tributary	2014	2015	2014	2015
Loup Loup Cr	18,806 ± 1,567	5,036 ± 654	2,542 ± 319	1,453 ± 135
Salmon Cr	39,491 ± 6,046	48,089 ± 5,210	29,019 ± 2,049	28,751 ± 2,092
Omak Cr	23,045 ± 1,647	21,694 ± 2,698	6,958 ± 886	3,957 ± 338
Johnson Cr	Not sampled	Not sampled	Not sampled	Not sampled
Wanacut Cr	0	0	0	0
Tunk Cr	0	0	193 ± 31	0
Aeneas Cr	86 ± 14	11 ± 1	106 ± 20	43 ± 22
Bonaparte Cr	2,922 ± 368	918 ± 336	127 ± 20	254 ± 42
Antoine Cr	Not sampled	Not sampled	Not sampled	Not sampled
Wildhorse Sp Cr	Not sampled	Not sampled	Not sampled	Not sampled
Tonasket Cr	2,192 ± 716	0	526 ± 51	9 ± 0
Ninemile Cr	4,184 ± 756	2,191 ± 552	2,393 ± 375	1,610 ± 196
Total	90,726 ± 11,114	77,939 ± 9,451	41,864 ± 3,751	36,077 ± 2,825

Outmigration

The Okanogan Basin Monitoring and Evaluation Program operated a rotary screw trap from 2004 through 2011 on the mainstem Okanogan River to monitor outmigration of juvenile salmonids. However, very few captures of natural origin steelhead yielded highly variable and unreliable estimates. New procedures were fully implemented in 2014 when OBMEP began conducting the tributary juvenile monitoring study to estimate abundance and outmigration of natural origin juvenile steelhead. Based on detection of PIT tagged fish from within and outside of the Okanogan subbasin, an estimated total of 17,908 (95%CL=16,449 to 19,367, SE=744) juvenile steelhead outmigrated during the fall of 2014 through summer of 2015. The numbers of outmigrants by subwatershed are presented in Figure 3. Any potential production from outside the sampling area, including the mainstem Okanogan River, Similkameen River, or British Columbia would not be factored into those estimates. Preliminary data based on PIT tag detections suggest that juvenile *O. mykiss* may utilize the mainstem in the fall, winter, and spring seasons, although those findings are not quantifiable at this time. Additional details are presented in Appendix B.

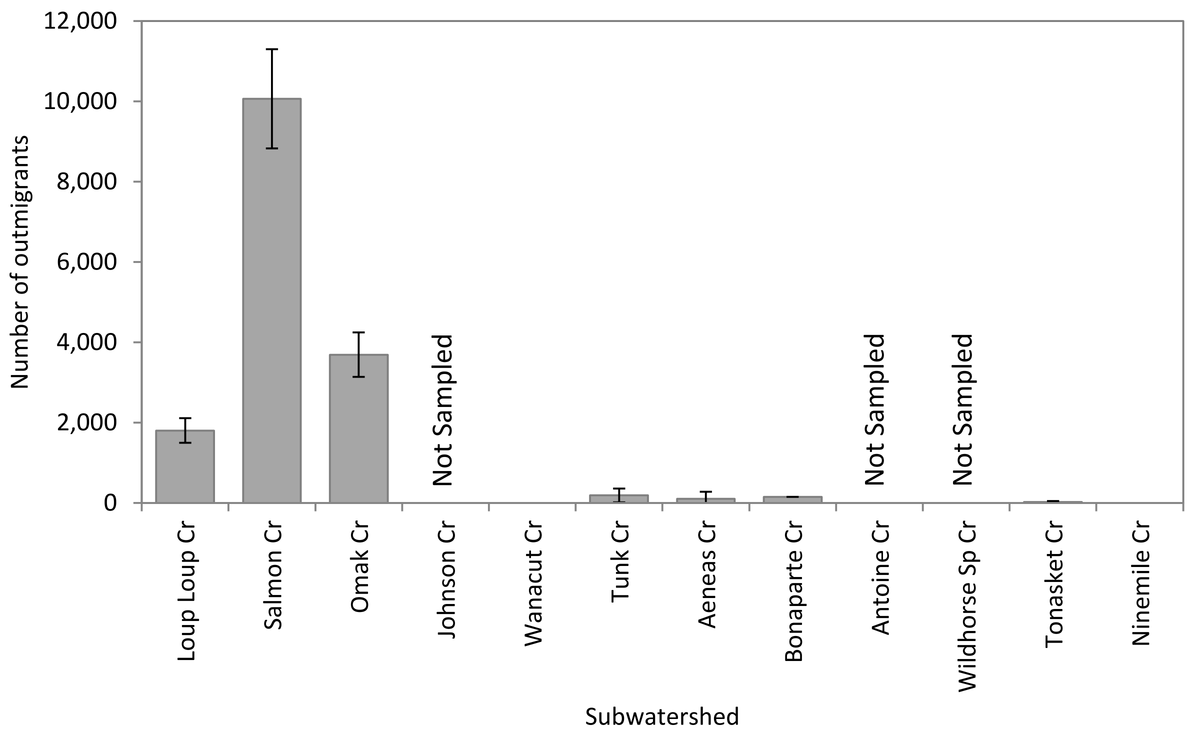

Figure 3. Estimated 2015 juvenile steelhead outmigration (±95%CI) by subwatershed.

Snorkel Surveys

Results from snorkel surveys suggest that during the summer base-flow periods, considerably higher densities of juvenile *O. mykiss* are found in tributaries, compared with the mainstem Okanogan River. These findings have remained constant over the past 11 years of data collection. Detailed results showing general trends in observed abundance from snorkel surveys from annual habitat monitoring sites are presented in Appendix C. In the U.S. portion of the Okanogan from 2004 to 2015, the trend in total abundance of juvenile *O. mykiss* at annual monitoring sites increased in tributaries (Loup Loup Creek, Omak Creek, and Salmon Creek, with slight downward trends in Bonaparte, Ninemile, and Tunk creeks), but remained near or at zero for nearly all mainstem Okanogan River survey sites. In British Columbia, from 2005 to 2015, the trend in total abundance of juvenile *O. mykiss* at annual tributary monitoring sites increased in Shingle and McLean creeks, had a slight upward trend in Inkaneep Creek, Shuttleworth Creek, and Vaseux Creek, and decreased slightly in Ellis Creek. Abundance at annual survey sites in the British Columbia mainstem Okanagan River remained low, averaging only 0.17 fish/ha, which was higher than in the Washington State portion of the Okanogan River.

3.2 Habitat Status and Trend Monitoring

The Okanogan subbasin habitat status and trends analyses are presented in two reports, one for summer steelhead and one for summer/fall Chinook. The most recent status and trends reports, delivered in 2015, and containing data collected through 2013 can be accessed at the web links below.

Summer Steelhead:
http://www.colvilletribes.com/media/files/2015SteelheadHabitatStatusandTrendsReport.pdf
Summer/Fall Chinook:
http://www.colvilletribes.com/media/files/2015ChinookHabitatStatusandTrendReport.pdf

Results are presented in a series of hierarchically arranged report cards scaling down from the Population Level (Okanogan subbasin), to the Diagnostic Level (stream segment composed of many reaches) and finally to the Reach Level.

The Population Report Card:

- provides a summary of target species population abundance and trend since the last 4 year monitoring cycle,
- summarizes significant management achievements made during the monitoring cycle,
- ranks the information quality for data used in each monitoring cycle,
- shows positive, negative or neutral trend results for productivity, abundance, habitat capacity and life-history diversity for each of the habitats analyzed,
- identifies specific subbasin locations where restoration or preservation projects would have the greatest impact to population abundance, and
- presents graphs for the theoretical adult and juvenile population size the habitat can support.

The trends in habitat condition in the 2013 EDT scenarios are the result of changes in habitat condition and improvements in the quality and quantity of empirical information supporting EDT. The quality of information that was used in the 2013 EDT model runs was a substantial improvement when compared to 2009 (Figure 4 and 5).

Summer Steelhead Population (US)

The trend shown in the population report card for Okanogan (U.S.) steelhead suggests a relatively stable habitat capacity and abundance performance even though habitat performance for steelhead declined slightly between the 2009 and 2013 scenarios for both adults and juveniles (Figure 4). Between 2009 and 2013, modeled adult habitat capacity showed a 2% decrease and adult abundance fell 19%, however, results indicate that current habitat conditions have the capacity to support a viable population of summer steelhead (> 500) in the U.S. portion of the Okanogan.

Upper Salmon Creek was the highest priority for protection because it had the highest potential for reductions in productivity if habitat conditions were to degrade. Priority habitats in both lower and upper Salmon Creek also showed some of the largest potential gains for increased population productivity if restored (Figure 4). Steelhead habitat potential in upper and lower Salmon Creek shows a positive trend in all parameters except the habitat capacity trend which decreased more than 5% in lower Salmon Creek between 2009 and 2013.

Model results also suggested that Johnson Creek showed potential for increasing population productivity with restoration (Figure 4). However, no habitat improvement projects were conducted before the end of the data collection cycle that fed the 2013 model run so most of the trends in Johnson Creek were negative or neutral.

Summer/fall Chinook Population (US)

The population report card for Okanogan (U.S.) summer/fall Chinook is presented in Figure 5. Habitat capacity and abundance show positive trends between 2009 and 2013, with capacity increasing by 53% during this period. Juvenile habitat capacity increases substantially during this period to 94% of template, while juvenile abundance increased 43%. Habitat productivity is similar between the 2009 and 2013 scenarios, but the proportion of self-sustaining trajectories drops from 29% to 20% during this period, indicating that the 2013 scenario was supported by a narrower range of life history diversity.

Most Okanogan River reaches show potential for increasing population productivity with restoration actions. Diagnostic unit and reach specific habitat performance can be found in the summer/fall Chinook status and trend report link above.

Summer Steelhead Diagnostic Unit

An example diagnostic unit report card for Loup Loup Creek has been provided in Figure 6. Findings indicate that Loup Loup Creek provided productive habitat for steelhead under historic (template) conditions. Historic capacity and abundance were estimated at 107 and 95-adult steelhead, respectively, with a juvenile outmigrant estimate of over 3,200. Under the 2009 scenario, Loup Loup Creek had an estimated capacity of 8 and an abundance of 3 due to fish passage barriers, streamflow diversions and the degraded condition of several survival factors. Habitat improvements under the 2013 scenario increase capacity to 37-adult steelhead with an equilibrium abundance of 27. Three critical survival factors in Loup Loup Creek show opposing positive and negative performance trends between 2009 and 2013. The most heavily weighted survival factors are sediment conditions, flow conditions, and habitat diversity. Sediment conditions show a negative trend in performance between 2009 and 2013.

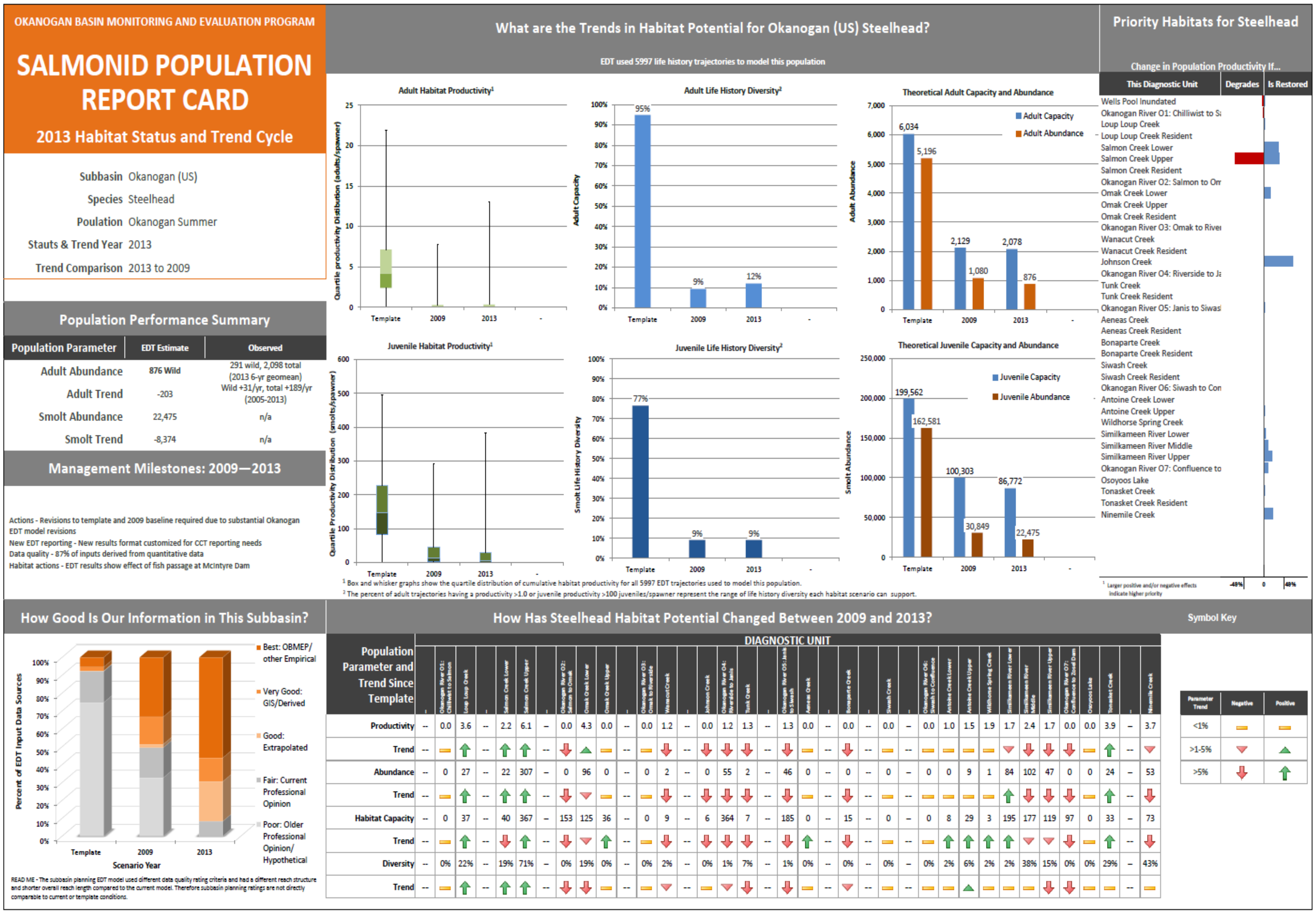

Figure 4. EDT results for the United States sub-population of summer steelhead from the Okanogan River (best viewed at 200% zoom).

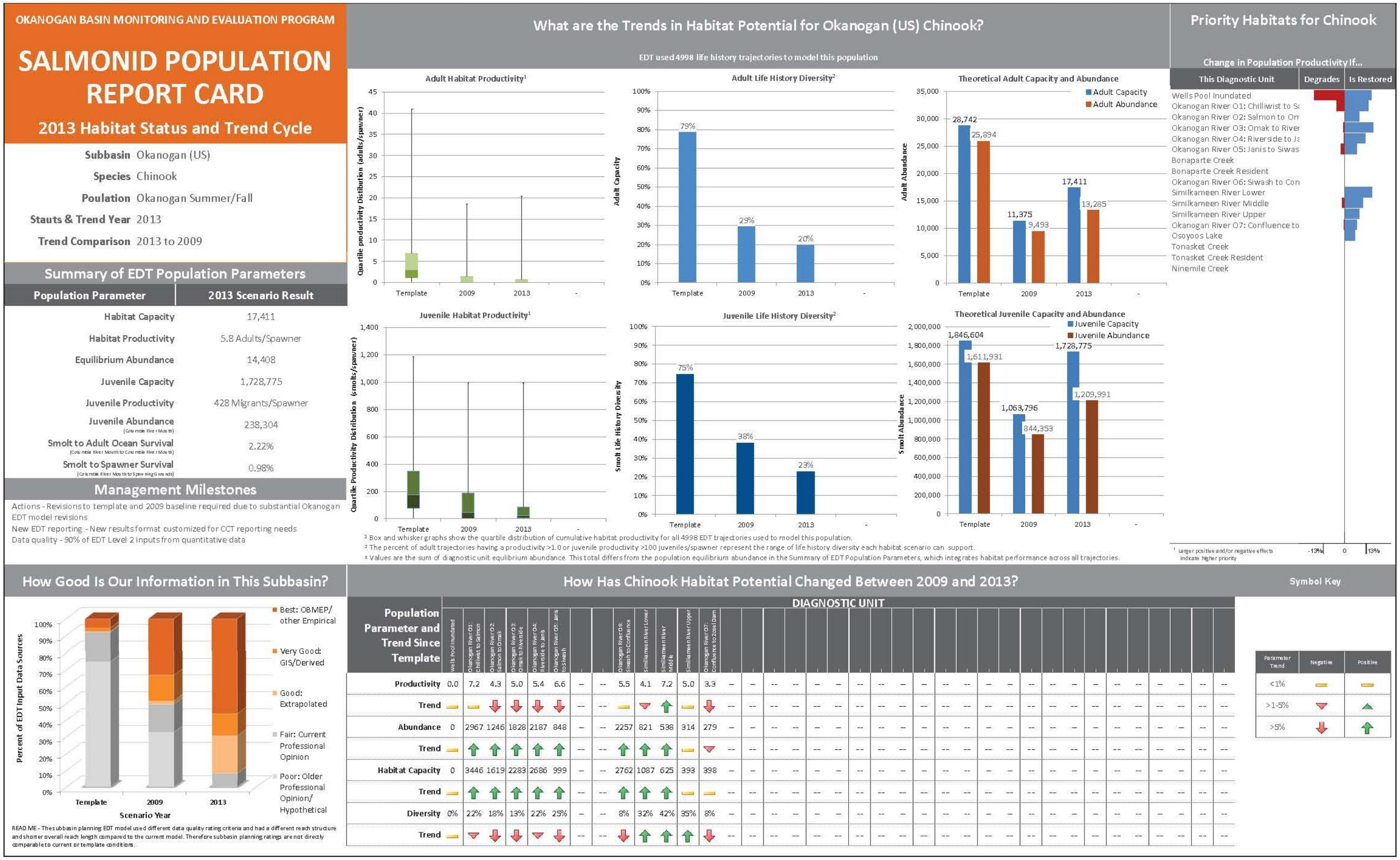

Figure 5. EDT results for the United States sub-population of summer Chinook from the Okanogan River (best viewed at 200% zoom).

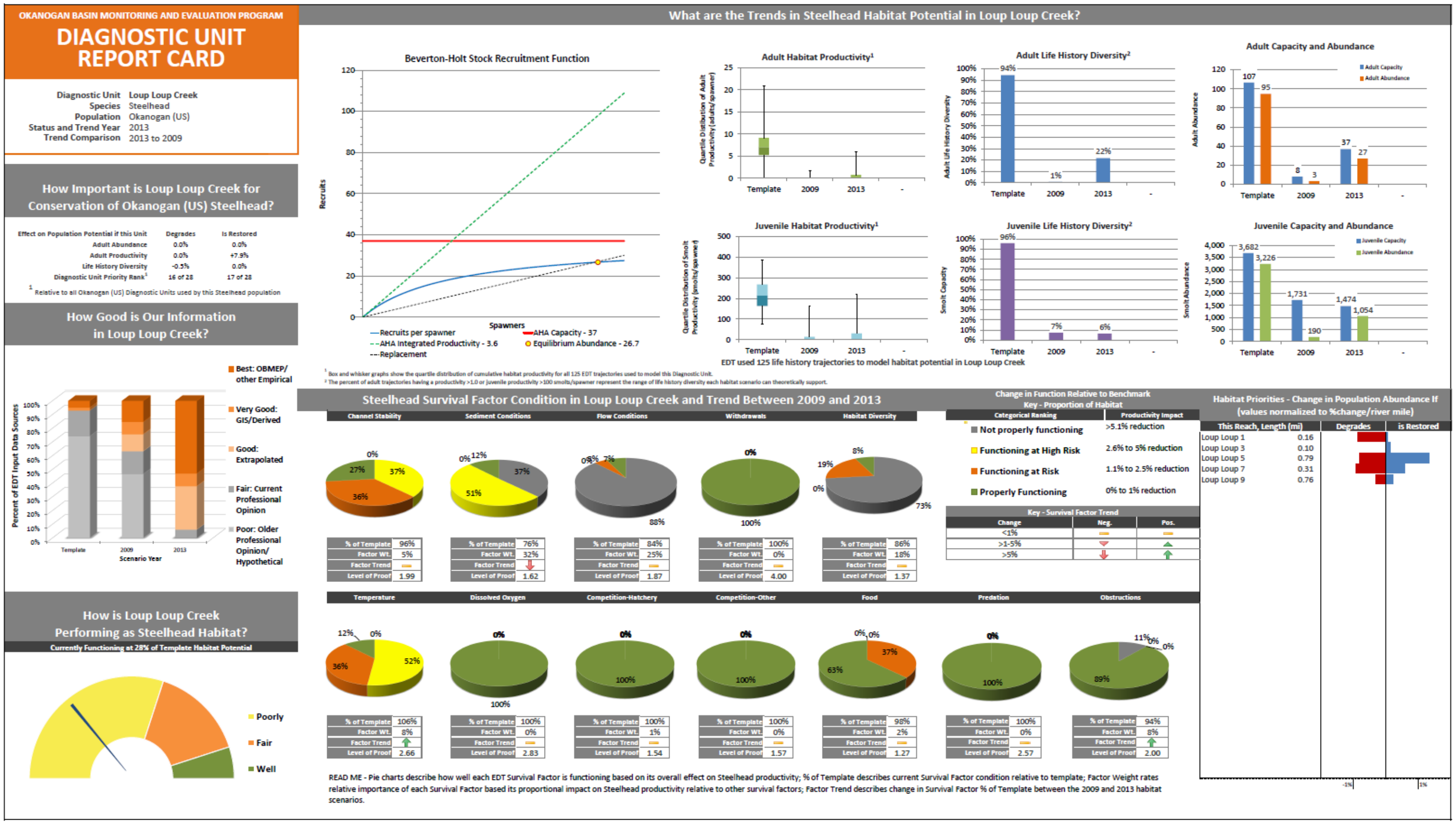

Figure 6. EDT results for the Loup Loup Creek diagnostic unit for summer steelhead (Best viewed at 200% zoom).

Additional Habitat Monitoring Results

Maximum weekly maximum temperature (MWMT) and maximum weekly average temperature (MWAT) values were calculated for all streams in Washington and British Columbia that had complete data sets for the months of June, July, August, and September. General temperature thresholds discussed below are further described in Appendix D, Table 11; > 18°C is likely above the preferred rearing temperature and represents an elevated disease risk (USEPA 2001a,b); > 23-26°C represents potentially lethal 1-week temperatures (USEPA 2001c). Median MWAT values for the current dataset (2005 - 2015) were above 23°C for the mainstem Okanogan in Washington State and British Columbia; median MWAT values for most tributaries were between 18 and 23°C (Figure 7). Although similar daily maximum values were being reached in the tributaries, the minimum daily values were also much lower resulting in a lower average. Based on long-term monitoring data and known limitations of cold-water salmonid species (reviews by Currie et al. 1998 and Beitinger et al. 2000), water temperature represents a limiting factor for rearing summer steelhead parr in the Okanogan River. Detailed results, including differences in amplitude in daily water temperature measurements and effects of water temperature during incubation and rearing are further discussed in Appendix D.

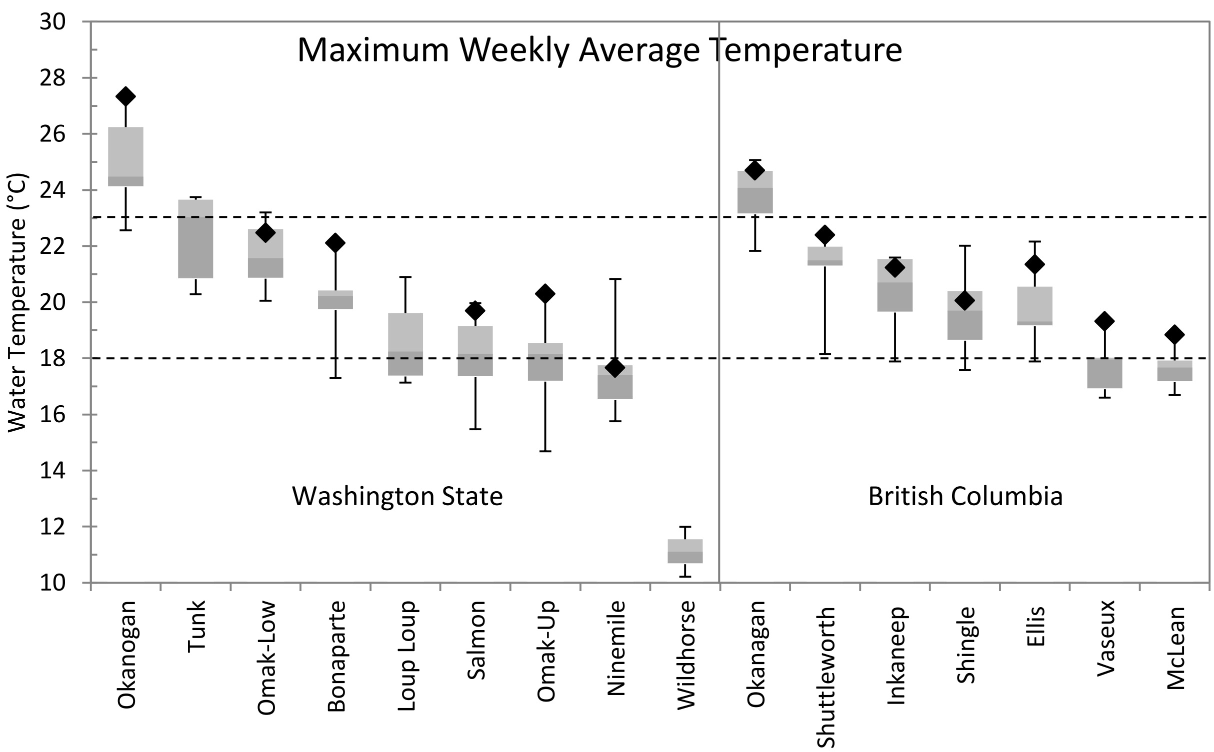

Figure 7. Maximum weekly average water temperatures in the Okanogan subbasin from 2005-2015. Black markers are 2015 data; dashed lines represent general 18 and 23°C thresholds (EPA 2003).

Low snowpack during the winter of 2014/2015 combined with above-normal temperatures and below-normal precipitation throughout 2015 resulted in record low stream flow conditions in the Okanogan subbasin. The USGS has continuously operated the Okanogan mainstem stream gage at Tonasket for the last 86 years; the mean monthly discharge at this gage in July 2015 was only 26% of the July monthly mean for the full period of record (Figure 8). Discharge in tributaries were characterized by an early February runoff period, returning to base flow by the end of June. The lower reaches of the majority of tributaries dried up completely during the 2015 base flow period. Additional trends in water quantity are presented in Appendix E. Although additional analyses have not specifically quantified effects outside of the EDT model, quantity of water in tributaries to the Okanogan River has been observed to have effects on various life stages of steelhead.

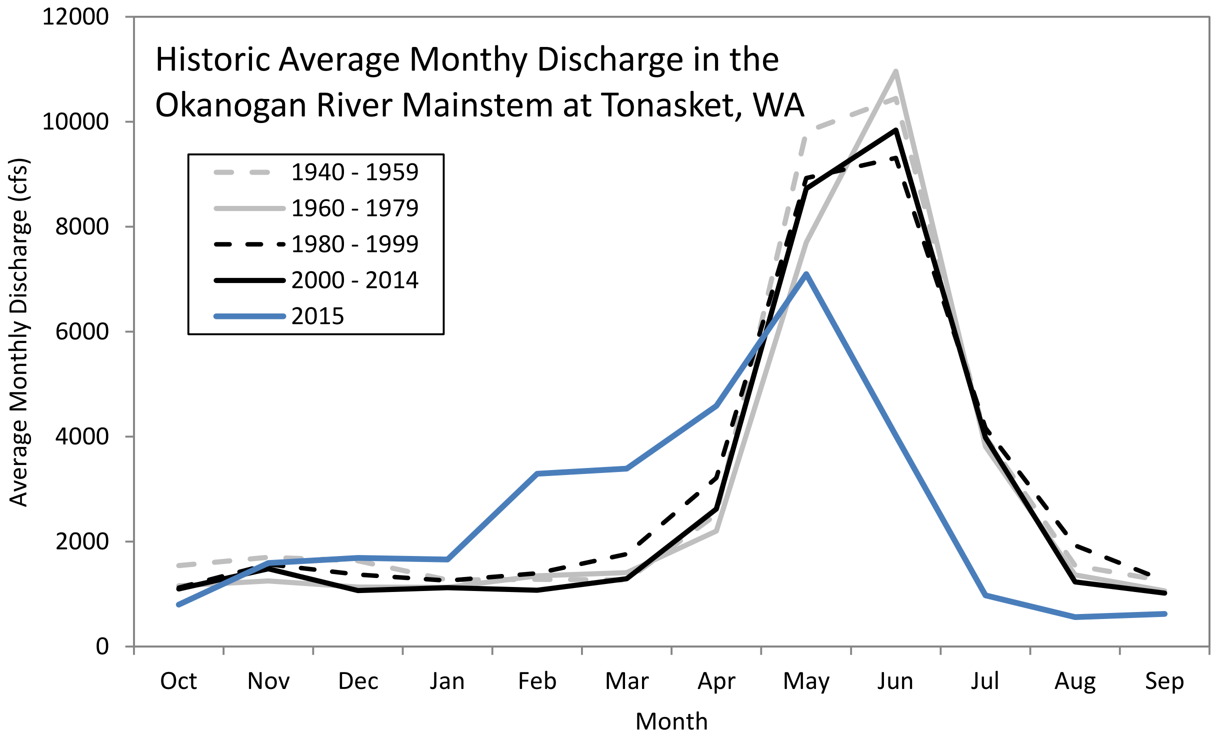

Figure 8. Average monthly discharge of the Okanogan River at Tonasket, WA (USGS Station 12445000, Okanogan River near Tonasket, WA).

4.0 Discussion/Conclusion

With the listing of several salmonid species within the Columbia River Basin as threatened or endangered under the Endangered Species Act, federal, state, tribal, and other entities have made considerable investments in salmon and steelhead population monitoring and habitat restoration. Tracking status of salmon and steelhead populations as they relate to habitat capacity and limiting factors remains an important part of determining if conditions are improving or degrading. Over the long-term, status data are used to examine trends, which may indicate if salmon and steelhead populations and their respective habitats are improving or degrading. In the absence of OBMEP monitoring efforts, very little empirical information would exist on the Okanogan subbasin. Data collected through this program has helped to address RPA 50.6 fish population status monitoring, RPA 56.3 habitat status and trend monitoring, RPA 71.4 data management, and RPA 72.1 coordination forums. Future monitoring will continue to support validation of trends, while some modifications of protocols may be needed to evaluate identified uncertainties.

Adult Steelhead Monitoring

Monitoring has benefitted steelhead populations in the Okanagan subbasin by informing specific restoration actions and prioritizing restoration and enhancement efforts. Steelhead spawning surveys have provided a means to document spawning distribution, timing, and an estimate of escapement in years when spring runoff occurs post-spawning. Defining the physical location of redds has helped to inform managers about the location of habitats being used for spawning and allow for tracking of spatial status and trends through time. Spatial distribution of redds has also been important when considering locations for restoring and/or protecting habitat. Detailed percent-natural-origin information has been provided and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. Values presented in this document represent a best estimate from available information, but the variability surrounding point estimates are currently undefined.

Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on redd surveys for determination of spawning estimates has become evident. Implementation of an Upper Columbia Basin-wide PIT tag interrogation system, coupled with the representative marking of returning adults at Priest Rapids Dam (Project # 2010-034-00) has 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 or access was limited. Continuation of these efforts will allow managers to describe the spatial extent of spawning in tributaries, monitor effectiveness of migration barrier removal, and better define escapement estimates with confidence intervals.

Juvenile Abundance and Outmigration Monitoring

The electrofishing-based juvenile abundance study implemented by OBMEP demonstrated that it was possible to determine an instream population estimate of juvenile salmonids in small creeks with a defined measure of precision. With continued years of data collection, change in status and trends in the population of juvenile steelhead in relatively small, spatially distinct watersheds have been detectable. Expanding these methods to additional subwatersheds within the Okanogan subbasin (such as in British Columbia) will allow for further examination of juvenile steelhead production and increase the number of PIT tagged fish available for interrogation to estimate out-migration for the subbasin as a whole. Many of the stated assumptions used in this study appeared to be adequate, but have remained untested (refer to Appendix B for further discussion). Detailed results from juvenile monitoring can be used to prioritize restoration or protective measures for habitat practitioners pertaining to priority stream reaches. Although the methods used in this study might not be applicable for larger systems, such as the mainstem Okanogan River, the representative fish sampling approach was shown to provide an estimate of juvenile steelhead in small watersheds, including outmigration estimates, with a high degree of precision.

Snorkel surveys of juvenile salmonids can show changes in relative abundance over time (Schill and Griffith 1984, Thurow 1994). Annual variation in observed abundance is calculable from the current long-term snorkel dataset for the Okanogan subbasin, but it remained unknown how these values related to total abundance until the recent implementation of electrofishing sampling at all tributary sample sites. Snorkel surveys conducted over the past 11 years showed trends in observed fish abundance, but results varied by site, even among subwatersheds. One of the difficulties in snorkel data collection is that the observation rate can vary, particularly in smaller tributaries with very shallow water depths. This effect can be further confounded on low water years, such as was experienced in 2015.

While OBMEP has strived to maintain consistency in observer bias, using the same snorkeler to collect tributary snorkel survey data for the past 7 years (2009-2015), variable observation rates were documented annually by site, and without a statistical evaluation it is not possible to definitively state if the trends are real. While snorkel survey methods have value and are relatively inexpensive, some level of caution should be used when interpreting these data, as many geomorphic and biological factors can affect results.

Habitat Status and Trend Monitoring

The quantity of water in streams in the semi-arid Okanogan River system plays a fundamental role in regulating abundance and distribution of salmonid species, particularly in small tributaries. Effects of extremely low discharge rates are compounded by warm water temperatures during the summer base flow period, which contribute to increased competition for food resources and rearing space. Results of stream flow and other habitat influences are further discussed in the EDT reports, where specific limiting factors are clearly defined by life stage. Results are provided at population, diagnostic unit and reach levels using habitat survival factors that can be "directly linked to existing management platforms like the Columbia Basin Expert Panel process and NMFS ecological concerns used to track regional trends in habitat condition and restoration actions (CCT 2015)". EDT results also include an assessment of the "reliability of results based on the strength of the underlying data and information used to generate survival factor results. Collectively, this information can be used to report on habitat status and trends, identify habitat protection and restoration priorities, and evaluate information needs and data gaps to guide future monitoring activities (CCT 2015)." Based on findings from the most recent EDT analysis, a list of recommendations has been developed for prioritization of habitat protection and restoration. Additional recommendations include improvements for the OBMEP/EDT integration to improve the reliability and utility of results in future model runs.

The overall outcome of monitoring in the Okanogan subbasin is to guide natural resource managers' decisions to minimize threats to salmon and steelhead, choose restoration actions that will have the most positive impact, and set measurable salmon and steelhead enhancement objectives to coincide with fiscal investments over multiple jurisdictions. Salmonid population monitoring also includes collecting applicable data that can be used in real-time decisions about harvest, hatchery management, and habitat project implementation. Information related to status and trends for salmon and steelhead within the Okanogan requires a long-term vision and commitment to provide answers about population-level actions and trends in habitat quantity and quality. As monitoring efforts continue to progress, the Okanogan Basin Monitoring and Evaluation Program expects to deliver practical status and trend monitoring data and to make those data readily available to agencies for use in more comprehensive, broad-scale analyses.

5.0 Adaptive Management & Lessons Learned

Explain how your results could be used by managers to inform program strategies; including habitat restoration, predation, or hatchery and hydrosystem operations.

Status and trend data collected through OBMEP under the Fish Population RM&E and Tributary Habitat RM&E program strategies have been used by a variety of managers. Long-term monitoring data collected and analyzed have been particularly useful for habitat practitioners (e.g., CCT Habitat Program, Trout Unlimited, Cascade Columbia Regional Fisheries Enhancement Group) performing restoration work within the Okanogan subbasin. Although data and analysis derived from OBMEP can and have been used to address effectiveness of habitat or hatchery projects, identifying causal mechanisms was not the specific intent of the original program research questions.

Some of the most requested monitoring data from managers have been fish abundance estimates, for both adult and juveniles. Adult abundance metrics have been used by habitat practitioners to evaluate success of tributary instream flow projects, irrigation management, potential water purchases, habitat protection measures, passage success before and after impediment removal/redesign, and hatchery stocking, among others. Percent of adults spawning in individual subwatersheds have been analyzed by origin (hatchery and natural) to examine current status and success of habitat projects and to modify hatchery broodstock collection goals. Juvenile abundance data have been used to prioritize reach-based habitat plans, manage flow patterns, examine survival by life stage, and in the future may be used to estimate survival or growth. Detailed results from juvenile monitoring can be used to prioritize restoration or protective measures for habitat practitioners, pertaining to priority stream reaches. Collection of detailed fish abundance data may also be used to validate or adjust EDT model parameters.

Metrics derived from long-term habitat monitoring in the Okanogan subbasin are also valuable for habitat practitioners. The OBMEP habitat status and trend approach has allowed the program to use a complex set of broad-ranging habitat data types to be integrated into a single model and output at multiple spatial scales. Data collected over the past 10 years have resulted in determination of limiting factors for salmonids and a list of recommendations for prioritization of habitat protection or potential restoration. The habitat status and trend analysis provided a detailed assessment of steelhead habitat potential in the Okanogan subbasin and characterized change in habitat conditions between 4-year monitoring cycles.

Describe how your results could be applied at the watershed, subbasin, and Columbia Basin scale.

Fisheries monitoring programs within the Columbia Basin are designed to detect changes in fish populations or habitat, identify potential sources of change, and/or measure success of management activities. Monitoring generally requires collecting and analyzing fine scale data and in turn, those data are rolled up to larger spatial analyses. At the Columbia Basin or Upper Columbia River scale, high level information, such as trends in spawner abundance or yearly outmigration estimates, are frequently used for ESU population-level tracking purposes. Temperature data collected at many sites throughout the subbasin over the past 10 years can be incorporated in to larger spatial analyses, such as the NorWeST project. Regional climate studies have utilized data collected through OBMEP. The USGS low snowpack river flow study in 2015 measured flow and temperature of hundreds of streams and rivers, including many of the stream flow stations in the Okanogan River subbasin. Habitat status and trend information can be directly linked to existing management platforms, such as the Columbia Basin Expert Panel process and NMFS ecological concerns used to track regional trends in habitat condition and restoration actions. Collectively, this information can be used to report on habitat status and trends, identify habitat protection and restoration priorities, and evaluate information needs and data gaps to guide future monitoring activities.

While high level, subbasin-wide indicators are some of the most commonly used information utilized in large-scale Columbia Basin-wide analyses, there is also substantial value in smaller, more site-specific datasets. Watershed, subwatershed, or reach-scale data are valuable for actively managing fish, hatcheries, and habitat restoration/protective actions, which lead to informed on-the-ground decisions that directly affect recovery of listed species. Adult abundance metrics and habitat status and trend information have been used by habitat practitioners to evaluate success of instream flow projects in specific subwatersheds, management of irrigation systems, identify measures to protect habitat, and evaluate passage impediments, among other uses. Juvenile abundance and small-scale habitat data have been used to prioritize reach-based habitat plans, manage flow patterns, and examine survival by life stage. Hatchery programs have managed or adjusted stocking of juvenile salmonids by specific subwatershed based on the proportion of natural origin spawners and available habitat. In season fish passage and temperature data have been used to inform international harvest goals. Information collected may also help to inform or update recovery goals, providing objective data about adult returns and juvenile habitat capacity based on actual data rather than subjective or professional opinion.

Discuss how your results will be shared with other resource managers.

According to the Framework for the Fish and Wildlife Program Data Management (BPA 2013) and the Guidance for Monitoring Recovery of Pacific Northwest Salmon & Steelhead listed under the Federal Endangered Species Act (Crawford and Rumsey 2011), there is a need for readily available data to support fisheries management processes and entities such as the Fish and Wildlife Program, the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp), and NOAA's 5-year review of ESA-listed species to determine their listing status. BPA's strategy for achieving this goal is to develop compatible networks of data management systems that have standardized documentation and data exchange formats. OBMEP has made significant gains in coordinating, standardizing, and disseminating data which support the RM&E program. As a BPA-funded project, the program has been keeping pace with these goals by utilizing tools such as Monitoring Methods.org to document and standardize protocols, developing electronic methods for data collection, review, transfer, and storage. The program has also submitted data types such as fish passage, redd surveys, and snorkel surveys to approved data repositories such as Data Access in Real Time (DART), Passive Integrated Transponder (PIT) Tag Information System (PTAGIS), and Streamnet. Finally, dissemination of other specific data (GIS layers, EDT reaches, steelhead redd GPS coordinates, and water temperature data) are made available on the OBMEP website at: http://www.colvilletribes.com/obmep_project_data.php

By inputting some data types in DART, PTAGIS, Streamnet, and other regional forums, we have learned that it is easier to share data when the end format is defined and there are data validations built in to the data collection event. For example, collecting PIT tag data destined for the PTAGIS database is very straightforward if the data are collected in the P3 software, which already contains data validation and a means to synchronize the data with the central database. As methods become more standardized in Monitoring Methods, perhaps it may be cost-efficient to develop data forms for the most utilized methods, so users can collect their data in a standardized format. In the absence of standardized data forms, tools such as the Coordinated Assessment Data Exchange Standard are going to be integral in standardizing data metrics after they are collected, so various datasets across the region can be integrated and rolled up to calculate higher level indicators for a given population.

Specifically within the Okanogan subbasin, considerable coordination has occurred between monitoring, habitat implementation, and hatchery programs. Due to close organization of these programs within the Colville Tribes Fish and Wildlife Department, findings from monitoring projects can be effectively communicated to habitat and hatchery programs in an efficient manner. For example, output from the EDT model for summer/fall Chinook is used by the CJH program at the Annual Program Review. Outlined in this document and the accompanying habitat status and trend reports are a number of factors that may be limiting recovery of salmonids within the Okanogan subbasin. Subsequent recommendations to habitat practitioners are included throughout these documents, which were derived from 11 years of monitoring data, analyses, and extensive professional experience working in the field.

Although results from monitoring can be reported in relatively succinct summaries, it is important to understand that a number of assumptions exist behind many of these studies, which can be difficult to explain in short segments (Salmon Monitoring Advisor 2010). Additionally, fisheries data are frequently complex, and “without manipulative experiments, it is not possible to definitively identify causes that lead to clear actions for mitigating the effects... on salmon ...” (Salmon Monitoring Advisor 2010). OBMEP was designed to monitor status and trends of abundance, productivity, diversity, and spatial structure of adult and juvenile Upper Columbia River summer steelhead and associated habitat in the Okanogan River and its tributaries. Although abductive inferences derived from status and trend data may help to address effectiveness of habitat or hatchery projects, identifying causal mechanisms was not the intent of the original program research questions. Readers and decision makers are encouraged to ask questions and learn more about relative assumptions and complexities of the data before investing in management decisions (Salmon Monitoring Advisor 2010). Additionally, monitoring staff can be contacted directly if more specific data or analyses are needed.

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Appendix A. Adult Steelhead Abundance and Distribution

For additional information pertaining to adult steelhead spawning estimates in the Washington State portion of the subbasin, refer to the technical report listed below:

OBMEP. 2016. 2015 Okanogan Subbasin Steelhead Spawning Abundance and Distribution. Colville Confederated Tribes Fish and Wildlife Department, Nespelem, WA. Report submitted to the Bonneville Power Administration, Project No. 2003-022-00. Available online at: http://www.colvilletribes.com/media/files/2015_Okanogan_Sth_Redd_Surveys.pdf

Additional information pertaining to adult steelhead in the British Columbia portion of the subbasin:

Introduction

In the Canadian portion of the Okanagan subbasin, previous studies have shown that, historically, steelhead were found throughout the Okanagan subbasin (Ernst and Vedan 2000). Prior to 2009, McIntyre Dam – at the outlet of nṗəxłpiẇ (Vaseux Lake) – was the upstream barrier for returning anadromous salmonids. During this time, akskʷəkʷant (Inkaneep Creek) and snʕax̌əlqaxʷiyaʔ (Vaseux Creek) were the only major tributaries accessible to anadromous steelhead for spawning and rearing. ONA Fisheries Department conducted redd surveys on both streams and operated a counting weir on akskʷəkʷant (Inkaneep Creek) through OBMEP from 2006 until 2011. While anadromous steelhead were documented during these monitoring actions (Audy et al. 2011), surveys were discontinued due to difficulties in data collection during spring freshet and low-confidence estimates. McIntyre Dam was refitted in 2009 to allow upstream migration of salmonids and, currently, migrating steelhead have access to habitat as far upstream as the kłusxnitkʷ (Okanagan Lake) outlet dam at snpintktn (Penticton). This allows steelhead access to at least four more major tributaries for spawning and rearing including Shuttleworth Creek, McLean Creek, snpiṅyaʔtkʷ (Ellis Creek) and akłxʷminaʔ (Shingle Creek). From 2012-2014, the only enumeration method used was a Passive Integrated Transponder (PIT) antenna array in the q̇awsitkʷ (Okanagan River) mainstem just upstream of suwiẇs (Osoyoos Lake) at Vertical Drop Structure (VDS) 3. In 2015, three more permanent PIT arrays were also installed in akskʷəkʷant (Inkaneep Creek), akłxʷminaʔ (Shingle Creek), and Shuttleworth Creek and redd surveys were conducted in akskʷəkʷant (Inkaneep Creek).

Results

For the Canadian portion of the Okanagan subbasin, PIT tag detections on the q̓awsitkʷ (Okanagan River) at VDS 3 (Okanagan Channel - OKC) upriver of suwiw̓s (Osoyoos Lake) are listed in Table 4 from 2010 to 2015. In all years listed, a higher proportion of wild steelhead detected at Zosel Dam continued up the q̓awsitkʷ (Okanagan River) upriver of suwiw̓s (Osoyoos Lake) than hatchery steelhead. However, these proportions were based on extremely small sample sizes.

During the Sockeye Salmon migration of 2012, the detection efficiency at the OKC array was estimated at 88.9% (Fryer et al. 2013); however, the detection rate may change between seasons and years. The Washington Department of Fish and Wildlife has conducted a PIT tagging effort at Priest Rapids Dam (PRD), on the Columbia River, since 2011 (Ben Truscott, pers. comm.) and abundance estimates listed below are taken from the tagging rates at PRD during sampling times only. Using a simple expansion factor based on the proportion of tagged to untagged fish at PRD and adjusting for the detection rate, escapement at the OKC PIT antenna array was estimated as follows:

Table 4. Abundance estimates of steelhead passage at OKC antenna array on the q̓awsitkʷ (Okanagan River) upstream of suwiw̓s (Osoyoos Lake).

Year	Origin	Number of tags detected at OKC (from PRD sample)	Adjusted number of tags based on detection rate	PRD tag rate* $Tag\ Rate = \frac{M}{N}$	Abundance estimate based on expansion factor $C = \frac{1}{Tag\ Rate} \times R$
2011	Hatchery	0	0	0.0834	0
2011	Wild	2	2.25	0.0834	27
2012	Hatchery	2	2.25	0.1309	17
2012	Wild	2	2.25	0.1311	17
2013	Hatchery	0	0	0.1343	0
2013	Wild	3	3.37	0.1339	25
2014	Hatchery	2	2.25	0.1448	16
2014	Wild	3	3.37	0.1448	23
2015	Hatchery	3	3.37	0.1740	19
2015	Wild	10	11.25	0.1740	65

* *C* = estimate of steelhead passage at OKC antenna array
* *N* = total number of steelhead sampled in Priest Rapids Dam study
* *M* = number of marked steelhead sampled in Priest Rapids Dam study
* *R* = number of marked steelhead detected at OKC antenna array

It should be noted that all the estimates listed above are based on extremely low sample numbers at the OKC interrogation site. The fall-back rate was not estimated. Also, PIT detection numbers at OKC are based on a number of assumptions including: (1) PIT tags had no detectable effect on the distribution or survival of individuals, (2) all steelhead had an equal chance of detection, (3) there was no loss of tags, (4) the population was closed, and (5) fish falling back downstream had an equal chance of being detected as fish migrating upstream.

In 2015, permanent PIT arrays were installed in akskʷəkʷant (Inkaneep Creek), akɫxʷminaʔ (Shingle Creek), and Shuttleworth Creek and temporary PIT arrays were installed seasonally in McLean and Testalinden creeks. The PIT array was installed in akskʷəkʷant (Inkaneep Creek) just after peak spawning and two steelhead were detected shortly after installation. No detections were recorded in McLean or Testalinden creeks. The PIT arrays were installed in akɫxʷminaʔ (Shingle Creek) and Shuttleworth Creek in the summer of 2015 and were not in place during the 2015 steelhead spawning season.

Conclusions

The removal of barriers in the Canadian portion of the Okanagan subbasin potentially allows steelhead to access more tributary habitat for spawning and rearing. While current sample sizes are not sufficient to provide confident abundance estimates, baseline data are needed in order to detect if summer steelhead recolonize newly accessible habitat. Currently, the distribution of steelhead spawning past OKC antenna array is unknown. Expanding the PIT program further upriver and into tributaries would give resolution needed to determine more specific spawning areas and timing and could be coordinated with reintroduction programs. Adding more antenna arrays in the Canadian Okanagan River subbasin could also be used to test assumptions about detection efficiency of downstream arrays.

Additional Datasets

Table 5. Table of Steelhead PIT tag detections on the q̓awsitkʷ (Okanagan River) at VDS 3 (OKC) as compared to detections at Zosel Dam.

		Detection Site		
		OKC[4]	Zosel Dam	% of tagged fish past OKC from Zosel
2010	Summer Steelhead (Hatchery)	2	NA	NA
	Summer Steelhead (Unknown)	5 (4 PRD[5])	NA	NA
	Summer Steelhead (Wild)	0	NA	NA
	2010 Total	**7**	**NA**	**NA**
2011	Summer Steelhead (Hatchery)	4	31	12.90%
	Summer Steelhead (Unknown)	0	2	0.00%
	Summer Steelhead (Wild)	3 (2 PRD)	9	33.33%
	2011 Total	**7**	**42**	**16.67%**
2012	Summer Steelhead (Hatchery)	3 (2 PRD)	50	6.00%
	Summer Steelhead (Unknown)	0	3	0.00%
	Summer Steelhead (Wild)	2 (2 PRD)	7	28.57%
	2012 Total	**5**	**60**	**8.33%**
2013	Summer Steelhead (Hatchery)	2	48	4.17%
	Summer Steelhead (Unknown)	0	3	0.00%
	Summer Steelhead (Wild)	4 (3 PRD)	11	36.36%
	2013 Total	**6**	**62**	**9.68%**
2014	Summer Steelhead (Hatchery)	5 (2 PRD)	22	22.73%
	Steelhead (unknown run & r/t)	1	0	NA
	Summer Steelhead (Unknown)	0	9	0%
	Summer Steelhead (Wild)	5 (3 PRD)	20	25.00%
	2014 Total	**11**	**51**	**21.57%**
2015	Summer Steelhead (Hatchery)	5 (4 PRD)	45	11.11%
	Steelhead (unknown run & r/t)	0	2	0%
	Wild O. mykiss (unknown migratory status)	0	1	0%
	Summer Steelhead (Wild)	10 (10 PRD)	30	33.33%
	2015 Total	**16**	**78**	**20.51%**

[4] Number of tags detected have not been corrected for detection rates.

[5] Steelhead sampled and tagged as part of the WDFW study at Priest Rapids Dam and later detected at OKC are listed in brackets as PRD. The other detections were tags that passed PRD at non-sampled times.

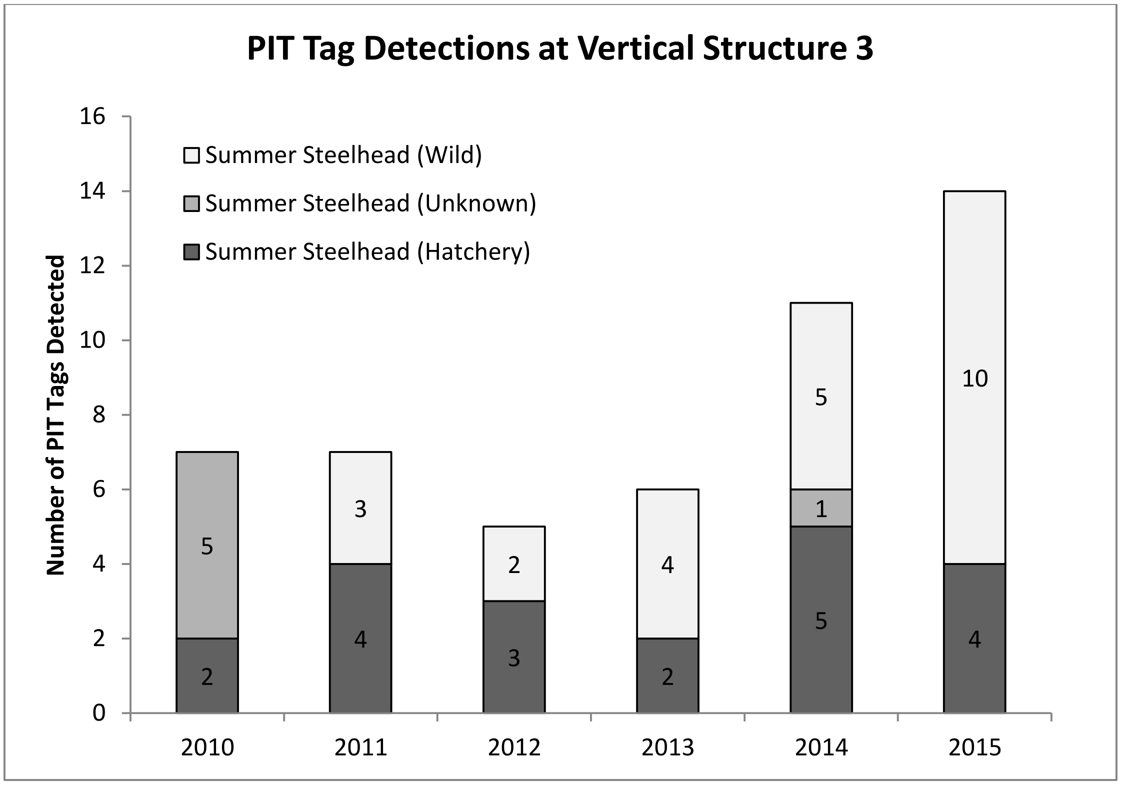


Figure 9. Graph of steelhead PIT tag detections by year at Okanagan Channel (OKC) at VDS 3 broken down for hatchery and wild fish.

Table 6. Chart of total counts and PIT tag rate of steelhead released by year in the Priest Rapids Dam release group study (BPA Project # 2010-034-00).

Spawning Year	PRD Steelhead Count*	PRD Tag Rate**	
		Hatchery	Wild
2011	26,476	0.0834	0.0834
2012	20,757	0.1309	0.1311
2013	17,230	0.1343	0.1339
2014	15,011	0.1448	0.1448
2015		0.1740	0.1740

*Data from the Fish Passage Center website, fpc.org
**Data provided by WDFW (Ben Truscott, WDFW, pers com)

Appendix B. Juvenile Steelhead Abundance and Distribution

Introduction

Summer steelhead (*Oncorhynchus mykiss)* are currently listed as threatened in the Upper Columbia River. Monitoring the status and trends of tributary populations in the Upper Columbia allow researchers to track progress towards recovery goals, as outlined in the Monitoring Strategy for the Upper Columbia Basin (Hillman 2006). Until recently, estimating the population size of naturally produced juvenile steelhead in the Okanogan subbasin continued to be a challenging task. Life history strategies and residence time of juvenile steelhead can be highly variable. The timing of outmigration can vary widely, even among the same brood year and between sexes (Peven et al. 1994). Consequently, interpreting migrational movements (i.e. resident vs. anadromous) can be challenging. The Okanogan Basin Monitoring and Evaluation Program operated a rotary screw trap (RST) from 2004 to 2011 on the mainstem Okanogan River, but very few captures of naturally produced steelhead produced highly variable and unreliable estimates of population size.

Snorkel surveys of juvenile salmonids can show changes in relative abundance over time (Schill and Griffith 1984, Thurow 1994). Annual variation in observed abundance is calculable from the current long-term snorkel dataset for the Okanogan subbasin, but it remained unknown how these values related to absolute abundance. Data from snorkel surveys conducted from 2004 through 2014 show very low numbers of juvenile steelhead in the mainstem and considerably higher densities in tributaries. Therefore, in order to more accurately monitor population status and trends of naturally produced juvenile steelhead in the subbasin, population monitoring efforts are being refocused to the cool water tributaries.

The Washington Department of Fish and Wildlife (WDFW) and the Colville Confederated Tribes (CCT) installed a series of permanent and temporary PIT tag arrays from 2012-2014 near the mouth of tributaries with known or potential steelhead spawning habitat (BPA Project #2010-034-00). The arrays were primarily installed to monitor movements of adult steelhead during the spring spawning period and better define annual escapement estimates. These PIT tag interrogation systems also have the capacity to detect PIT tagged juvenile salmonids as they out-migrate from the system.

This study was designed to assess utilization of tributaries to the Okanogan River by juvenile steelhead, while conforming to existing monitoring frameworks in the subbasin. This task was accomplished with the use of electrofishing, remote PIT tagging, mark-recapture events, and in-stream PIT tag interrogations. The primary study goals were to: (1) estimate abundance of juvenile *O. mykiss* in small streams, (2) calculate precision of estimates, and (3) calculate an independent, stream-based population emigration estimate from PIT tagged fish. These methods allow the program to more accurately monitor annual abundance of juvenile steelhead in the Okanogan, estimate precision and bias associated with methods, and to determine trends in juvenile abundance, spatial distribution, and diversity through time.

Methods

OBMEP - Juvenile Abundance - Mark-Recapture (ID:194)
https://www.monitoringmethods.org/Protocol/Details/194

a. Study Location and Site Selection

Loup Loup Creek

Loup Loup Creek is a tributary that enters the Okanogan River at RKM 24, in the town of Malott, WA. The creek frequently dried up annually during mid-summer, until 2010, when irrigation district water rights were adjusted from being drawn from Loup Loup Creek surface water to being drawn from the mainstem Okanogan River. A noticeable increase in juvenile abundance was noted from 2010 to 2014 (refer to OBMEP annual reports).

Loup Loup Creek was divided into three reaches below a naturally occurring falls. Within each of the three reaches, one ~150-200 m site was randomly selected to perform a site based population estimate (Figure 10). A PIT tag array (site LLC) is located in the town of Malott, WA; the system consists of three pass-over PVC antennas in series.

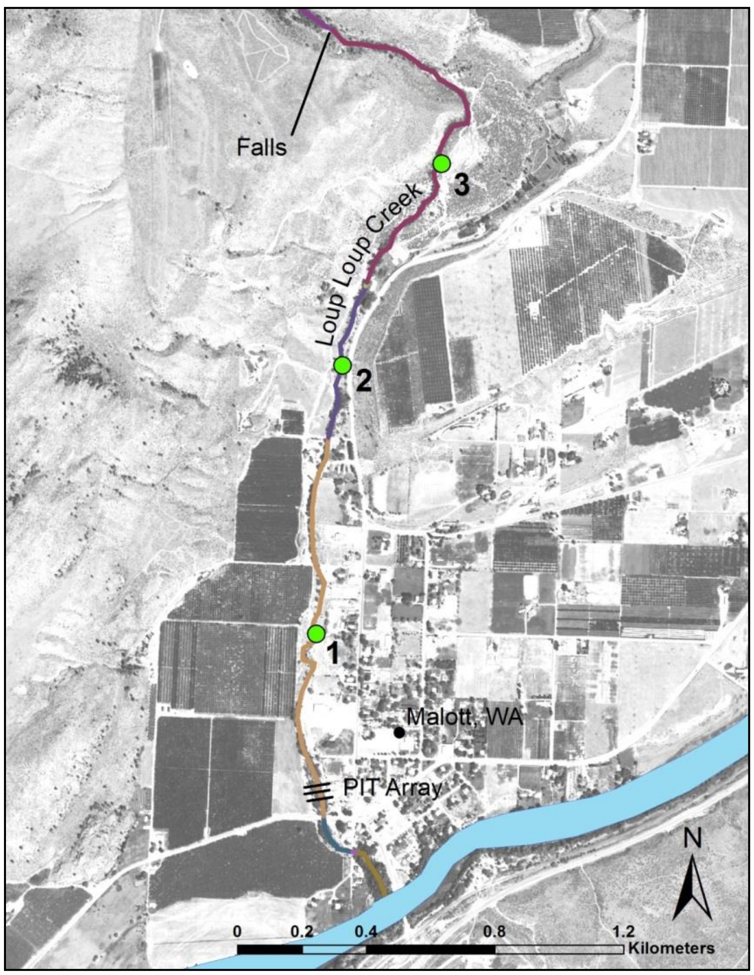


Figure 10. Loup Loup Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Salmon Creek

Salmon Creek is a highly managed, medium sized tributary that enters the Okanogan River at RKM 41.3, in the city of Okanogan, WA. Since the early 1900's, the majority of water from Salmon Creek had been diverted for irrigation usage. The largely dry stream channel extended from the Okanogan Irrigation District (OID) diversion dam (7.2 km) to the confluence with the Okanogan River. Occasionally, uncontrolled spills greater than 300 cfs occurred downstream of the OID diversion dam in high water years. These spills typically occurred in mid-May to June, which is after summer steelhead have already moved into tributaries to spawn. In order to provide sufficient water during the migration window of spring-spawning steelhead, the Colville Tribes purchased water from the OID and allowed it to flow down the channel to the Okanogan River. After several years of successful evaluations of steelhead passage, the Tribes negotiated a long term water lease agreement with the OID. Since 2006, the long term water lease has provided a small window of water for returning adults and out-migrating juvenile salmonids.

Salmon Creek was divided into nine biologically distinct reaches below the anadromous barrier (Conconully Dam) as part of an EDT analysis (Figure 11). Reach breaks were determined by changes in habitat, gradients, confluence with other streams, or man-made features in the stream that may affect distribution of fish (ex. culverts, irrigation diversion). Within each of the nine reaches, one ~150-200 m site was randomly selected to perform a site based population estimate. All nine sites were drawn from a previous GRTS sampling effort for habitat monitoring. It was assumed that sites were representative of each reach because reaches were defined by analogous habitat type and a site was randomly located within respective reach bounds.

A PIT tag interrogation array (site SA1) is located upstream from mouth of Salmon Creek, 2.9 km upstream from the confluence with the Okanogan River. The system arrangement consists of three pass-over PVC antennas grouped in three series.

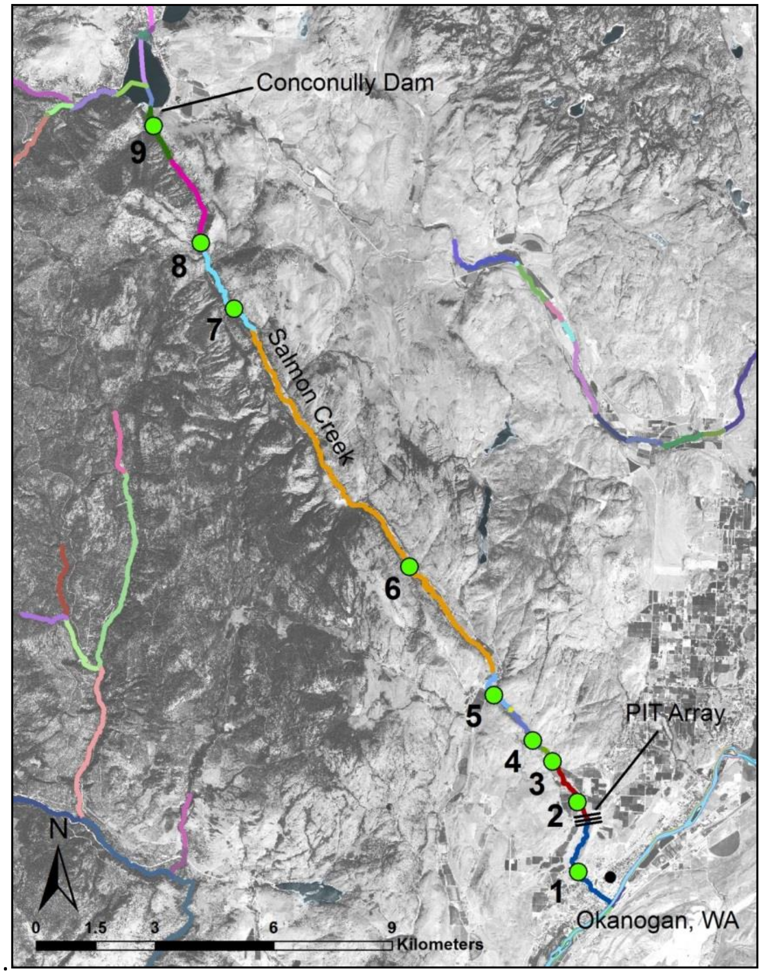


Figure 11. Salmon Creek juvenile *O. mykiss* mark-recapture (green numbered dots) and strata (colored stream lines).

Omak Creek

Omak Creek is characterized as a perennial, medium sized tributary that enters the Okanogan River at RKM 51.5, approximately 1.0 km upstream from the city of Omak, WA. Discharge rates in the creek range from a base flow of 10 cfs to over 150 cfs during the spring. During the base flow period, wetted widths range from approximately 2 to 8 m. Omak Creek was divided into seven biologically distinct reaches below the anadromous barrier (Mission Falls) as part of an EDT analysis (Figure 12). Reach breaks were determined by changes in habitat, gradients, confluence with other streams, or man-made features in the stream that may affect distribution of fish (e.g. culverts, adult fish weir, juvenile hatchery stocking locations). Within each of the seven reaches, one ~150 m site was randomly selected to perform a site based population estimate. Five of the sites were drawn from a previous GRTS sampling effort for habitat monitoring. Two of the remaining reaches did not contain a GRTS site and a random site was selected within the respective reach boundaries. It was assumed that sites were representative of each reach because reaches were defined by analogous habitat type and a site was randomly located within respective reach bounds.

A parallel PIT tag array (site OMK) is located near the mouth of Omak Creek, 0.24 km upstream from the confluence with the Okanogan River. The antenna arrangement consists of 6 pass-over PVC antennas grouped in two series, three upstream and three downstream. A 5' rotary screw trap (RST) is operated in the spring, 225 m upstream of the PIT tag antennas. However, due to site and flow-based restrictions, operation of the trap is limited to discharges between 25 and 75 cfs. Captures and releases of PIT tagged juvenile steelhead at the RST will be used to determine detection efficiency at the downstream PIT antennas at various discharge rates.

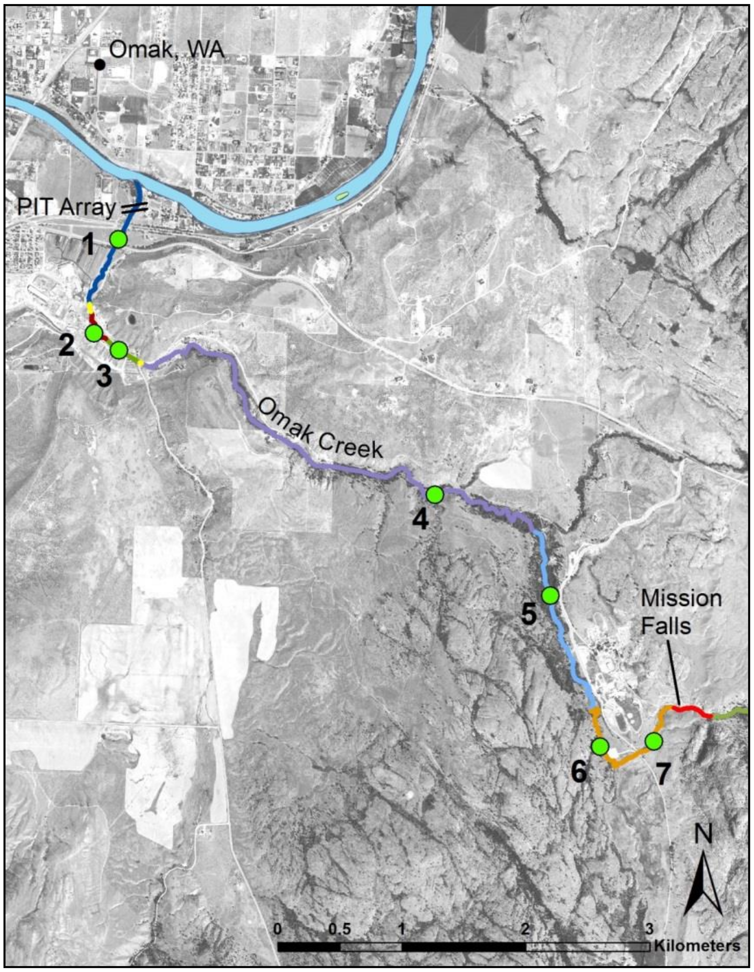


Figure 12. Omak Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Wanacut Creek

Wanacut Creek is a small ephemeral stream that meets the Okanogan River at approximately RKM 56, between Omak and Riverside, WA (Figure 13). The 51 km^2 Wanacut Creek drainage stems from Omak Mountain, located on the Colville Reservation. A large natural falls exists a short distance from the confluence with the Okanogan River and the creek frequently flows subsurface, except during spring runoff. However, small numbers of adult steelhead have been shown to utilize Wanacut Creek for spawning on years where sufficient water depth exists in March through May. A temporary PIT tag antenna (site WAN) is placed seasonally near the mouth of the creek to document PIT tagged steelhead movements. The creek was broken up into three separate reaches for subsampling.

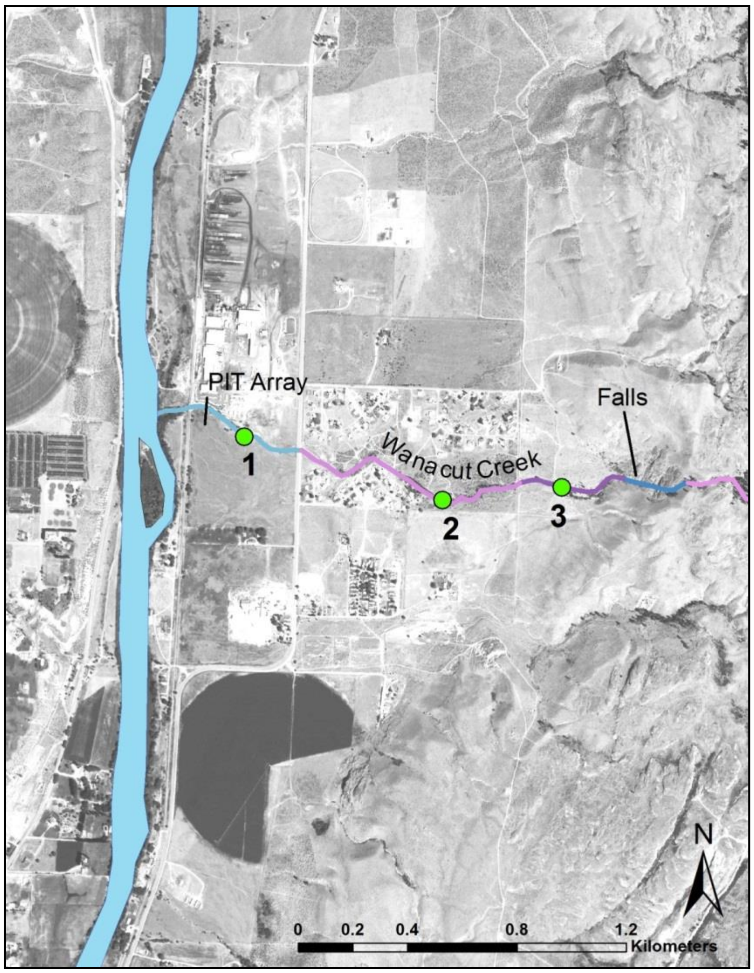


Figure 13. Wanacut Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Tunk Creek

Tunk Creek is a small tributary that meets the Okanogan River at RKM 72, upstream of Riverside, WA. Although the drainage area of Tunk Creek is approximately 186 km^2, only the lower ~1.2 KM are accessible to anadromous fish, due to a natural falls (Figure 14). The creek frequently flows subsurface in the lower reaches, although efforts are being made to improve instream flow (moving wells back from the creek, etc). A temporary single PIT tag antenna (site TNK) is installed seasonally near the mouth of the creek. Tunk Creek was surveyed in two reaches below the falls.

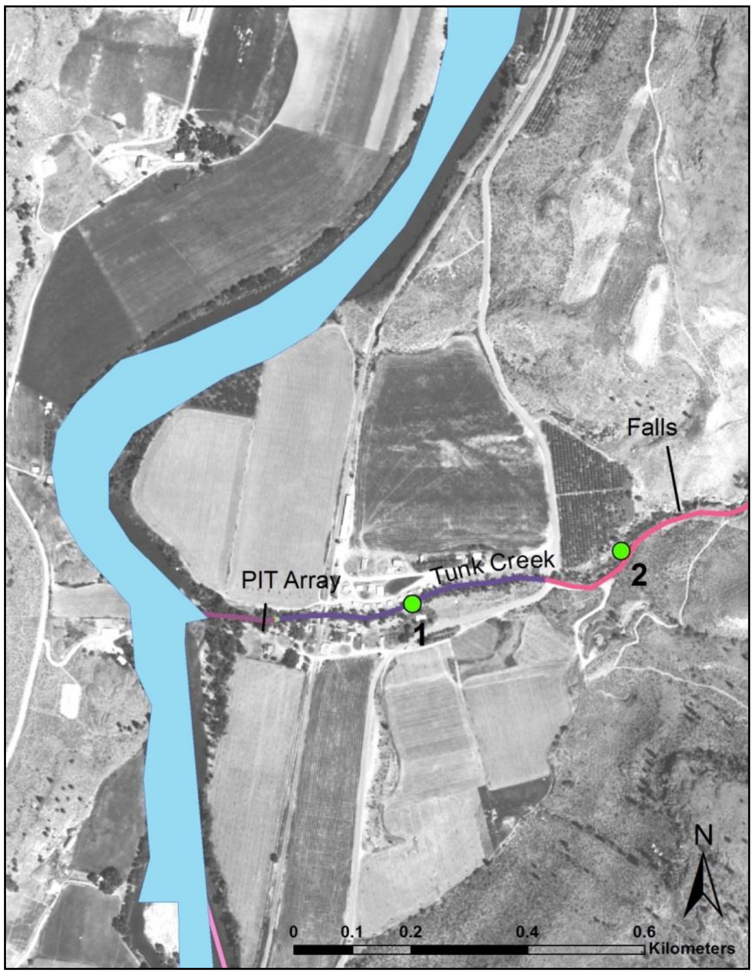


Figure 14. Tunk Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Aeneas Creek

A small creek with a drainage area of only 25 km^2, Aeneas Creek enters the Okanogan River just south of the town of Tonasket, WA (RKM 85). The lower section of the creek was impounded with a series of very large beaver dams that were cemented in with calcified clay. In 2012, many of these structures were removed, allowing adult steelhead passage into a short section of the creek. The total habitat accessible to anadromous fish is fairly short, likely limited by a culvert and steep gradient by the highway, although potential passage has not been specifically examined at that location (Figure 15). A temporary PIT tag antenna was placed near the mouth of the creek to document utilization by adult steelhead. The first adults were detected in the spring of 2014 and GPS points were taken of two redds that were identified. Aeneas Creek was surveyed as one reach for juvenile salmonids.

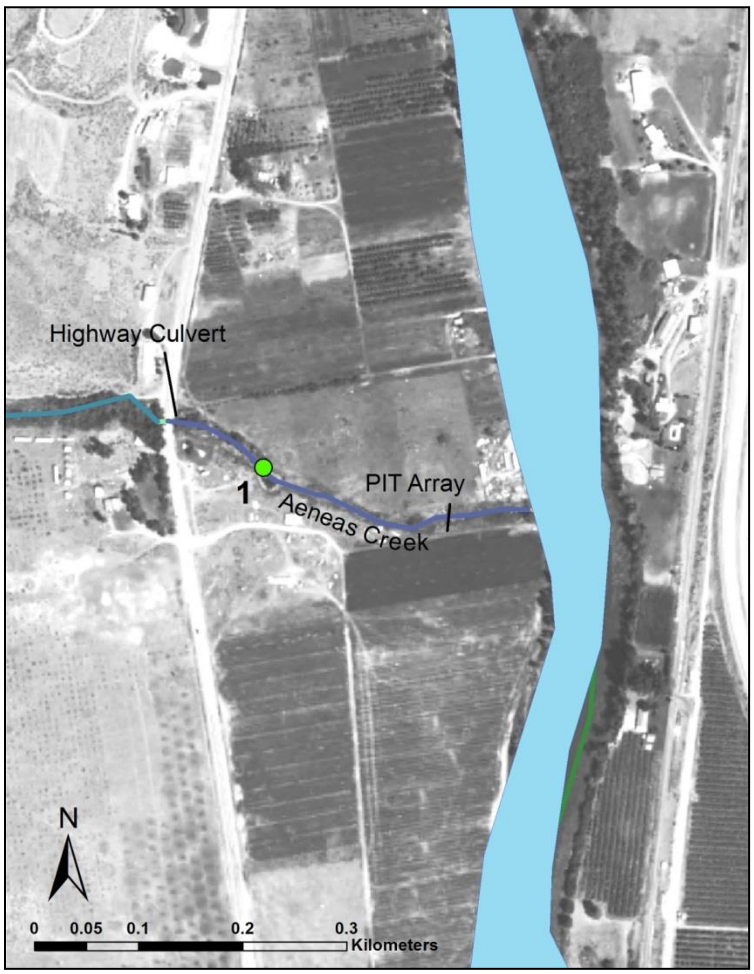


Figure 15. Aeneas Creek juvenile *O. mykiss* mark-recapture study site (green numbered dot) and strata (colored stream lines).

Bonaparte Creek

Within the US portion of the Okanogan subbasin, the Bonaparte Creek watershed is fairly extensive, stemming from Bonaparte Lake, near Wauconda, WA, and entering the Okanogan River at RKM 91. The Bonaparte Creek watershed has a drainage area of 396 km^2; discharge ranges from 1 cfs during low flow conditions and may reach 20 to over 40 cfs during peak runoff. During summer base flow, wetted widths range from 1.5 m to 3 m. The total stream kilometers available to anadromous fish is relatively limited, totaling only 1.6 km below a natural falls.

Bonaparte Creek was sampled as one reach, from the confluence with the Okanogan River, 1.6 km upstream to the anadromous barrier (natural falls). The selected sample site corresponded with the annual OBMEP habitat survey site (Figure 16). A PIT tag interrogation site (BON) is located at the mouth of the creek, approximately 80 m from the confluence with the Okanogan River, and consists of three pass-through PVC antennas in series.

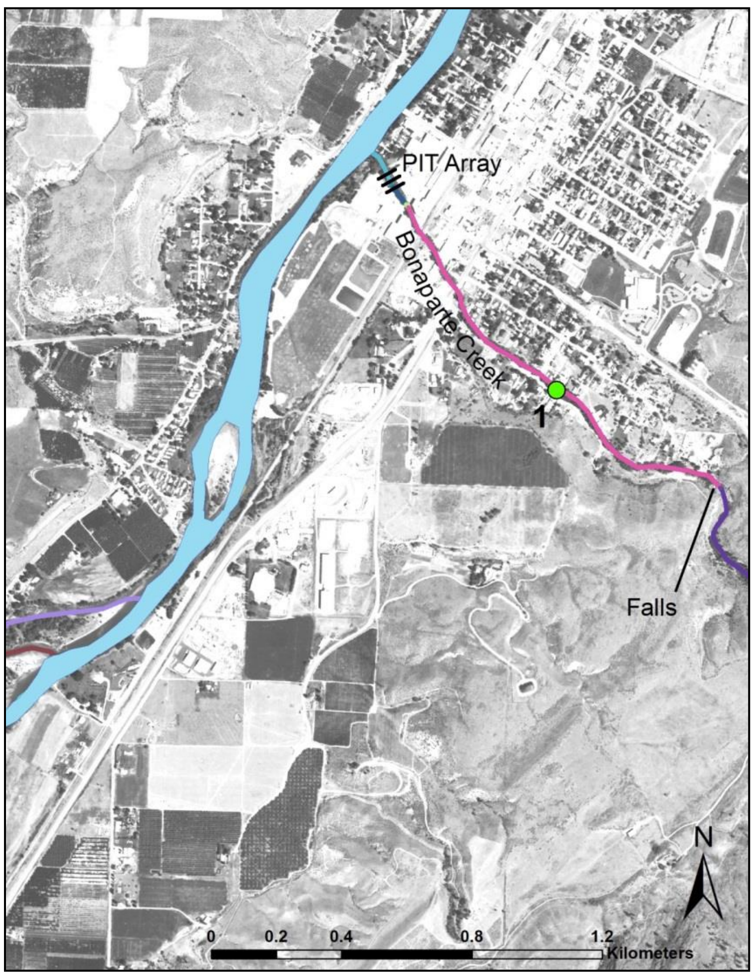


Figure 16. Bonaparte Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Tonasket Creek

Tonasket Creek is a third order stream that has a drainage area of 153 km^2. The confluence is located at Okanogan River RKM 125, just upstream from Zosel Dam. The lower two reaches are known to go dry on an annual basis, however, there is typically some flow in the upper most reach, below the natural falls (Figure 17). A single seasonal PIT tag antenna is operated near the confluence of the creek with the Okanogan River.

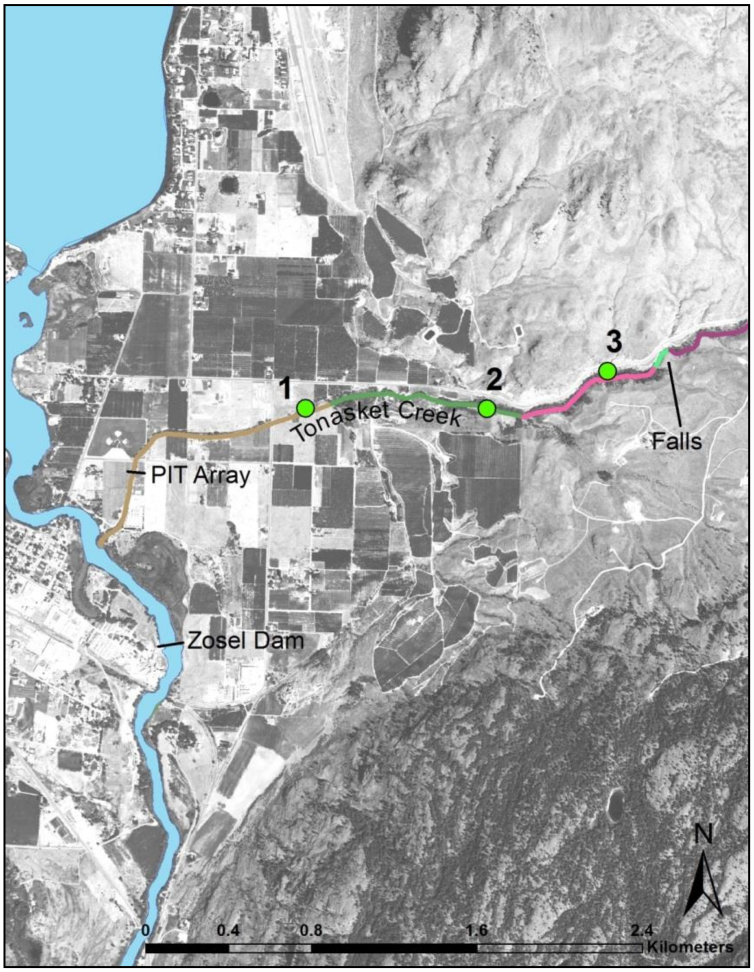


Figure 17. Tonasket Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Ninemile Creek

The drainage area of Ninemile Creek is 55 km^2, roughly one third the size of the Tonasket Creek watershed. The creek was divided into three survey reaches, as defined by an EDT analysis (Figure 18). Ninemile Creek is known to flow sub-surface annually in the middle reach, but surface flows are usually present in the upper and lower reach. A permanent four-antenna PIT tag array is located near the mouth of the creek, which enters into the east side of Lake Osoyoos.

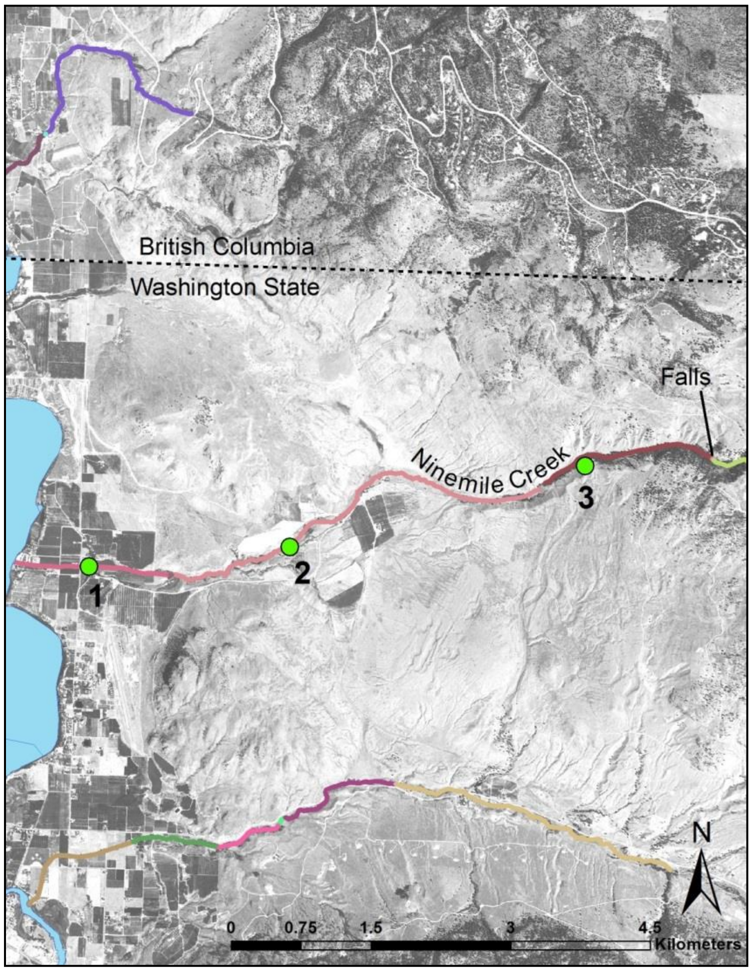


Figure 18. Ninemile Creek juvenile *O. mykiss* mark-recapture study sites (green numbered dots) and strata (colored stream lines).

Additional Watersheds

A number of creeks draining into the Washington State portion of the Okanogan subbasin may not have been sampled during 2014 or 2015. Reasons for not sampling these systems may have been due to lack of landowner permissions, insufficient funding or field staff time, or monitoring strategies were not yet defined. Tributaries not sampled, but may be included in future years studies include Chilliwist, Johnson, Antoine, Whitestone, and upper Omak Creek above Mission Falls.

a. Site Based Abundance Estimate

To estimate site abundance of juvenile steelhead within each site, a two-pass Lincoln-Petersen mark-recapture study was performed. Block nets were placed at the bottom and top extent of each site in order to create a closed population. Fish were sampled with a backpack electrofisher. Captured fish were anesthetized with MS-222 to reduce injury during handling and render fish immobile for tagging. During the first pass, *O. mykiss* greater than 95 mm were marked with a PIT tag and *O. mykiss* less than 95 mm were marked with a top caudal fin clip. All other fish species handled had lengths measured and received a top caudal mark. Fish were released and evenly distributed throughout the reach, close to their initial capture locations.

In order to complete the site in one day and to maintain a closed population with the use of block nets (which are frequently weighed down with heavy leaf fall during the fall season), a three hour wait period occurred before the second pass was conducted (Temple and Pearsons 2006). During the second pass, all fish were examined for a mark. If the fish was unmarked, the length was recorded and the fish was released at the location where captured. Unmarked *O. mykiss* greater than 95 mm also received a PIT tag in order to increase the number of PIT tagged fish available for later interrogation (i.e. when emigrating from the creek).

During mark-recapture sampling events, it was assumed that: (1) the population remained closed with the use of block nets, (2) sampling effort remained the same on the first and second pass, (3) marking of fish did not affect the likelihood of recapture, (4) marked fish were randomly distributed with unmarked fish, and (5) no marks were lost and all marks were detected upon recapture. Given those assumptions, site based abundance estimates were calculated using the Lincoln-Peterson mark-recapture model, as modified by Chapman (1951):

$$N = \frac{(M+1)(C+1)}{R+1} - 1$$

(eq. 1)

where N = Estimate of site abundance size for *O. mykiss*,
M = Number of *O. mykiss* captured and marked on the first pass,
C = Total number of *O. mykiss* captured on the second pass,
R = Number of marked *O. mykiss* captured on the second pass.

The site abundance (N) variance was estimated as:

$$var(N) = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)(R+1)(R+2)}.$$

(eq. 2)

b. Expanding Site Abundance to Reach and Tributary Population Estimates

The site-based abundance N was expanded to estimate the population of juvenile *O. mykiss* in each of the strata (ex. Omak Creek, $\widehat{N}_i$ for $i = 1, \ldots, 7$). It was assumed that each site was representative of the reach in which it is located and that fish were evenly distributed throughout the reach. Each reach has an expansion factor for the area not sampled (i.e., R_i),

$$R_i = \frac{Reach\ Length_{\ i}}{Sample\ Site\ Length_{\ i}}. \quad \text{(eq. 3)}$$

The expansion factor R_i was used to expand site based abundance estimates to individual reaches as follows,

$$\widehat{N}_i = N_i R_i\ . \quad \text{(eq. 4)}$$

Therefore, the total population estimate across all seven strata was calculated as:

$$\widehat{N} = \sum_{i=1}^{7} \widehat{N}_i R_i\ , \quad \text{(eq. 5)}$$

with a variance of

$$\widehat{\mathrm{Var}}(\widehat{N}) = \sum_{i=1}^{7} R_i^2 \times \widehat{\mathrm{Var}}(\widehat{N}_i)\ , \quad \text{(eq. 6)}$$

and a 95% confidence interval (CI) of

$$\widehat{N} \pm 1.96\sqrt{\widehat{\mathrm{Var}}(\widehat{N})}\ . \quad \text{(eq. 7)}$$

The coefficient of variation (CV) was calculated as:

$$\mathrm{CV}(\widehat{N}) = \frac{\sqrt{\widehat{\mathrm{Var}}(\widehat{N})}}{N}. \quad \text{(eq. 8)}$$

c. Out-Migration Estimates Based on PIT Tagged Fish

The location of PIT tag interrogation sites near the mouth of each creek may allow for determination of an emigration estimate. Assuming that marked fish are representitive of the total population of juvenile *O. mykiss*, the estimated proportion of tags from the study that pass the array will be applied to the population estimate to determine a total yearly emigration estimate. Two methods may be used to estimate outmigration. The first is based on the Chapman (1951) modification of the Lincolin index (1930), where outmigration of fish is estimated at a double-PIT tag array site. However, many of the interrogation sites within the Okanogan subbasin were installed in a lay-down orientation, rather than a pass-through system. While the lay-down configuration allows the PVC antennas to persist through larger flood events, an unknown number of tagged fish may miss both antennas by passing above the detection range. To reduce this inherent bias of lay-down antennas, a second method based on the Cormack-Jolly-Seber estimator may be used. This method involves pooling all detections at the in-creek site as one detection site and using a second pooled downstream detection site which includes all down-river detections (ex. mainstem dams, juvenile bypass systems, esturary trawl, etc). Both methods are further detailed below.

Method 1:

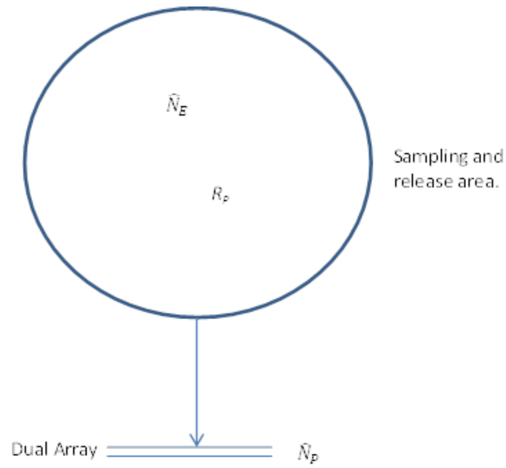


Figure 19. Diagram of the study.

where n_{10} = total PIT-tagged steelhead detected at the first site only,
n_{01} = total PIT-tagged steelhead detected at the second site only,
n_{11} = total PIT-tagged steelhead detected at both detection sites, and
R_p = total PIT-tagged steelhead released.

The total outmigration abundance is estimated in three steps.

Step 1. Estimate the total outmigration abundance of PIT-tagged steelhead at the dual array.

The Lincoln Index (Lincoln 1930) is asymptotically unbiased as sample size approaches infinity, but is biased at small sample sizes. The Chapman (1951) modification to the Lincoln Index is less biased, therefore is used to estimate the abundance ($\hat{N}_P$) of PIT-tagged steelhead outmigrating past the dual array.

$$\hat{N}_P = \frac{(n_1+1)(n_2+1)}{(m+1)} - 1 \qquad \text{(eq. 9)}$$

Where n_1 = total PIT-tagged steelhead detected at the first array,
n_2 = total PIT-tagged steelhead detected at the second array, and
m = total PIT-tagged steelhead detected at both arrays.

With the variance estimate (Seber 1982)

$$\widehat{Var}(\widehat{N}_P) = \frac{(n_1+1)(n_2+1)(n_1-m)(n_2-m)}{(m+1)^2(m+2)}. \quad \text{(eq. 10)}$$

Step 2. Estimate the proportion of PIT-tagged steelhead outmigrating.

The proportion of the PIT-tagged steelhead ($\widehat{P}$) outmigrating from the creek is simply the estimated abundance at the dual array divided by the total PIT-tagged steelhead.

$$\widehat{P} = \frac{\widehat{N}_P}{R_p} \quad \text{(eq. 11)}$$

with a variance of

$$\widehat{Var}(\widehat{P}) = (\frac{1}{R_p})^2 * \widehat{Var}(\widehat{N}_P) + \frac{\left(\frac{\widehat{N}_P}{R_p}\right)\left(1-\frac{\widehat{N}_P}{R_p}\right)}{R_p}. \quad \text{(eq. 12)}$$

Step 3. Estimate the total abundance of the steelhead population outmigrating from the creek.

Assuming that the proportion of outmigrating PIT-tagged steelhead is the same as the untagged steelhead, the total abundance of outmigrating steelhead ($\widehat{N}_{all}$) is estimated by

$$\widehat{N}_{all} = \widehat{N}_E * \widehat{P} \quad \text{(eq. 13)}$$

with a variance of

$$\widehat{Var}(\widehat{N}_{all}) = \widehat{P}^2 * \widehat{Var}(\widehat{N}_E) + \widehat{N}_E^2 * \widehat{Var}(\widehat{P}) - \widehat{Var}(\widehat{N}_E) * \widehat{Var}(\widehat{P}) \quad \text{(eq. 14)}$$

Method 2:

An alternative method is to estimate the proportion of PIT-tagged steelhead outmigrating from a creek is to use the pooled detections at the dual array as a single detection site and the pooled detections anywhere after the dual array as a second detection site. This may be desirable in cases where the dual array appears to be biased (higher than expected number of tags not detected at either array, but are detected downriver).

Alternative Step 1. Estimate the total outmigration abundance of PIT-tagged steelhead at the dual array.

Cormack (1964), Jolly (1965), and Seber (1965) developed closed-form estimates of the parameters of a multinomial likelihood (CJS model) describing a release-recapture study with survival (*S*) processes occurring between detection events (*p*). The probability of detection at an interrogation site is estimated by the proportion of detections at the array of the total known to have passed the array. Based on methods described in Burnham (1987), the equations below were simplified to a two-detection site analysis. Using the pooled, unique detection count at the array and the pooled detections downriver of the dual array, the probability of detection (p_1) is:

$$\hat{p}_1 = \left(\frac{n_{11}}{n_{11}+n_{01}}\right) \quad \text{(eq. 15)}$$

where n_{01} = total PIT-tagged steelhead detected at the second site only, and
n_{11} = total PIT-tagged steelhead detected at both detection sites.

With the variance estimate

$$\widehat{Var}(\hat{p}_1) = (\hat{p}_1 * (1 - \hat{p}_1))^2 * \left(\frac{1}{n_{11}} + \frac{1}{n_{01}}\right). \quad \text{(eq. 16)}$$

The abundance ($\widehat{N}_P$) of PIT-tagged steelhead outmigrating past the dual array is then

$$\widehat{N}_P = \frac{n_{1*}}{\hat{p}_1} \quad \text{(eq. 17)}$$

where n_{1*} = total unique PIT-tagged steelhead detected at the dual array.

Using the delta method, the variance estimate is

$$\widehat{Var}(\widehat{N}_P) = \widehat{Var}(\hat{p}_1) * \frac{n_{1*}^2}{\hat{p}_1^4}. \quad \text{(eq. 18)}$$

Alternative Step 2. Estimate the proportion of PIT-tagged steelhead outmigrating.

Continuing with the CJS model, the probability of survival for the period from release to detection at the dual array (S_1) can be interpreted as the proportion of PIT-tagged steelhead that are outmigrating from the creek. Though this proportion can be obtained by dividing the total abundance of outmigrating PIT-tagged steelhead ($\widehat{N}_p$) estimated earlier, by the total number released, estimating S_1 directly from the CJS model results in a slightly smaller variance by removing a step.

$$\hat{S}_1 = \frac{n_{11} + n_{10}}{R_p} * \left(1 + \frac{n_{01}}{n_{11}}\right) \quad \text{(eq. 19)}$$

where n_{10} = total PIT-tagged steelhead detected at the first site only,
n_{01} = total PIT-tagged steelhead detected at the second site only,
n_{11} = total PIT-tagged steelhead detected at both detection sites, and
R_p = total PIT-tagged steelhead released.

With the variance estimate

$$\widehat{Var}(\hat{S}_1) = \hat{S}_1^2 * \left[\left(\frac{1}{n_{11}+n_{10}+n_{01}} - \frac{1}{R_p}\right) + (1 - \hat{p}_1)^2 * \left(\frac{1}{n_{11}} - \frac{1}{n_{11}+n_{10}}\right) + \hat{p}_1 * (1 - \hat{p}_1) * \left(\frac{n_{10}^2}{n_{11} * (n_{11}+n_{10}) * (n_{11}+n_{10}+n_{01})}\right)\right]. \quad \text{(eq. 20)}$$

The process then continues to Step 3, as described previously, with $\hat{S}_1$ from the CJS model in place of the proportion outmigrating estimated in the 1st method.

d. Estimating age breaks

When designing and implementing this field study, it was initially necessary to define arbitrary breaks in length; 95 mm was selected as the general break point between "age-0" and "age-1+", primairly for regulatory permits and PIT tagging potential steelhead outmigrants. However, actual age breaks by length are oftentimes more blurred in reality, which can vary among location and between years. In the absence of sufficient scale data for linking length to age within the subbasin, it may be feasible to coarsely estimate age breaks visually from obvious bi-modal distributions. Length frequency distributions are much more distinct at the site-level, before rolling data up to the sub-watershed-level. In this document and in the early years of this study, we may refer to fry (age-0) and parr/juvenile+ (age-1+) age classes, but it is important to note that those divisions came from professional judgement based on length frequency distributions rather than scale aging. In future years if time and funding allow, scale data or statistical analysis of length frequency distributions may be used to more precisely define length by age-class.

Results

Steps a. through c. outlined in the methods section were conducted during the fall of 2014 and 2015.

During the 2014 and 2015 field seasons, nine tributaries were representatively sampled to determine abundance of juvenile *O. mykiss* in stream reaches accessible to anadromous fish. Estimated abundance with 95% confidence intervals are presented in Table 7. The largest number of fry and juvenile *O. mykiss* in the Okanogan subbasin were found in Salmon Creek, followed by Omak and Loup Loup Creeks (Figure 20 and 21). A number of small creeks in the Okanogan subbasin contain flowing water in the upper reaches, but water flows sub-surface before entering the mainstem Okanogan River in late-summer, including Salmon, Wanacut, Tunk, and Tonasket Creeks.

Table 7. Abundance estimates of natural-origin *O. mykiss* (±95%CI) in tributaries to the Okanogan River, 2014-2015.

	< 95 mm *O. mykiss*		> 95 mm *O. mykiss*	
Tributary	2014	2015	2014	2015
Loup Loup Cr	18,806 ± 1,567	5,036 ± 654	2,542 ± 319	1,453 ± 135
Salmon Cr	39,491 ± 6,046	48,089 ± 5,210	29,019 ± 2,049	28,751 ± 2,092
Omak Cr	23,045 ± 1,647	21,694 ± 2,698	6,958 ± 886	3,957 ± 338
Johnson Cr	Not sampled	Not sampled	Not sampled	Not sampled
Wanacut Cr	0	0	0	0
Tunk Cr	0	0	193 ± 31	0
Aeneas Cr	86 ± 14	11 ± 1	106 ± 20	43 ± 22
Bonaparte Cr	2,922 ± 368	918 ± 336	127 ± 20	254 ± 42
Antoine Cr	Not sampled	Not sampled	Not sampled	Not sampled
Wildhorse Sp Cr	Not sampled	Not sampled	Not sampled	Not sampled
Tonasket Cr	2,192 ± 716	0	526 ± 51	9 ± 0
Ninemile Cr	4,184 ± 756	2,191 ± 552	2,393 ± 375	1,610 ± 196
Total	90,726 ± 11,114	77,939 ± 9,451	41,864 ± 3,751	36,077 ± 2,825

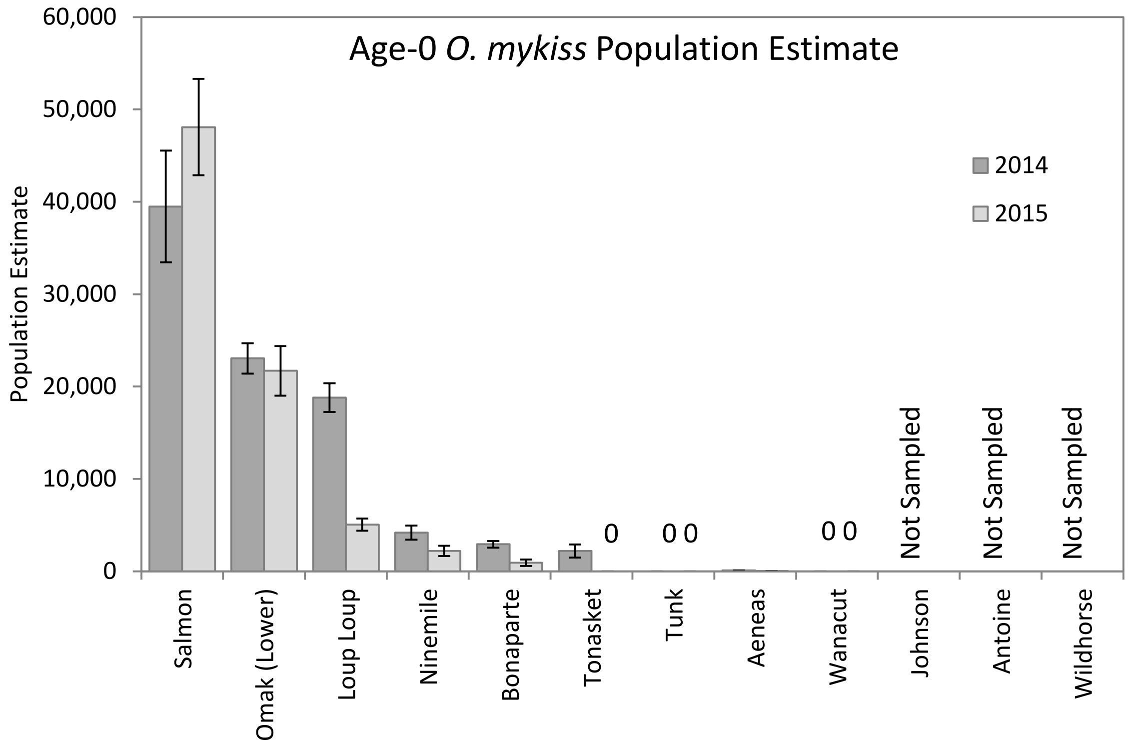


Figure 20. Population estimates of age-0 juvenile *O.mykiss* (<95mm) by subwatershed.

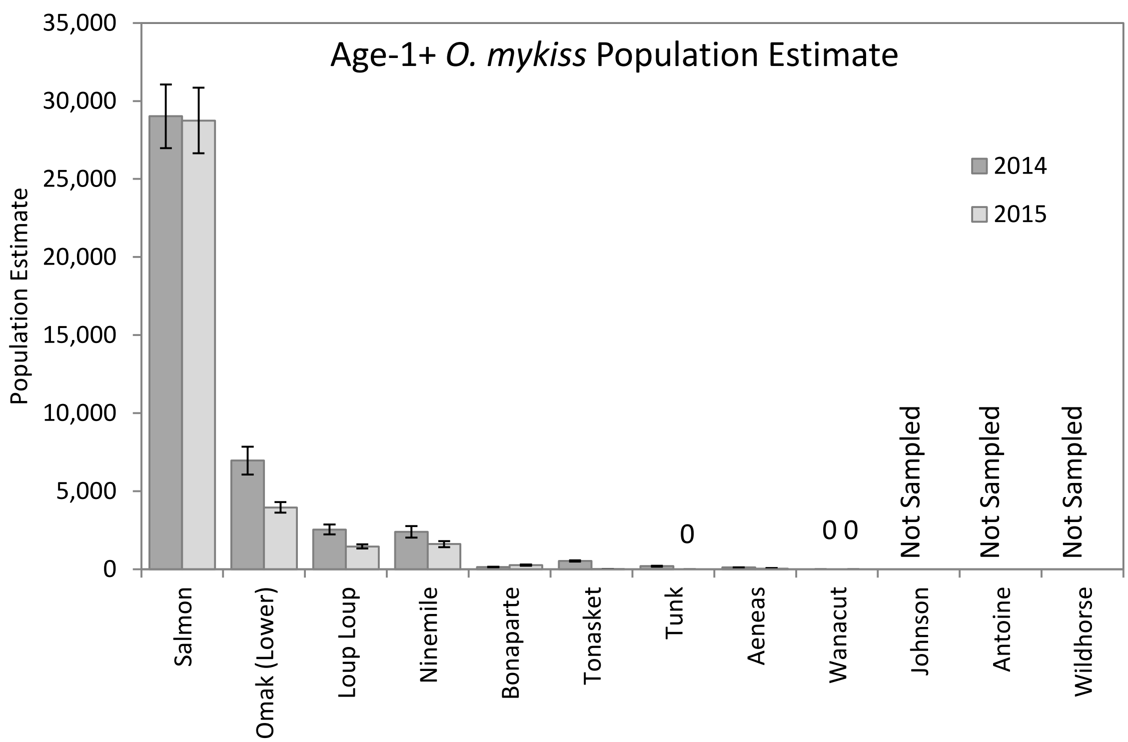


Figure 21. Population estimates of age-1+ juvenile *O.mykiss* (>95mm) by subwatershed.

Spatial distribution of juvenile *O. mykiss* varied within and between sub-watersheds, both by density and length distribution. Annual abundance of juvenile *O. mykiss* also varied by reach. For example, Figure 22 shows four years of data for Omak Creek, divided by strata. Reach 1 is the lowest reach and Reach 7 is the uppermost reach sampled, below Mission Falls. Due to the low water year in 2015, Reach 1 went dry prior to sampling and thus the total abundance was zero for 2015 for both age classes. Although not presented in this document, detailed length frequency data are available for all individual reaches in all sampled streams, which can be provided upon request by contacting OBMEP staff. Trends in spatial distribution of *O. mykiss* by length and age will be presented as further years of data become available for the subbasin.

PIT tag detection and calculation of outmigration estimates occur in the year following the marking season, and thus, total emigration results are reported one year later from the mark-year. The data presented in Table 8 represent outmigration of juvenile steelhead from the period of September 2014 through August 2015, derived from fish PIT tagged and released in the fall of 2014. Based on combined detections of PIT tagged fish from within and out of the Okanogan subbasin, a total of 17,908 (95%CI= 16,449 to 19,367) juvenile steelhead outmigrated from the defined strata.

Outmigration of juvenile steelhead also varied by strata. Two sets of data have been presented to illustrate spatial difference in the percent of outmigrating fish by linear distance from the confluence with the Okanogan River. In Figure 23, a higher proportion of the total age-1 and older juvenile steelhead outmigrated in the lower reaches of Omak creek compared with the upper reaches. A similar trend was documented in Salmon Creek (Figure 24), where a larger proportion of fish outmigrated from the lower reaches, compared with higher in the watershed. However, the lower reaches of Salmon Creek (Reach 1 and 3) are frequently dry, due to water diversions, so no fish existed in those reaches during sample events.

Table 8. Juvenile steelhead outmigration estimates from subwatersheds within the Okanogan subbasin, fall 2014 through summer 2015.

Tributary	Outmigration Estimate	Lower 95% CI	Upper 95% CI
Loup Loup Cr	1,801	1,495	2,107
Salmon Cr	10,062	8,829	11,295
Omak Cr	3,688	3,135	4,241
Johnson Cr	NA	NA	NA
Wanacut Cr	0	0	0
Tunk Cr	185	17	354
Aeneas Cr	103	null	276
Bonaparte Cr	150	null	null
Antoine Cr	NA	NA	NA
Wildhorse Sp Cr	NA	NA	NA
Tonasket Cr	24	3	45
Ninemile Cr	null	null	null

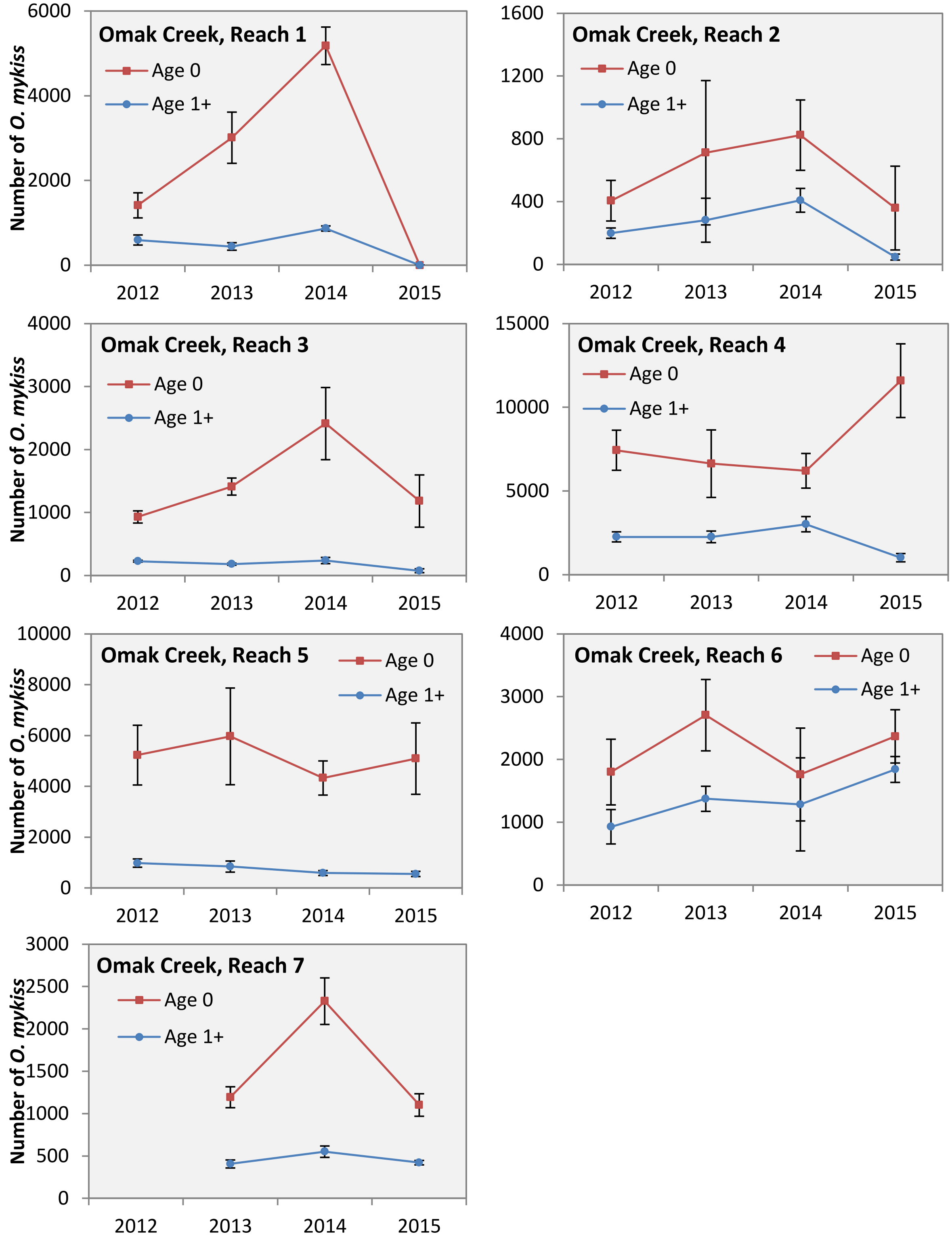


Figure 22. Trend in juvenile *O. mykiss* abundance (95%CI) by reach in Omak Creek, from downstream (Reach 1) to upstream (Reach 7).

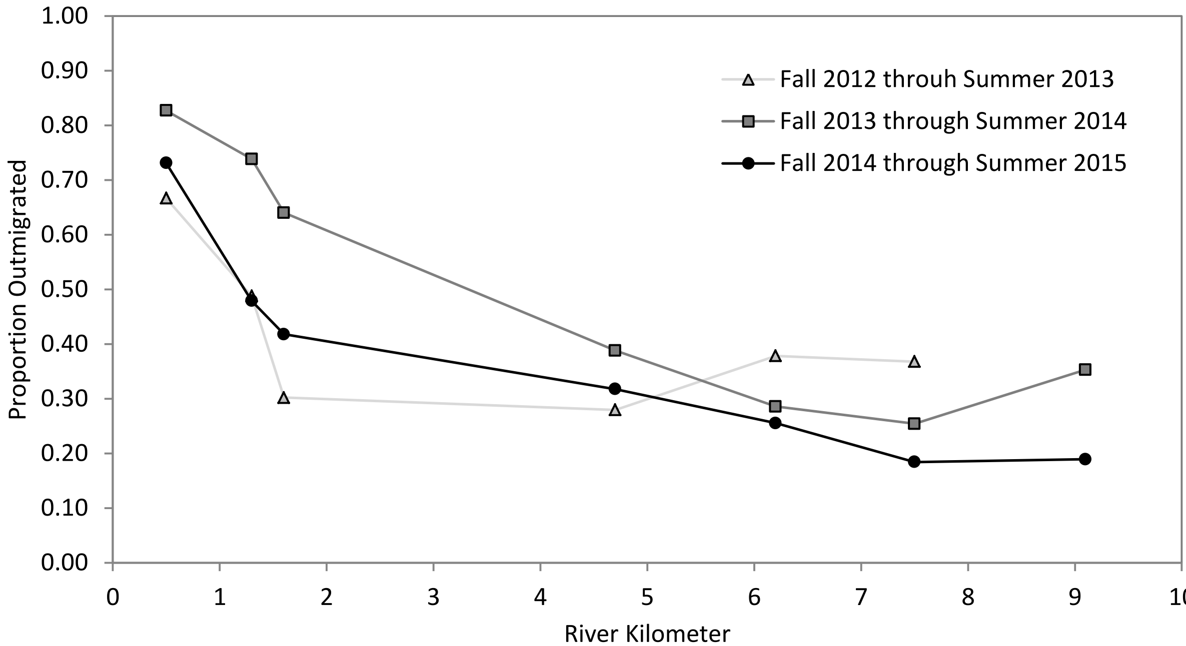


Figure 23. Proportion of PIT tagged natural origin juvenile steelhead that outmigrated in Omak Creek by river kilometer, from lower (Strata 1) to higher (Strata 7) in the subwatershed.

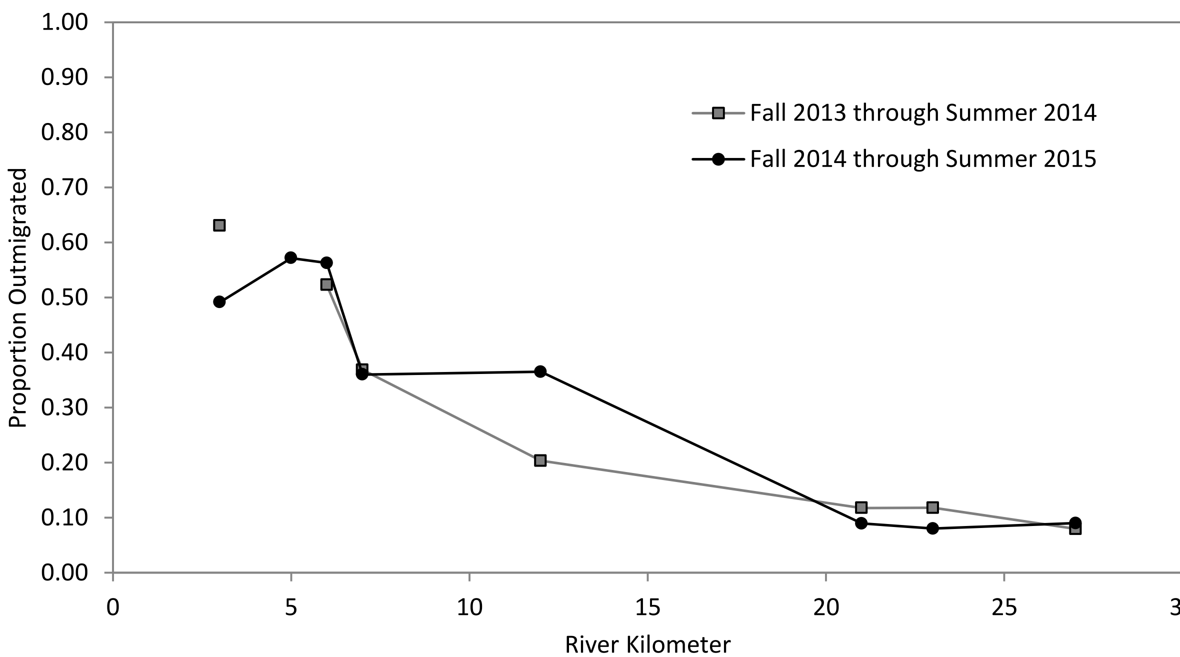


Figure 24. Proportion of PIT tagged natural origin juvenile steelhead that outmigrated in Salmon Creek by river kilometer, from lower (Strata 1) to higher (Strata 9) in the subwatershed.

Conclusions

This study demonstrated that it was possible to determine a population estimate of juvenile steelhead in small creeks with a defined measure of precision. While this technique might not be an optimal approach in larger systems, such as the mainstem Okanogan River, it was shown to be fairly precise in smaller watersheds. With multiple years of data collection, it may be possible to detect change in status and trends in the population of juvenile steelhead in relatively small, spatially distinct watersheds. Expanding these methods to additional tributaries within the Okanogan subbasin will allow for further examination of juvenile steelhead production in this system and increase the number of PIT tagged fish available for interrogation to estimate out-migration for the subbasin as a whole.

Many of the stated assumptions used in this study appeared to be adequate, but remained untested. Block nets were meticulously placed in small trenches and back filled with substrate in attempts to create a closed population during mark-recapture events, detections of marks were easily distinguishable with the use of PIT tags and top caudal fin clips, sampling effort was monitored to remain consistent between the first and second pass, and fish were evenly distributed throughout the site upon release in the mark-recapture sampling close to their initial capture location. Assumptions that may contribute to more bias include that handling and marking of fish did not affect the likelihood of recapture and that no marks were lost prior to outmigration. In this study, no fish were recaptured that had a tag puncture wound and were found without a tag. Additionally, studies have shown that short term retention of PIT tags to be quite high, near 100% (Prentice et al. 1990, Zydlewski et al. 2003).

One factor that may warrant further consideration is the assumption that fish are evenly distributed throughout the reach, or more specifically, that the sample site was representative of the reach as a whole. Violation of this assumption may lead to less certainty in the accuracy of abundance of fish within that reach. Some studies have shown that spatial variation in fish density across a watershed may be considerable (Bisson et al. 1988, Kiffney et al. 2006). This bias may be inflated in longer reaches such as Omak Creek Reach 4 and Salmon Creek Reach 6, where the sample site only covered 3.6% and 1.0% of the reach length, respectively. However, this bias was minimized overall by randomly sampling all reaches in each sub-watershed. Additionally, the relatively large site length-to-wetted width ratio (ex. Omak Creek, 150 m / ~5 m) may accommodate habitat variation within this small system. If time and budget allow, the placement of multiple randomly selected sites within a reach will allow us to quantify inter-site variability of fish density within each reach. For reaches that are too short for multiple sites (ex. Omak Creek Reach 2, 275 m in total length), sampling of the entire reach could remove concern of site variation within the reach.

Spatial distribution of fish throughout the creek may vary by age and size class (Roper et al. 1994). For example, density of steelhead fry may be linked to spawning location of adults the previous spring. Distribution of juvenile salmonids may also be linked to specific habitat variables, such as water velocity and substrate (Bisson et al. 1988, Everest and Chapman 1972, Nielsen et al. 1994), log/beaver jams (Roni and Quinn 2001), and overhead cover (Fausch 1993), among others. While the distribution of fish in relation to specific habitat variables was not examined in this study period, it may be possible to explore hypotheses in the future, due to the fact that these abundance data were collected at existing long-term habitat monitoring sites. Determining abundance of fish in respect to specific habitat characteristics may help to further describe variables favored in this system and assist in focusing habitat restoration efforts.

All naturally produced juvenile *O. mykiss* that were 95 mm and larger were PIT tagged. Additional years of outmigration data may be able to show if naturally produced *O. mykiss* in streams contribute to returns of adult steelhead, or if contribution from certain small watersheds is minimal, relative to the number of adults that spawn in these streams. Representatively marking a known proportion of the population upstream of the PIT tag array enabled the program to estimate emigration, even in the absence of a rotary screw trap. This method can also be applied to small watersheds where monitoring of juvenile production was previously infeasible. Dividing the creek into biologically distinct reaches allowed for subsampling to occur at a finer scale and site-based abundance of juvenile steelhead were only expanded within similar habitat types. Outmigration trend analyses will continue to be produced with further years of data. Although the methods outlined in this report might not be applicable for larger systems, the representative fish sampling approach was shown to provide an estimate of juvenile steelhead in small watersheds with a high degree of precision.

Appendix C. Snorkel Surveys

Total numbers and densities of juvenile *O. mykiss* for all streams and rivers in 2015 are shown in Table 9 for Washington and Table 10 for British Columbia. Due to the rotating panel design, not all tributaries are sampled each year and are labeled as “not sampled” in the table below. Sites are also labeled “not sampled” if the sites were dry. Specific long term results are shown in further detail in the figures following, organized by individual site.

Table 9. Total observed numbers and densities of juvenile *O. mykiss* in the United States portion of the Okanogan subbasin, 2015.

Stream Name	Total Observed *O. mykiss* (N)	Density (fish/ha)
Aeneas Creek	not sampled	n/a
Antoine Creek	not sampled, site dry	n/a
Bonaparte Creek	19	994
Chiliwist Creek	not sampled	n/a
Johnson Creek	not sampled	n/a
Loup Loup Creek	6	172
Ninemile Creek	not sampled, site dry	n/a
Okanogan River	1 [a]	0.02 [b]
Omak Creek	418 [a]	1,629 [b]
Salmon Creek	434 [a]	2,787 [b]
Similkameen River	11 [a]	2.1 [b]
Siwash Creek	not sampled	n/a
Stapaloop Creek	not sampled	n/a
Tonasket Creek	not sampled	n/a
Trail Creek	not sampled	n/a
Tunk Creek	1	42
Wanacut Creek	not sampled, site dry	n/a
Wildhorse Spring Cr.	not sampled	n/a

[a] sum of all juvenile *O. mykiss* from multiple sites per creek.
[b] average density of all juvenile *O. mykiss* from multiple sites per creek.

Table 10. Total observed numbers and densities of juvenile *O. mykiss* in the Canadian portion of the Okanagan subbasin, 2015.

Stream Name	Total Observed *O. mykiss*	Density (fish/ha)
snpin’yaʔtkʷ (Ellis Creek)	3	30
akskʷəkʷant (Inkaneep Creek)	74[a]	729[b]
McLean Creek	489	7,474
q̓awsitkʷ (Okanagan River)	1[a]	0.2[b]
akłxʷminaʔ (Shingle Creek)	80[a]	471[b]
Shuttleworth Creek	50	625
snʕax̌əlqaxʷiyaʔ (Vaseux Creek)	344[a]	1,019[b]
Testalinden Creek	0	0
Wolfcub Creek	17	243

[a] sum of all juvenile *O. mykiss* from multiple sites per creek.
[b] average density of all juvenile *O. mykiss* from multiple sites per creek.

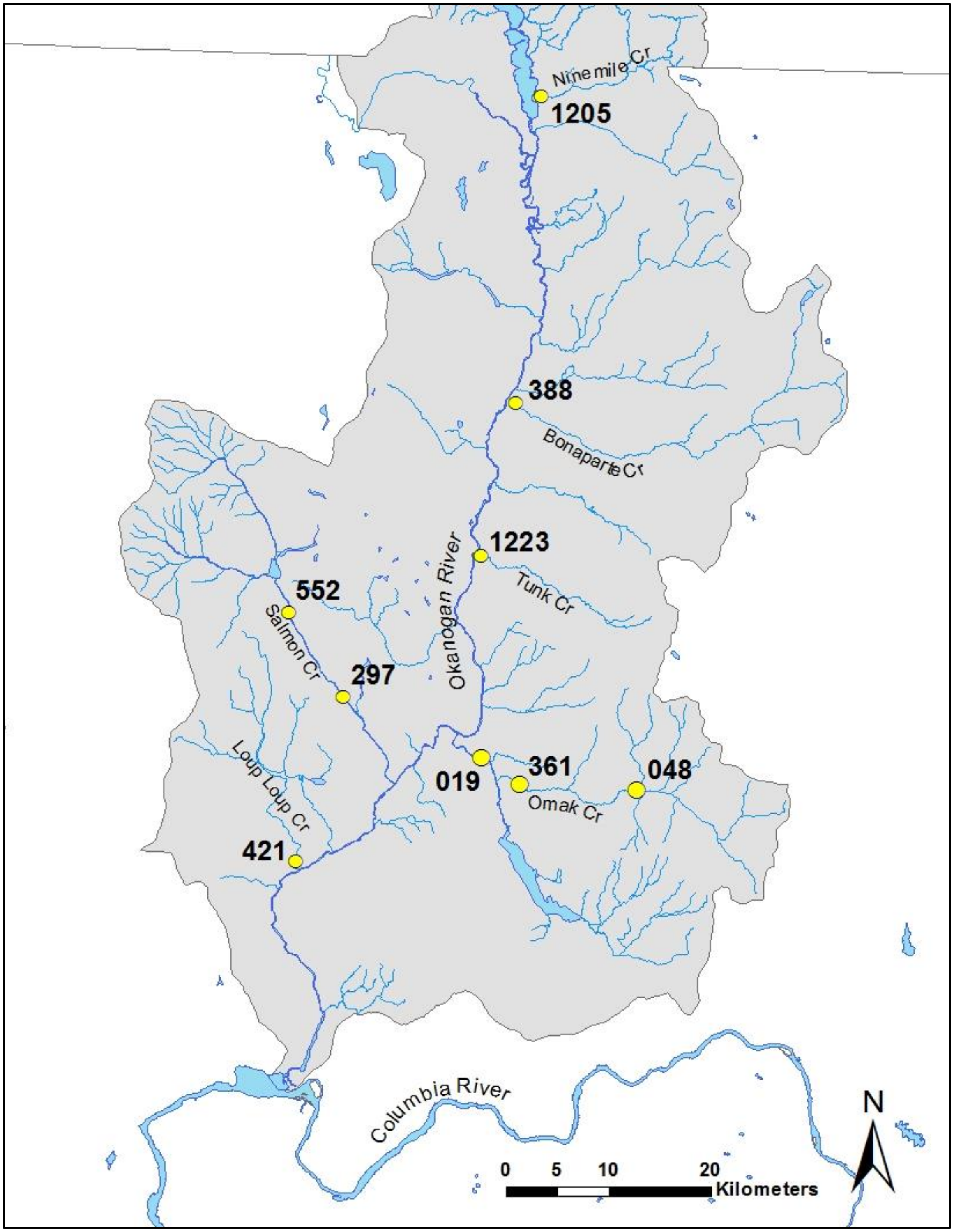
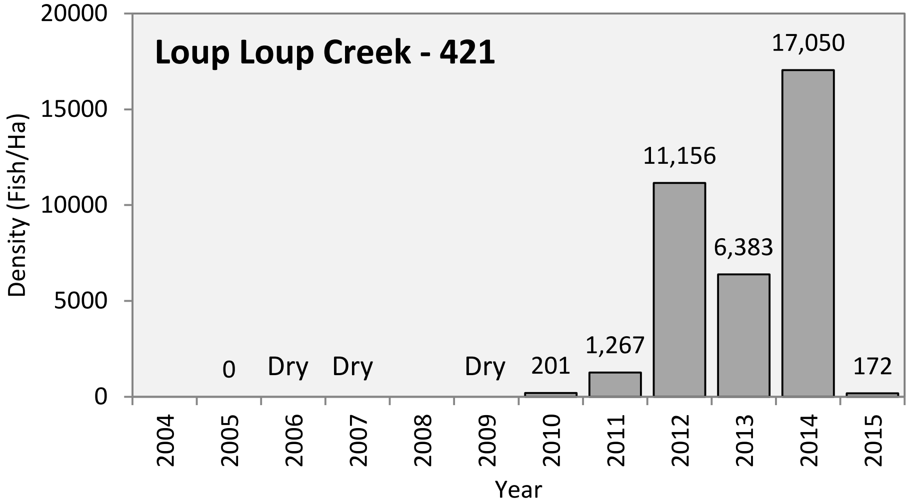
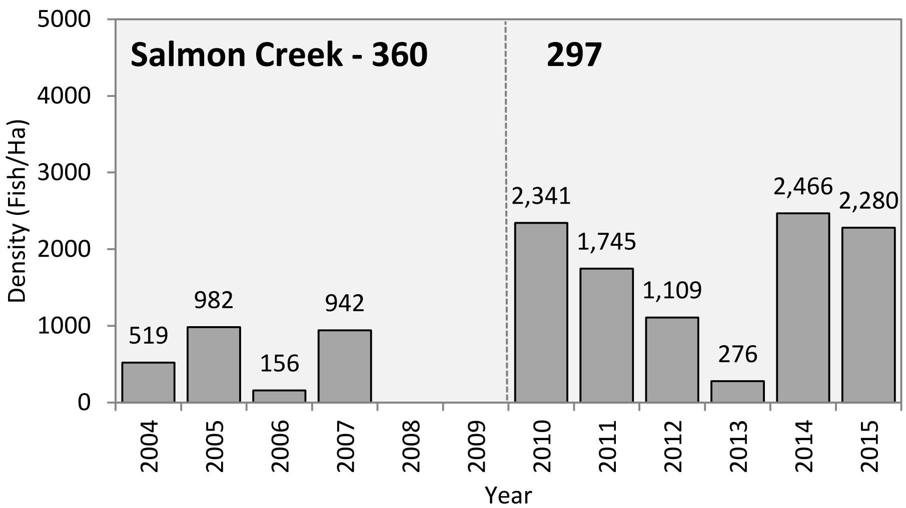


Figure 25. Location of annual snorkel survey sites on tributaries to the Okanogan River. Rotating panel sites are not shown due to fewer years of data for each site.



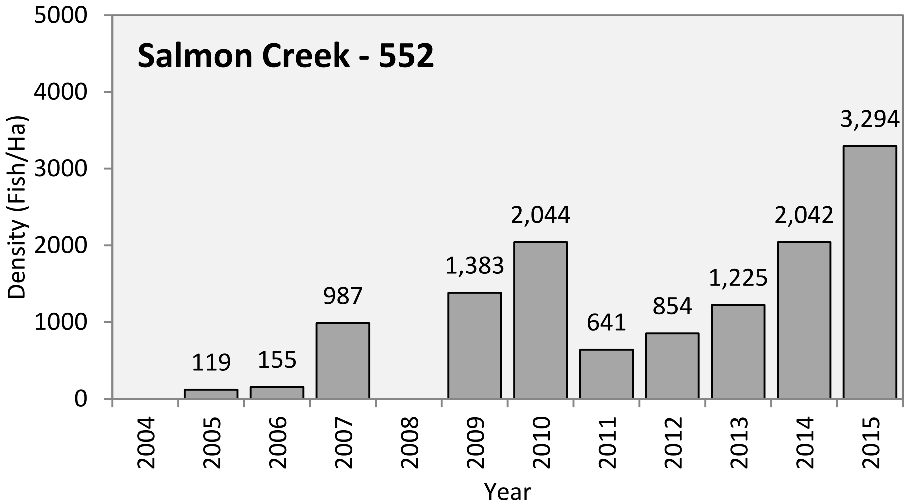
Year	# Obs.
2004	NS
2005	0
2006	Dry
2007	Dry
2008	NA
2009	Dry
2010	6
2011	48
2012	484
2013	269
2014	587
2015	6

Figure 26. Observed density and count of juvenile (< 300mm) *O. mykiss* in Loup Loup Creek, in the town of Malott, WA.



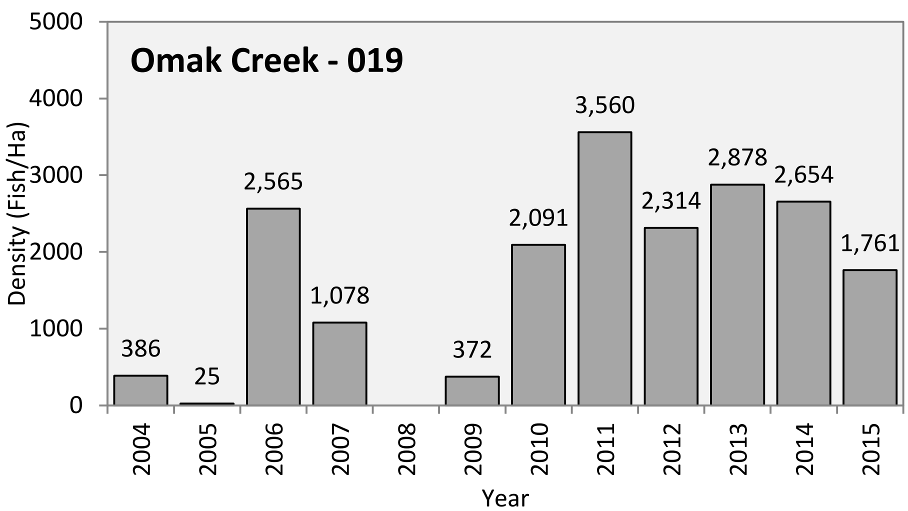
Year	# Obs.
2004	100
2005	157
2006	19
2007	104
2008	NA
2009	NS
2010	193
2011	158
2012	93
2013	20
2014	174
2015	167

Figure 27. Observed densities of juvenile (< 300mm) *O. mykiss* in Salmon Creek. In 2009, site 297 replaced nearby site 360 that was moved due to access related issues. In 2013, the site was electrofished prior to snorkeling, which may have affected observed counts.



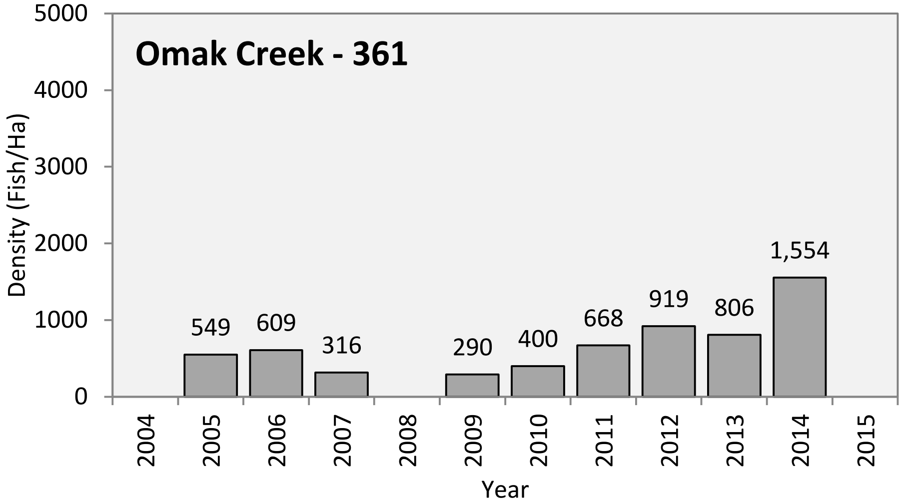
Year	# Obs.
2004	NS
2005	10
2006	18
2007	107
2008	NA
2009	103
2010	214
2011	75
2012	85
2013	126
2014	173
2015	267

Figure 28. Observed densities of juvenile (< 300mm) *O. mykiss* in Salmon Creek, the upper most annual site on the creek, near the historical townsite of Ruby.



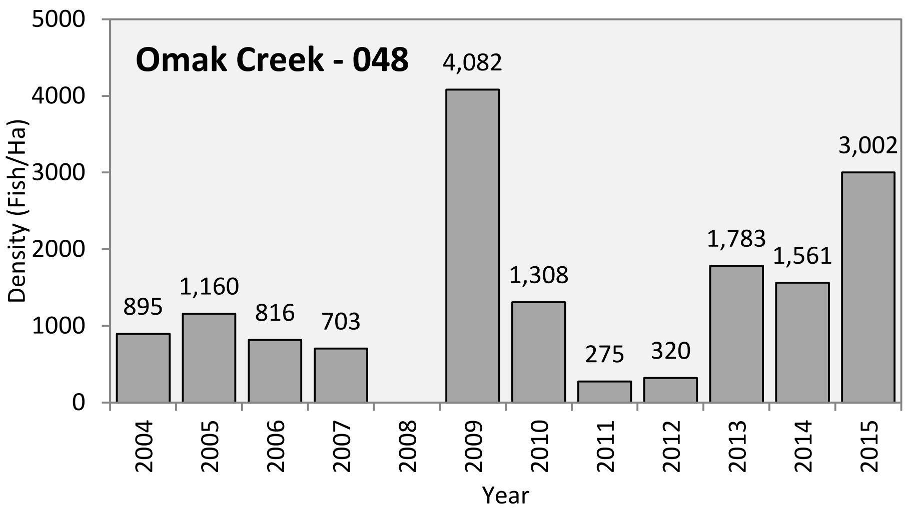
Year	# Obs.
2004	31
2005	2
2006	181
2007	67
2008	NA
2009	21
2010	142
2011	288
2012	176
2013	199
2014	174
2015	121

Figure 29. Observed densities of juvenile (< 300mm) *O. mykiss* in Omak Creek, the lower most site on the creek, and the only annual site below Mission Falls.



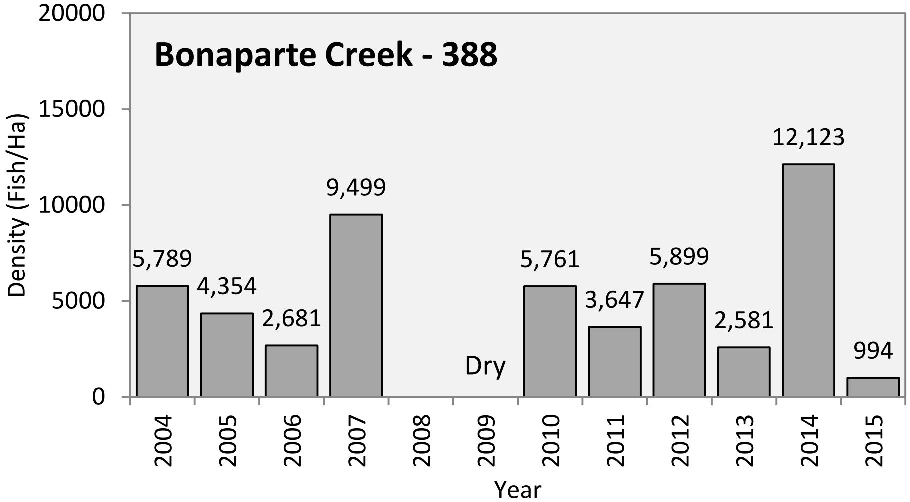
Year	# Obs.
2004	NS
2005	79
2006	106
2007	45
2008	NA
2009	26
2010	37
2011	108
2012	128
2013	126
2014	177
2015	NS

Figure 30. Observed densities of juvenile (< 300mm) *O. mykiss* in Omak Creek, located in the middle portion of the watershed, but above Mission Falls.



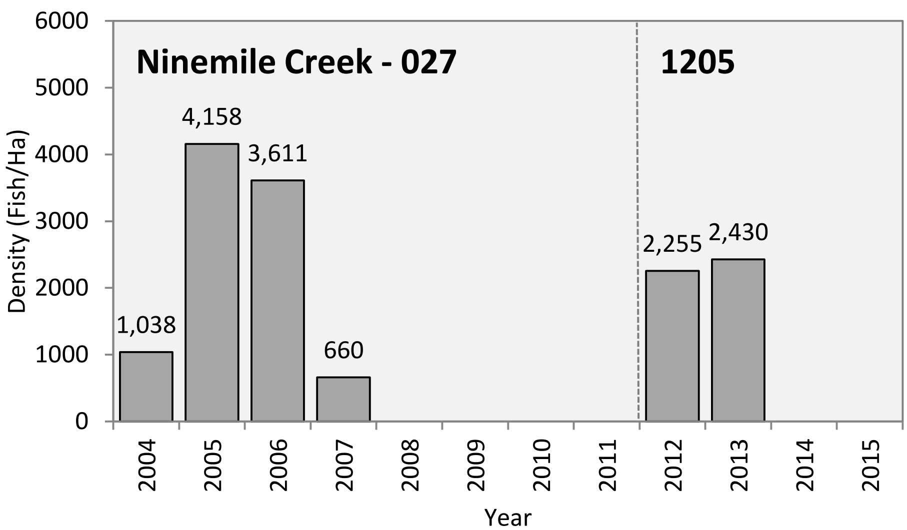
Year	# Obs.
2004	96
2005	108
2006	78
2007	74
2008	NA
2009	288
2010	141
2011	26
2012	33
2013	162
2014	142
2015	289

Figure 31. Observed densities of juvenile (< 300mm) *O. mykiss* in Omak Creek, the upper most site in the Omak Creek watershed.



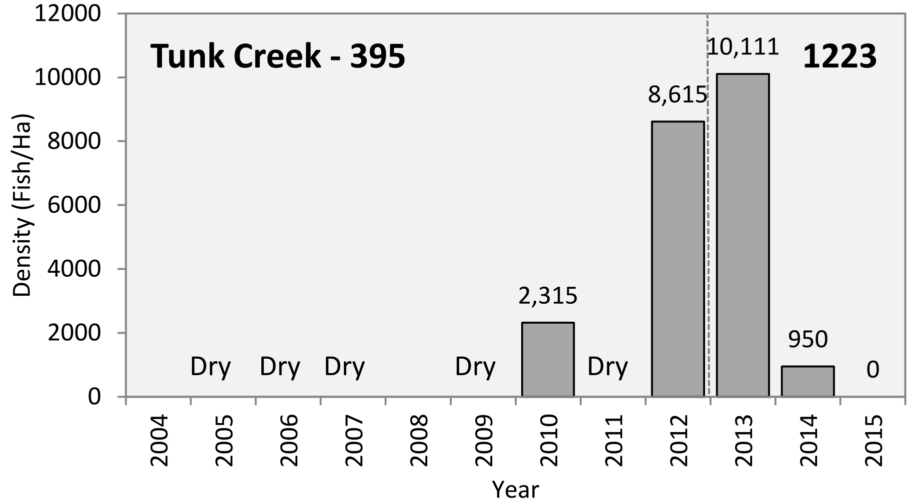
Year	# Obs.
2004	210
2005	149
2006	100
2007	220
2008	NA
2009	Dry
2010	179
2011	94
2012	144
2013	57
2014	237
2015	19

Figure 32. Observed densities of juvenile (< 300mm) *O. mykiss* in Bonaparte Creek in the city of Tonasket, WA.



Year	# Obs.
2004	29
2005	108
2006	99
2007	15
2008	NA
2009	NS
2010	NS
2011	NS
2012	72
2013	67
2014	NS
2015	NS

Figure 33. Observed densities of juvenile (<300mm) *O. mykiss* on Ninemile Creek. Site 1205 was shifted a few transects downstream of previous annual site 027; both sites occasionally could not be sampled due to complete poison ivy coverage or very low water depths.



Year	# Obs.
2004	NS
2005	Dry
2006	Dry
2007	Dry
2008	NA
2009	Dry
2010	83
2011	Dry
2012	288
2013	338
2014	21
2015	0

Figure 34. Observed densities of juvenile (<300mm) *O. mykiss* on Tunk Creek. In 2013, site 1223 was moved a few transects upstream of previous annual site 395 to fit within EDT reach breaks.

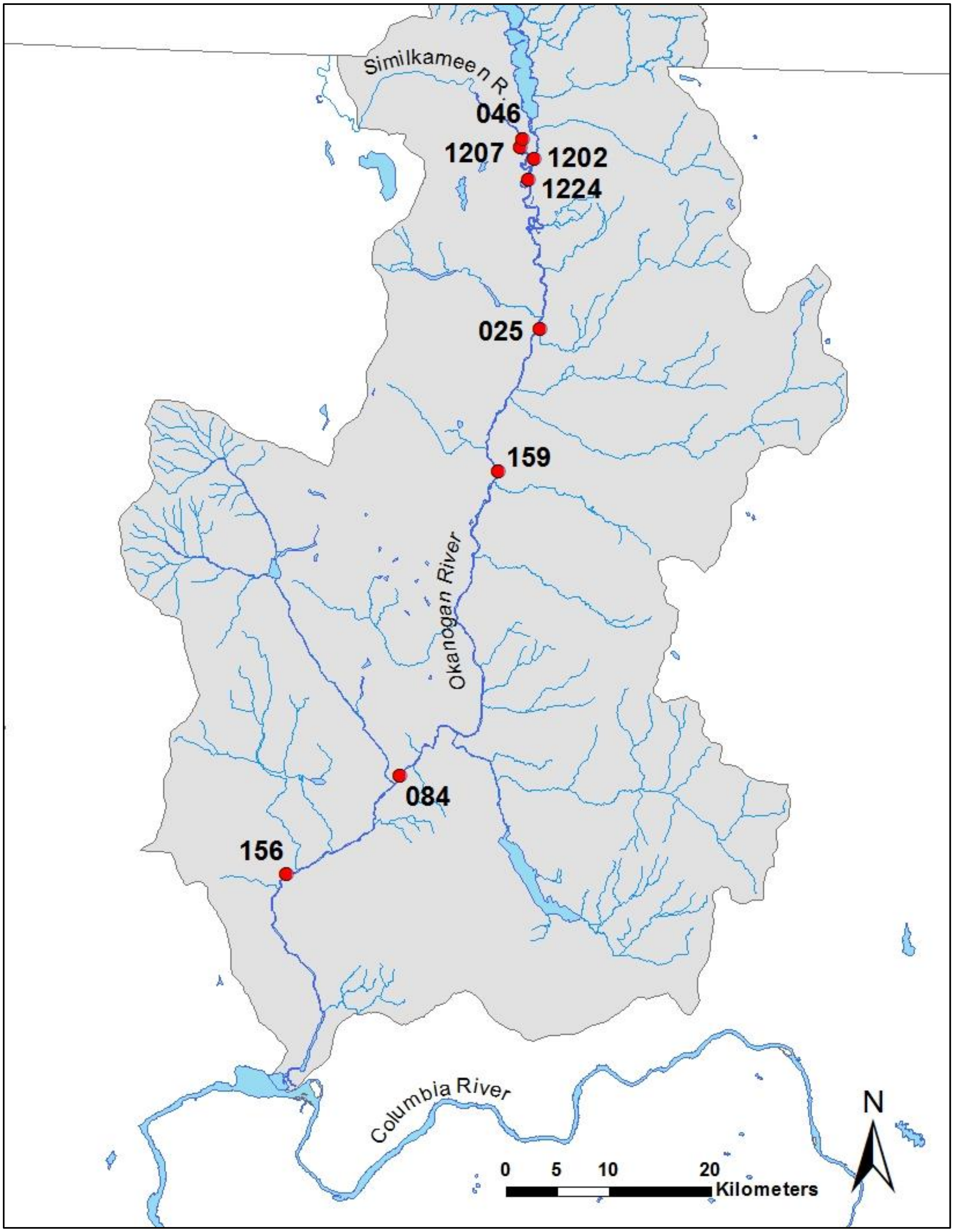
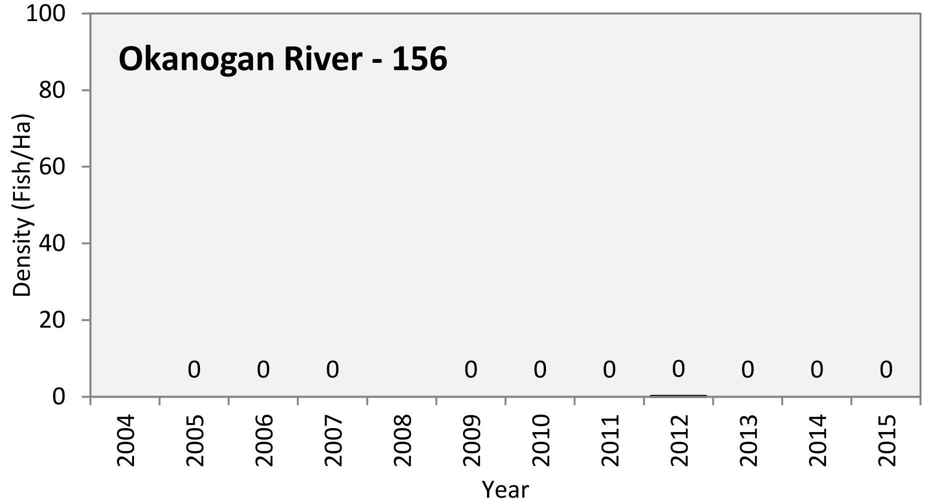
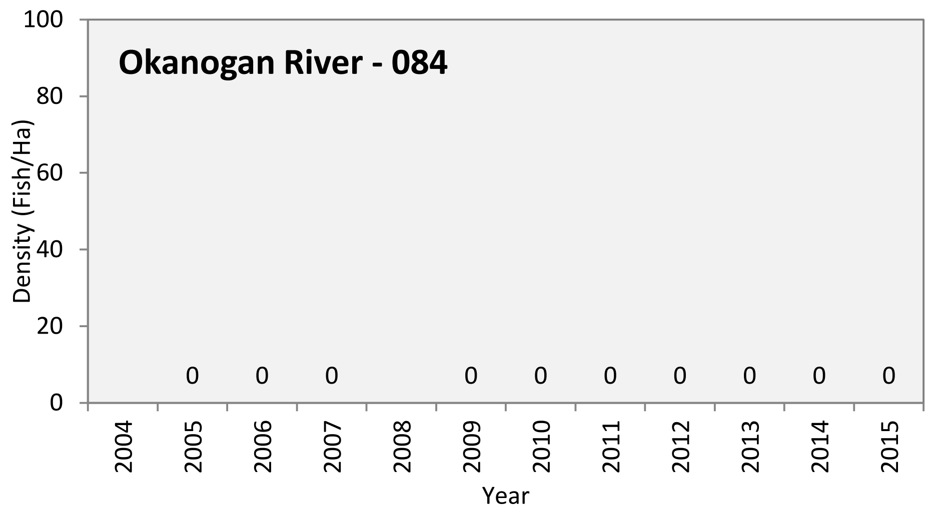


Figure 35. Location of annual snorkel survey sites on the mainstem Okanogan and Similkameen Rivers. Rotating panel sites are not shown due to fewer years of data.



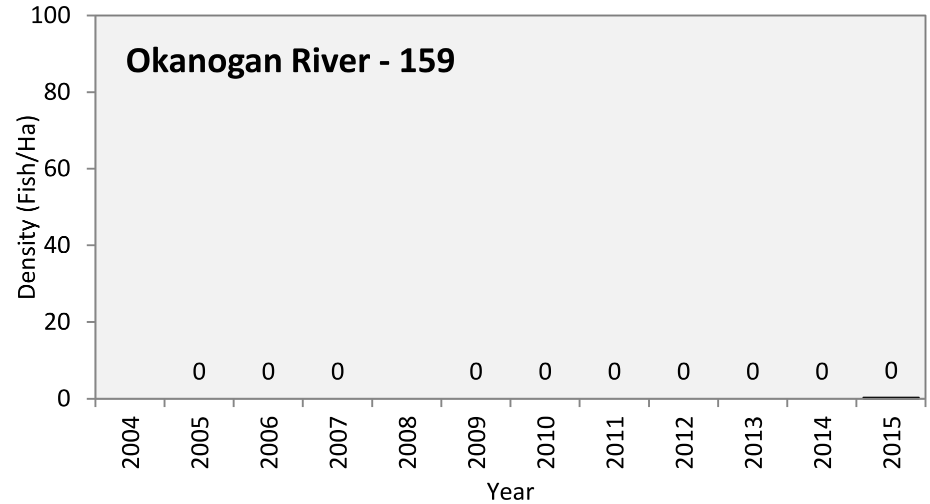
Year	# Obs.
2004	NS
2005	0
2006	0
2007	0
2008	NA
2009	0
2010	0
2011	0
2012	1
2013	0
2014	0
2015	0

Figure 36. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, downstream of the confluence with Loup Loup Creek.



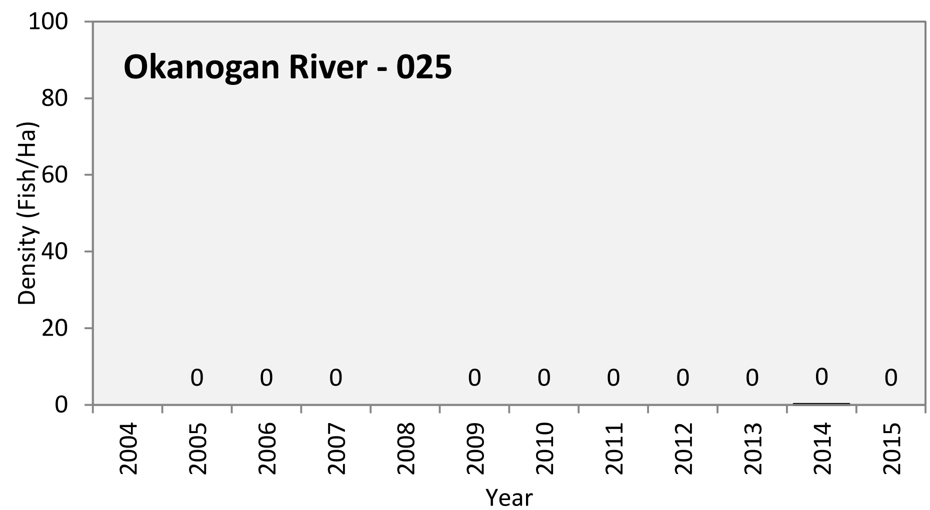
Year	# Obs.
2004	NS
2005	0
2006	0
2007	0
2008	NA
2009	0
2010	0
2011	0
2012	0
2013	0
2014	0
2015	0

Figure 37. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, upstream of the confluence with Salmon Creek.



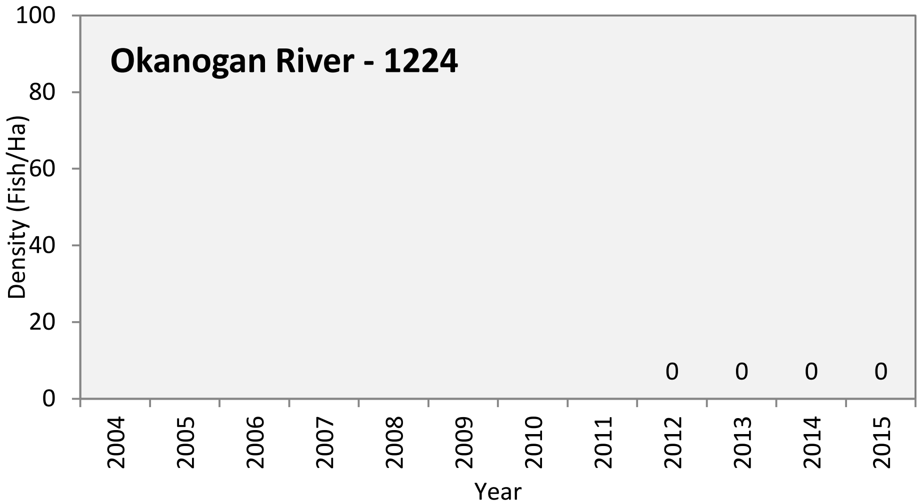
Year	# Obs.
2004	NS
2005	0
2006	0
2007	0
2008	NA
2009	0
2010	0
2011	0
2012	0
2013	0
2014	0
2015	1

Figure 38. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, south of Tonasket, WA, below Janis Bridge.



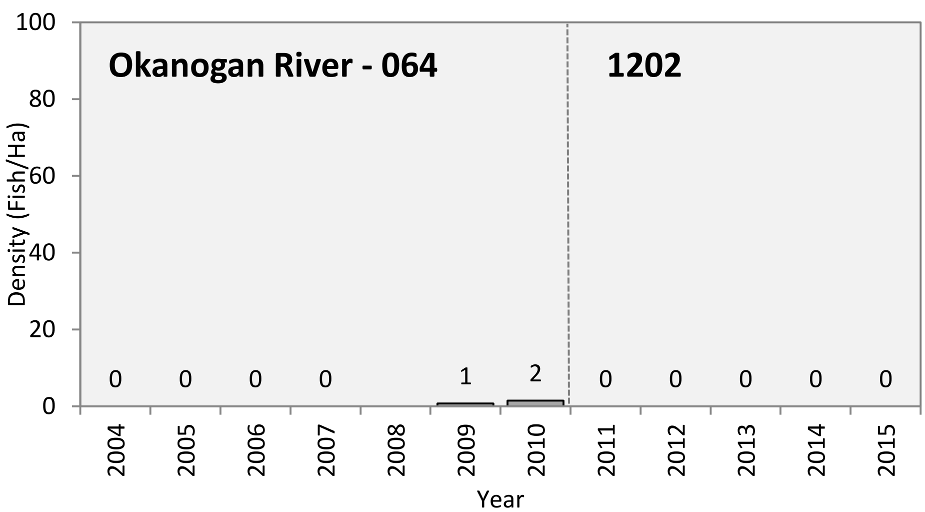
Year	# Obs.
2004	NS
2005	0
2006	0
2007	0
2008	NA
2009	0
2010	0
2011	0
2012	0
2013	0
2014	1
2015	0

Figure 39. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, upstream of the confluence with Antoine Creek.



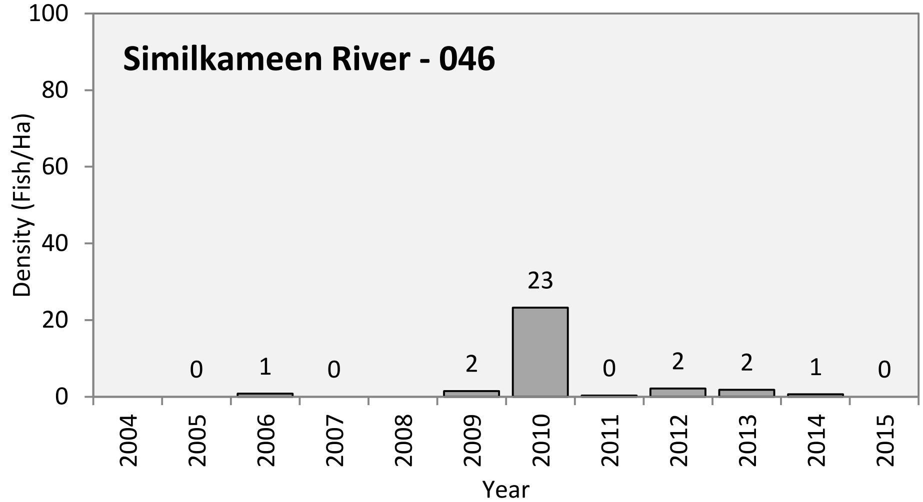
Year	# Obs.
2004	NA
2005	NA
2006	NA
2007	NA
2008	NA
2009	NA
2010	NA
2011	NA
2012	0
2013	0
2014	0
2015	0

Figure 40. Observed densities of juvenile (<300mm) *O. mykiss* in the Okanogan River. This new site was added in 2012 and is in the narrow part of the Okanogan River just before the confluence with the Similkameen.



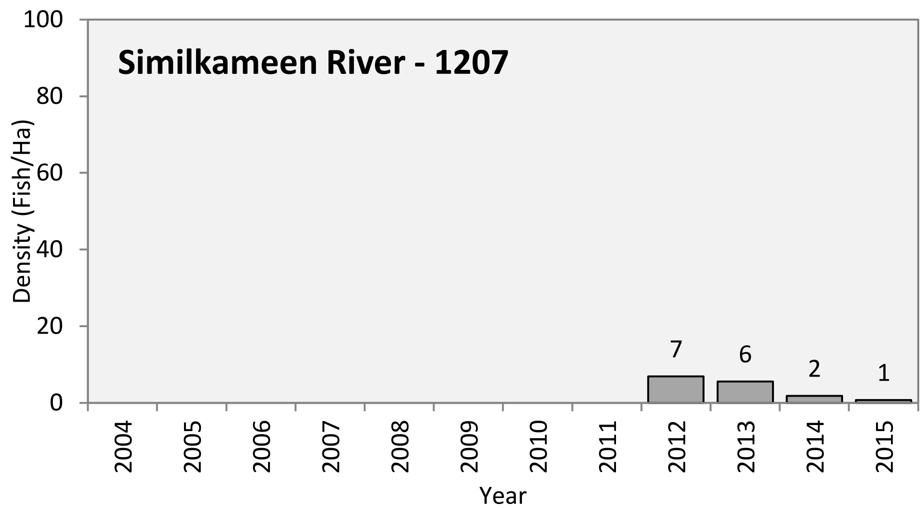
Year	# Obs.
2004	0
2005	0
2006	0
2007	0
2008	NA
2009	1
2010	2
2011	0
2012	0
2013	0
2014	0
2015	0

Figure 41. Observed densities of juvenile (<300mm) *O. mykiss* in the Okanogan River. Site 1202 was moved two transects downstream of previous annual site 064 which overlapped the upper cross-channel with the Similkameen.



Year	# Obs.
2004	NS
2005	0
2006	2
2007	0
2008	NA
2009	4
2010	75
2011	1
2012	6
2013	6
2014	2
2015	0

Figure 42. Observed densities of juvenile (< 300mm) *O. mykiss* in the Similkameen River, near the city of Oroville, WA.



Year	# Obs.
2004	NA
2005	NA
2006	NA
2007	NA
2008	NA
2009	NA
2010	NA
2011	NA
2012	18
2013	16
2014	5
2015	2

Figure 43. Observed densities of juvenile (<300mm) *O. mykiss* in the Similkameen River. This new site was added in 2012.

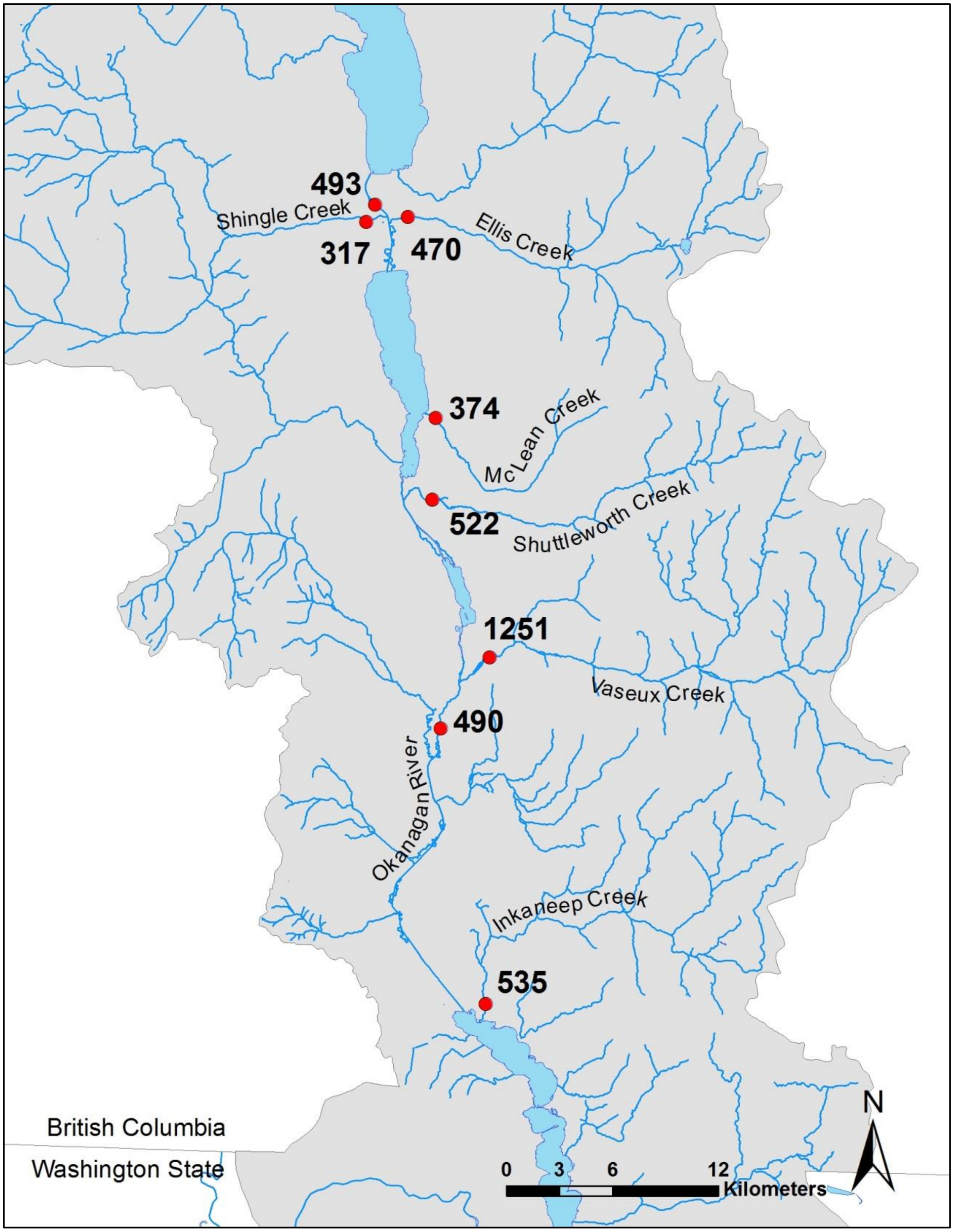
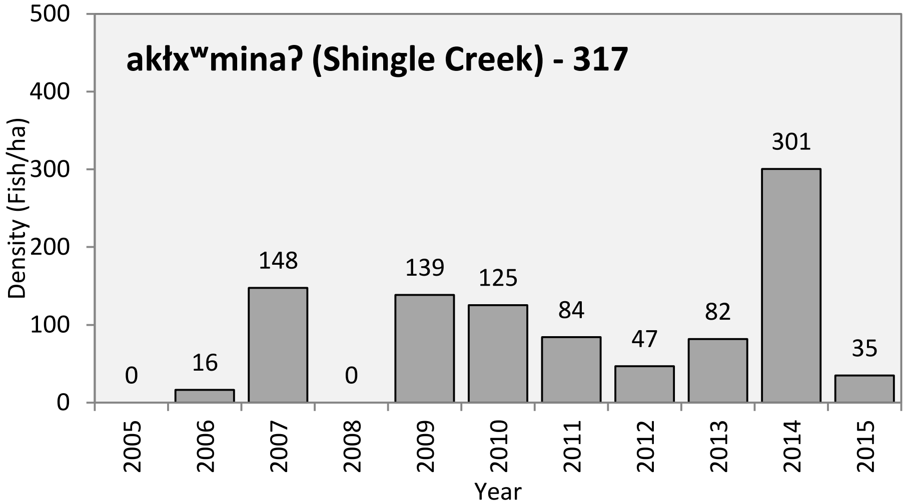
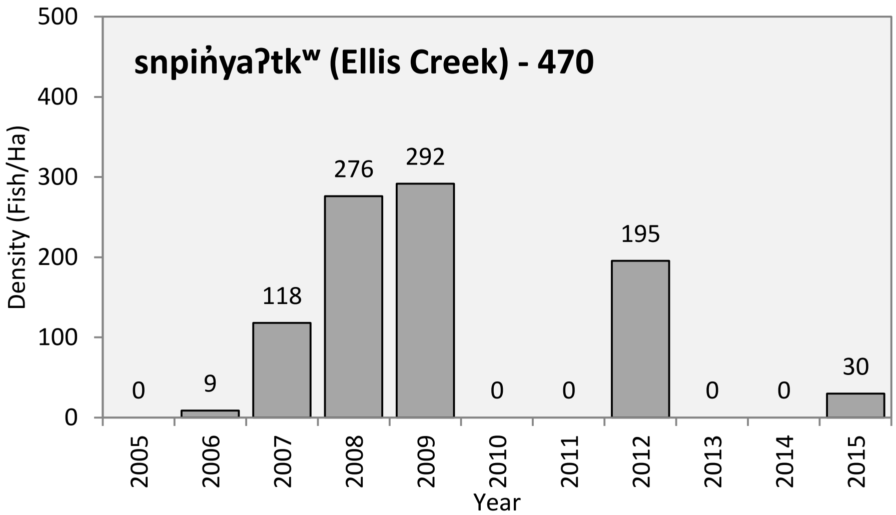


Figure 44. Location of annual snorkel survey sites on the British Columbia portion of the Okanagan subbasin. Rotating panel sites are not shown due to fewer years of data.



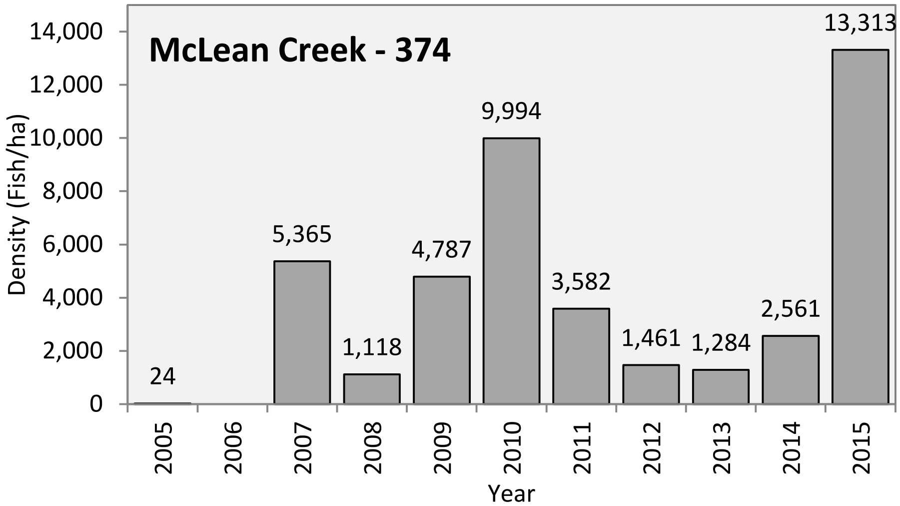
Year	# Obs.
2004	NA
2005	NA
2006	1
2007	10
2008	0
2009	8
2010	7
2011	5
2012	3
2013	5
2014	19
2015	2

Figure 45. Observed densities of juvenile (< 300mm) *O. mykiss* in lower akłx̌ʷminaʔ (Shingle Creek) at site 317.



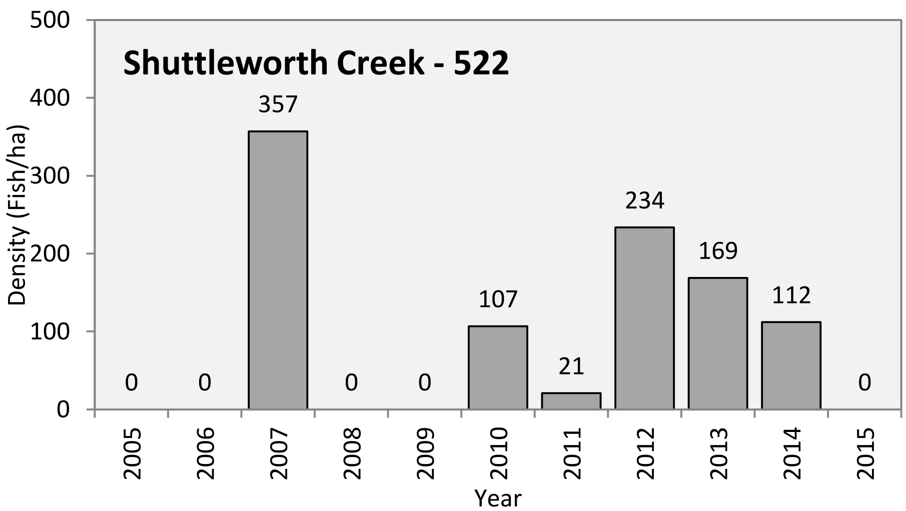
Year	# Obs.
2004	NA
2005	0
2006	1
2007	12
2008	28
2009	27
2010	0
2011	0
2012	23
2013	0
2014	0
2015	3

Figure 46. Observed densities of juvenile (< 300mm) *O. mykiss* in lower snpin'yaʔtkʷ (Ellis Creek) at site 470.



Year	# Obs.
2004	NA
2005	1
2006	NS
2007	178
2008	45
2009	93
2010	323
2011	139
2012	48
2013	47
2014	89
2015	446

Figure 47. Observed densities of juvenile (< 300mm) *O. mykiss* in McLean Creek at site 374.



Year	# Obs.
2004	NA
2005	0
2006	0
2007	25
2008	0
2009	0
2010	5
2011	1
2012	15
2013	13
2014	9
2015	0

Figure 48. Observed densities of juvenile (< 300mm) *O. mykiss* Shuttleworth Creek at site 522.

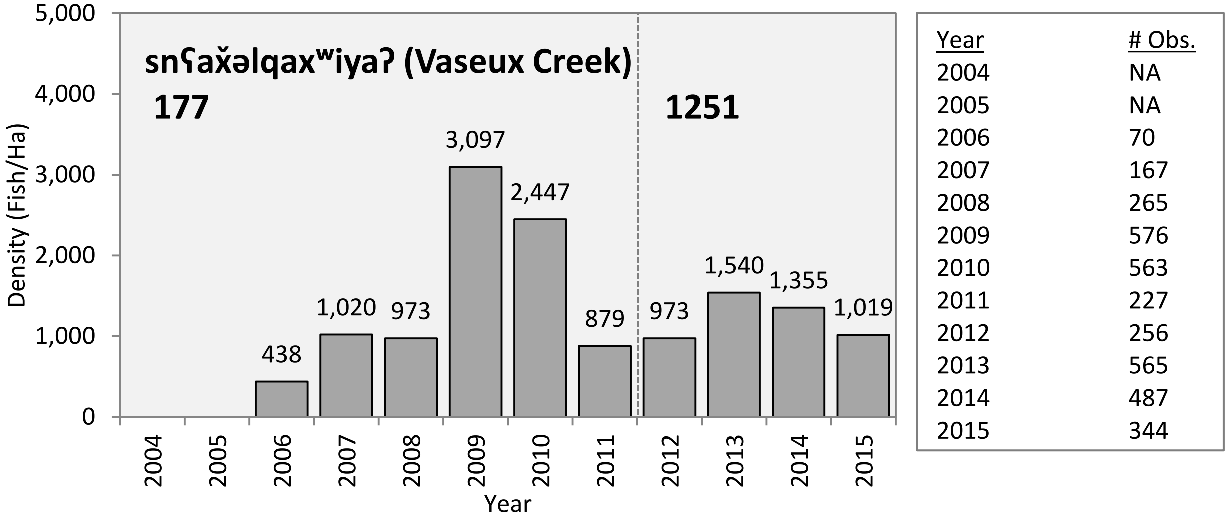


Figure 49. Observed densities of juvenile (< 300mm) *O. mykiss* snʕax̌əlqaxʷiyaʔ (Vaseux Creek). In 2012, site 177 was shifted a few transects down and renamed site 1251.

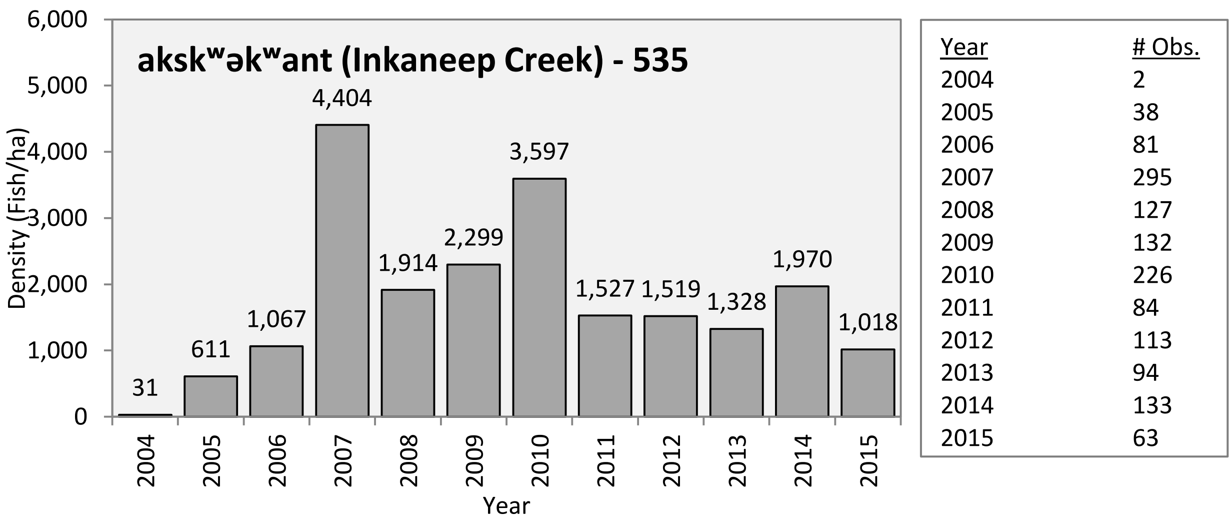
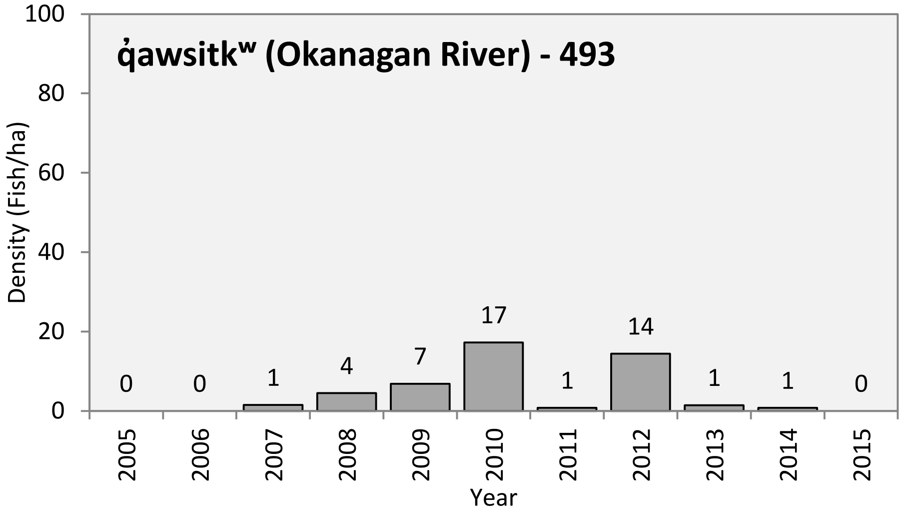
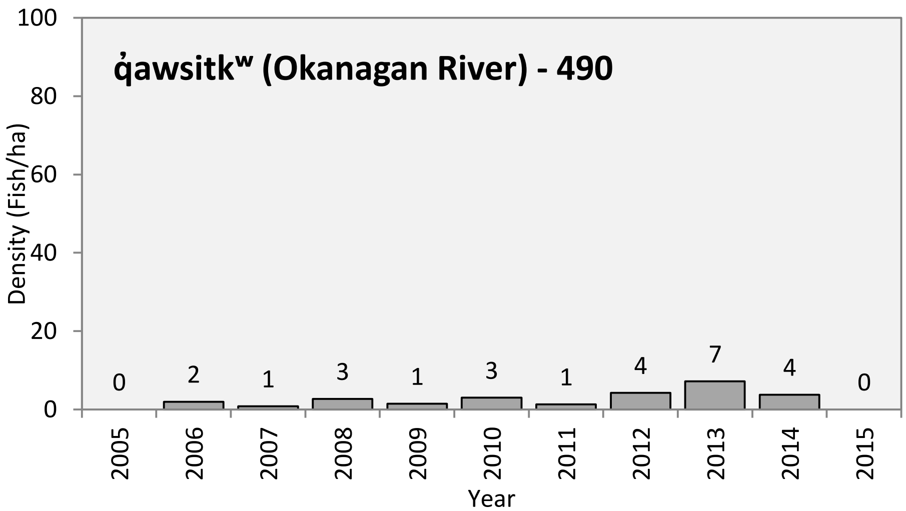


Figure 50. Observed densities of juvenile (< 300mm) *O. mykiss* akskʷəkʷant (Inkaneep Creek) at site 535.



Year	# Obs.
2004	NA
2005	0
2006	0
2007	2
2008	6
2009	9
2010	22
2011	1
2012	20
2013	2
2014	1
2015	0

Figure 51. Observed densities of juvenile (< 300mm) *O. mykiss* q̓awsitkʷ (Okanagan River) at site 493 (Penticton channel).



Year	# Obs.
2004	NA
2005	NA
2006	3
2007	1
2008	4
2009	2
2010	4
2011	2
2012	7
2013	11
2014	6
2015	0

Figure 52. Observed densities of juvenile (< 300mm) *O. mykiss* q̓awsitkʷ (Okanagan River) at site 490 (near Oliver).

Appendix D. Water Temperature

Introduction

Water temperature plays a fundamental role in dictating the distribution and abundance of salmonids in the Columbia River Basin. Water temperature data, including datasets from the Okanogan subbasin, are frequently used in large scale analysis or models, such as NorWeST, to describe changes in temperature through time. To describe water temperature in biologically relevant terms, data must be compared with species-specific criteria. When examining potential effects of water temperature on salmonids, it is useful to have a common measure. One commonly used measure to examine effects of elevated water temperatures is the maximum weekly maximum water temperature (MWMT), which is also referred to as the 7 day average of the daily maximum temperatures (7DADM). This metric is frequently used because "it describes the maximum temperatures in a stream, but is not overly influenced by the maximum temperature of a single day" (USEPA 2003). Table 11 outlines general temperature considerations for salmonids in the Pacific Northwest. These temperature ranges can be compared to water temperature data collected in the Okanogan subbasin, in streams where juvenile steelhead are known to exist. While this report does not contain a full discussion of temperature effects on juvenile salmonids, pertinent literature reviews that focus on lethal and sub-lethal effects of water temperature on salmonids are discussed further in Myrick and Cech 2001, USEPA 2003, and Carter 2005, among others.

While it may be possible for certain stocks to gain strain-level adaptations to variable conditions over time (Myrick and Cech 2001), Carter (2005, citing USEPA 2001) suggested that:

> Salmonid stocks do not tend to vary much in their life history thermal needs, regardless of their geographic location. The USEPA (2001) in their *Summary of Technical Literature Examining the Physiological Effects of Temperature on Salmonids* makes the case that there is not enough significant genetic variation among stocks or among species of salmonids to warrant geographically specific water temperature standards.
>
> > Climate conditions vary substantially among regions of the State and the entire Pacific Northwest. …Such [varying climatic] conditions could potentially have led to evolutionary adaptations, resulting in development of subspecies differences in thermal tolerance. …[However,] the literature on genetic variation in thermal effects indicates occasionally significant but very small differences among stocks and increasing differences among subspecies, species, and families of fishes. Many differences that had been attributed in the literature to stock differences are now considered to be statistical problems in analysis, fish behavioral responses under test conditions, or allowing insufficient time for fish to shift from field conditions to test conditions (Mathur and Silver 1980, Konecki et al. 1993, both cited in USEPA 2001).
>
> Additionally:
>
> > There are many possible explanations why salmonids have not made a significant adaptation to high temperature in streams of the Pacific Northwest. Temperature tolerance is probably controlled by multiple genes, and consequently would be a core characteristic of the species not easily modified through evolutionary change

without a radical shift in associated physiological systems. Also, the majority of the life cycle of salmon and steelhead is spent in the ocean rearing phase, where the smolt, subadults, and adults seek waters with temperatures less than 59°F (15°C) (Welch et al. 1995, as cited in USEPA 2001).

Due to a lack of specific data at this time to suggest that *O. mykiss* in the Okanogan River have developed adaptations to higher water temperatures, the values cited in Table 11 were considered appropriate for this preliminary analysis.

Table 11. Summary of temperature considerations for incubating and juvenile salmon and trout (adapted from USEPA 2003, Table 1, p.16).

Temperature Consideration	Temperature (unit)	Reference
Incubation and Emergence		
Optimal Range	6 - 10°C (constant)	USEPA 2001c
Good survival	4 - 12°C (constant)	USEPA 2001c
Increased mortality	> 15°C	Myrick and Cech 2001
Poor survival (< 7%)	> 16°C	Velsen 1987
Rearing Preference	10 - 17°C (constant)	USEPA 2001a
	< 18°C (7DADM)	Welsh et al. 2001
Optimal Growth		
Unlimited food	13 - 20°C (constant)	USEPA 2001c
Limited food	10 - 16°C (constant)	USEPA 2001c
Disease Risk		
Minimized	12 - 13°C (constant)	USEPA 2001b
Elevated	14 - 17°C (constant)	USEPA 2001b
High	> 18 - 20°C (constant)	USEPA 2001b
Lethal Temp		
1 Week	23 - 26°C (constant)	USEPA 2001c

In the Okanogan River subbasin, adult steelhead spawn from late-March through early-May, with peak spawning occurring in mid-April. After spawning occurs, steelhead eggs typically hatch between 50 and 30 days at temperatures from 10-15°C (Wydoski and Whitney 2003, Moyle 2002). Alevin may remain in the gravels for 2 to 3 weeks longer before emergence (Moyle 2002). Based on spawn-timing data from the Okanogan subbasin over the past 10 years (OBMEP 2015), steelhead eggs and alevin may be present in the gravels from March through June. Juvenile steelhead parr rear in the subbasin from one to two years or more before out-migrating to the ocean. Resident life histories of *O. mykiss* (Rainbow Trout) can be found in the Okanogan River subbasin year-round.

Acute lethal effects of temperature on steelhead egg survival have been published through a handful of studies (Myrick and Cech 2001). In a literature review, Myrick and Cech (2001) note 15°C as a temperature for egg incubation in which increased mortality has been noted to occur, although suggesting that strain-level variation may exist. Velsen (1987) compiled data on effects of temperature on incubation mortality and cited poor survival (< 7%) above 16°C. Additional sub-lethal effects due to elevated temperatures may also occur, but results are not as thoroughly quantifiable. For juvenile rearing, 18°C and below represents a preferred rearing temperature and above may represent a high risk for disease (Table 11). Although this temperature alone may not be deleterious, noting that increased growth rates occur in this range (USEPA 2001c), it represents a threshold where increased stressors and negative effects have been documented. Additionally, elevated stream temperatures may compound intra- and interspecific species competition for resources or rearing space (USEPA 2001a), particularly during summer low flows.

Methods

OBMEP - Water Quality Sampling (ID:5)
https://www.monitoringmethods.org/Protocol/Details/5
OBMEP - Habitat Monitoring (ID:9)
https://www.monitoringmethods.org/Protocol/Details/9

OBMEP collected hourly water temperature data in the Okanogan subbasin from 2005 through 2015, in both the mainstem and tributary reaches. Water temperature was collected at all annual and rotating panel tributary habitat sites using Onset HOBO® temperature loggers. Additionally, real time temperature data were collected at three sites on the Okanogan River in the United States at Malott, Tonasket, and Oroville by the USGS with funding from the Colville Tribes. Additional USGS sites are located on important tributaries to the Okanogan River. Data have been assimilated into the archives available on the USGS website, which provides access to the public and other agencies. In the British Columbia portion of the subbasin, monitoring on tributaries and the q̓awsitkʷ (Okanagan River) mainstem was also conducted through Water Survey of Canada (Environment Canada 2014). Web links for water temperature and discharge monitoring site data, within the Washington portion of the Okanogan subbasin, are provided in Appendix E. Water temperature data are compiled on the OBMEP server located at the Colville Tribes, Fish and Wildlife office in Omak, WA.

Maximum weekly maximum temperature (MWMT) values were calculated by averaging daily maximum water temperatures for each seven day period from June through September and selecting the highest seven day average value. Maximum weekly average temperature (MWAT) were determined by calculating daily mean temperature values during the summer period and selecting the highest seven day average. Water temperature data collected throughout the Okanogan subbasin were incorporated in the EDT model for long-term analysis. Additionally, in this report, water temperature data were compared with steelhead-specific, biologically relevant temperature ranges. During egg incubation, 15°C has been noted as a temperature in which increased mortality has been noted to occur (Myrick and Cech 2001); therefore we assessed the risk to incubating steelhead when temperatures exceed 15°C. For juvenile rearing, an 18°C threshold was used, below which represents a preferred rearing temperature and above may represent a high risk for disease (Welsh et al. 2001, USEPA 2001b).

Initial studies in 2015 began to characterize difference between surface and hyporheic water temperatures at select major spawning areas in the Okanogan subbasin. During the initial study year, four sites were selected, two on the Okanogan mainstem below Zosel dam, one on the Similkameen mainstem, and one on Omak Creek. Two piezometers were installed at each site, one to monitor surface water temperature and one to monitor hyporheic temperature at egg-pocket depth ~20cm below the river surface. Temperature data were recorded hourly. At each location the difference between readings were compared.

Results

Steelhead Incubation

The water temperature at time of incubation is shown in Figure 53 for Omak Creek, one of the primary spawning areas for steelhead. From 6 years of water temperature data, the average exceedance of 15°C occurred in mid-June. The earliest that temperature was exceeded and remained above was late-May in 2009 and the latest exceedance date was the end of June in 2013. From these results, elevated water temperatures in tributaries to the Okanogan River may not considerably limit incubation survival during many years; however some effects may be occurring to later spawning individuals. In one reach of the mainstem Okanogan River directly downstream of Zosel Dam, approximately 49% of the Okanogan steelhead population spawns annually (OBMEP 2015). As shown in Figure 54, the 10-year average temperature in this reach exceeded 15°C in mid-May. The earliest that the temperature was exceeded was early-May in 2005 and the latest exceedance date was the beginning of June in 2011. Although specific research has not been conducted on egg-to-fry survival for the Okanogan subbasin for steelhead, the temperature range presented by Myrick and Cech (2001) suggest that elevated temperature may be negatively affecting steelhead at the incubation and emergence life stages in this reach.

In 2015, research was conducted in the mainstem Okanogan River, Similkameen River, and Omak Creek to examine the interaction with surface and hyporheic temperatures during incubation and early life stages of summer steelhead. Hourly surface water temperature was typically close to the hyporheic temperature on the Okanogan River below Zosel Dam. At that location, the hyporheic temperature fluctuated daily, similar to the surface water. On the Similkameen River and Omak Creek, there was a 1-5 degree difference between hyporheic and surface water temperatures. Hyporheic water temperature did not exhibit strong daily fluctuations on the Similkameen River or Omak Creek.

The difference between daily average river and hyporheic temperatures was determined by subtracting the river from the hyporheic temperature (Figure 55). From April 15 through June 1st, the average difference between hyporheic and river temperatures on the Okanogan River was -0.1°C and -0.6°C compared to -2.7°C on the Similkameen and -2.3°C on Omak Creek. These initial data suggest that, when compared to surface water temperatures, cooler hyporheic water may buffer negative effects of warm water during the early life stages in the Similkameen River and Omak Creek. However, little cold water refugia may exist in the hyporheic zone in the mainstem river reach below Zosel dam (the reach where ~49% of spawning has been documented in the subbasin).

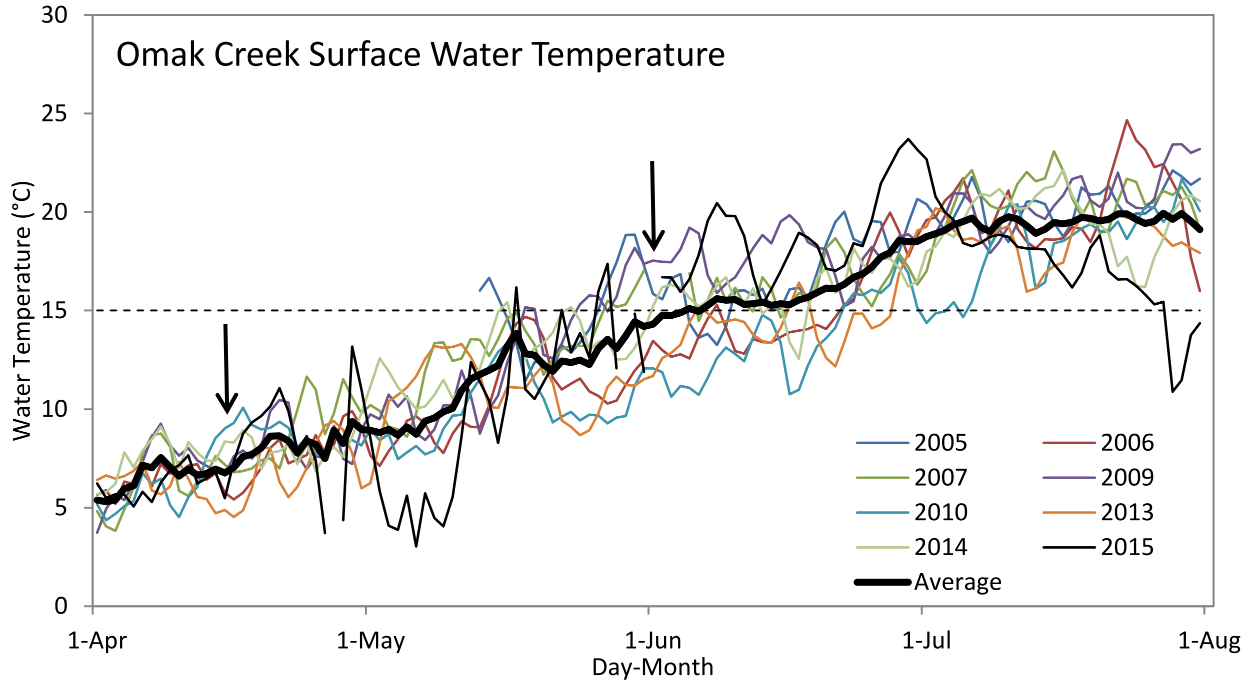


Figure 53. Mean daily water temperature for lower Omak Creek (data from OBMEP habitat site 019). Dashed line represents potential increased mortality for eggs above 15°C. Markers signify the approximate time after peak spawn timing that steelhead eggs or alevin may be in the gravel.

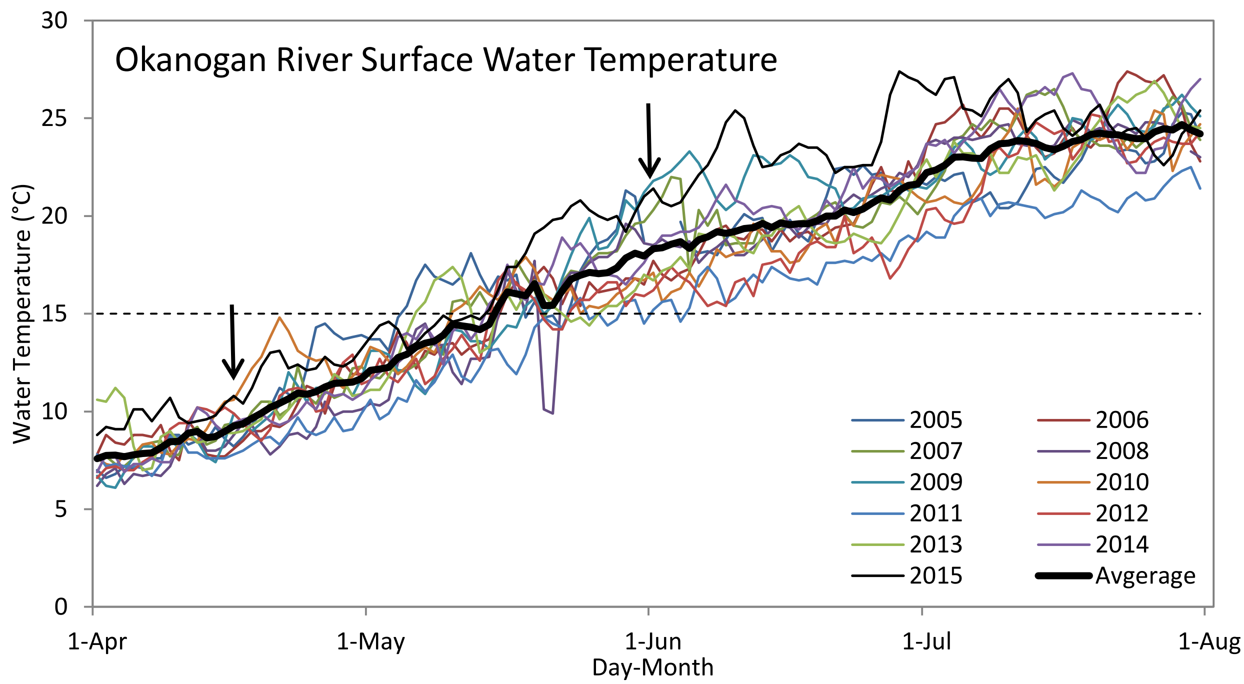


Figure 54. Mean daily water temperature of the Okanogan River below Zosel Dam (USGS Station 12439500, Okanogan River at Oroville, WA). Dashed line represents potential increased mortality for eggs above 15°C. Markers signify the approximate time after peak spawn timing that steelhead eggs or alevin may be in the gravel.

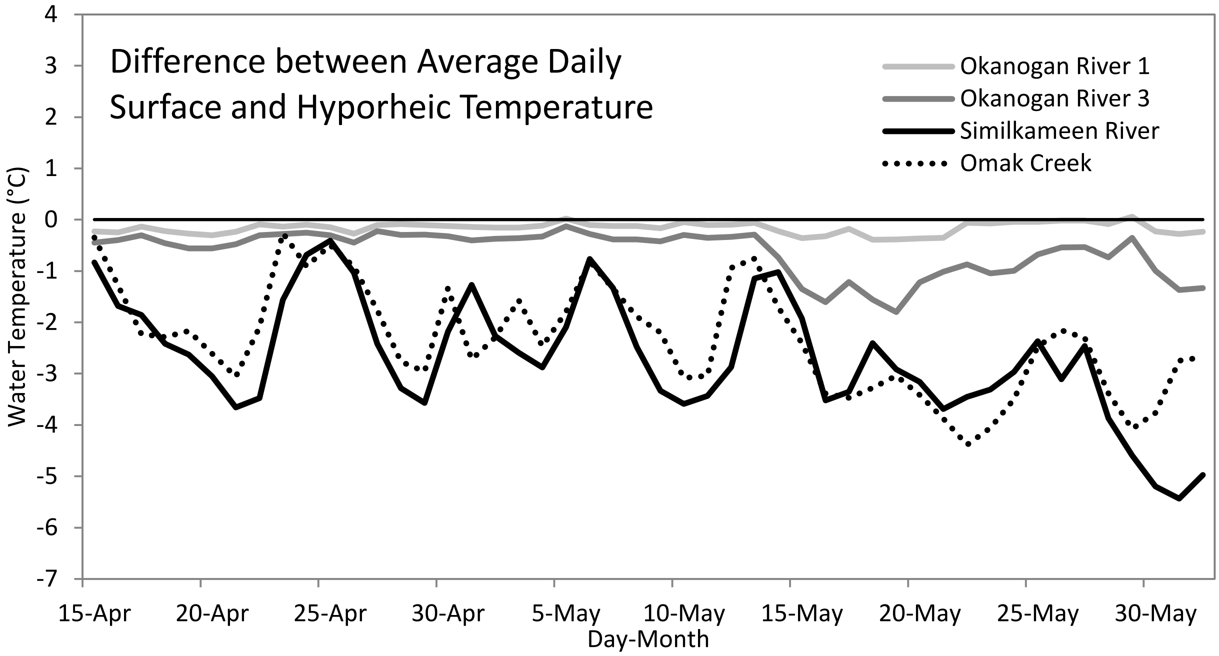


Figure 55. Difference between average daily river and hyporheic water temperatures in three major spawning areas for summer steelhead.

Juvenile Steelhead Rearing

Maximum weekly maximum temperature (MWMT) and maximum weekly average temperature (MWAT) values were calculated for all streams in Washington and British Columbia that had complete data sets for the months of June, July, August, and September. Median MWAT values for the current dataset (2005 - 2015) were above 23°C for the mainstem in Washington State and British Columbia; median MWAT values for most tributaries were between 18 and 23°C (Figure 56). MWMT values were calculated for all streams in the US and Canada that had complete data sets for the months of June, July, August, and September. From 2005 through 2015, the MWMT in the mainstem, most of the tributaries in the US, and all of the tributaries in Canada exceeded the 18°C threshold (Figure 57).

Juvenile steelhead were consistently observed during snorkel surveys in all of the tributaries and very few or none in the mainstem Okanogan River. Although nearly similar daily maximum values were being reached in the tributaries, the minimum daily values were also much lower (Figure 58). Based on long-term monitoring data and known limitations of cold-water salmonid species (reviews by Currie et al. 1998 and Beitinger et al. 2000), water temperature represents a limiting factor for rearing steelhead parr in the Okanogan River.

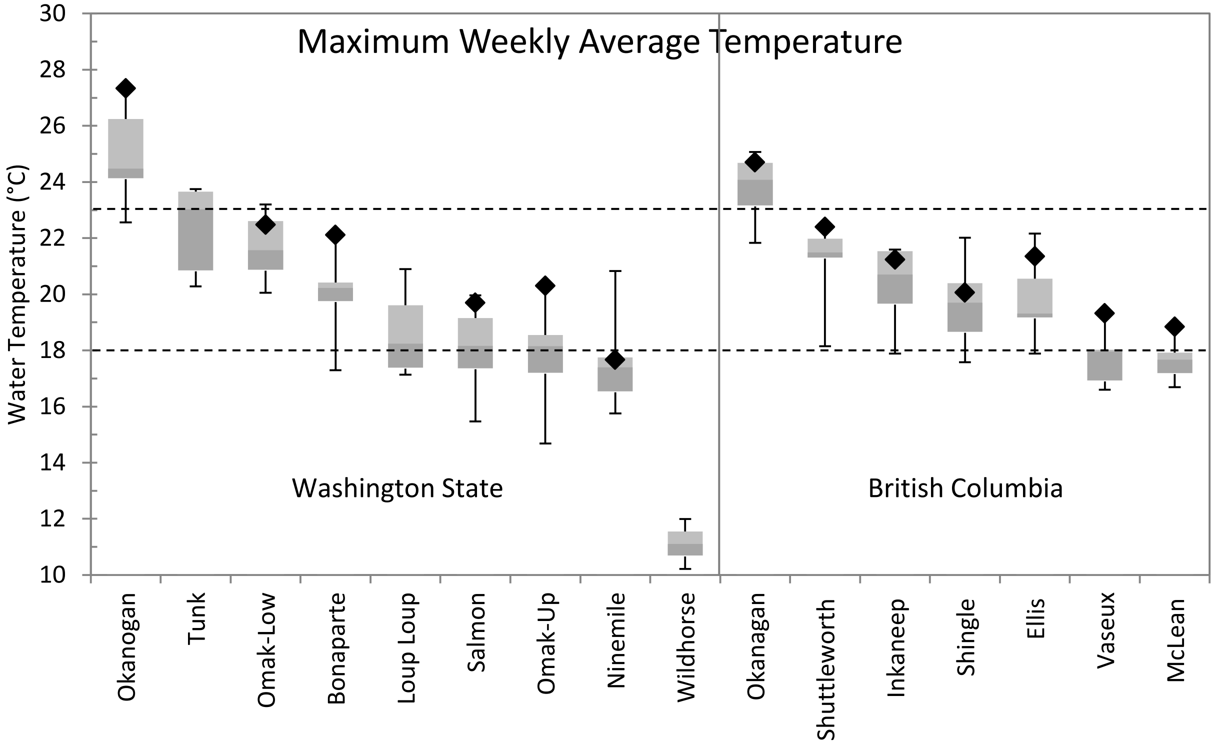


Figure 56. Maximum weekly average water temperatures in the Okanogan subbasin from 2005-2015. Black markers are 2015 data; dashed line represents 18 and 23°C exceedance (EPA 2003).

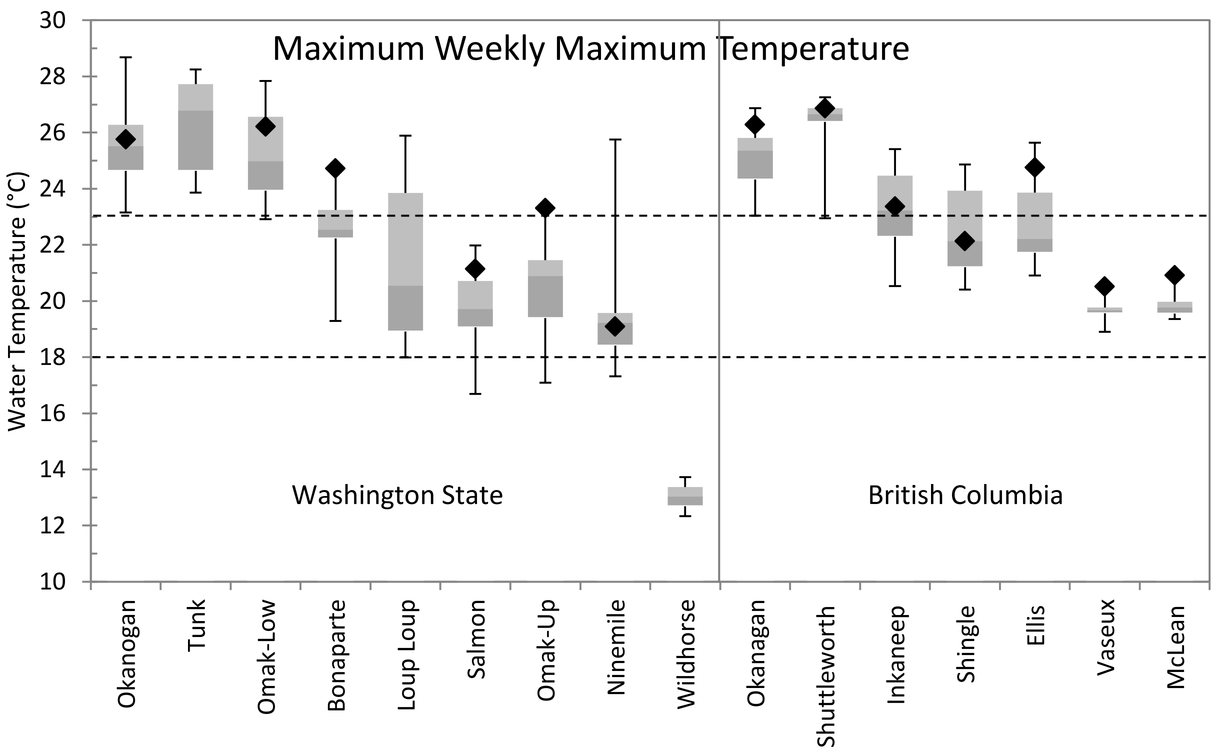


Figure 57. Maximum weekly maximum water temperatures in the Okanogan subbasin from 2005-2015. Black markers are 2015 data; dashed line represents 18 and 23°C exceedance (EPA 2003).

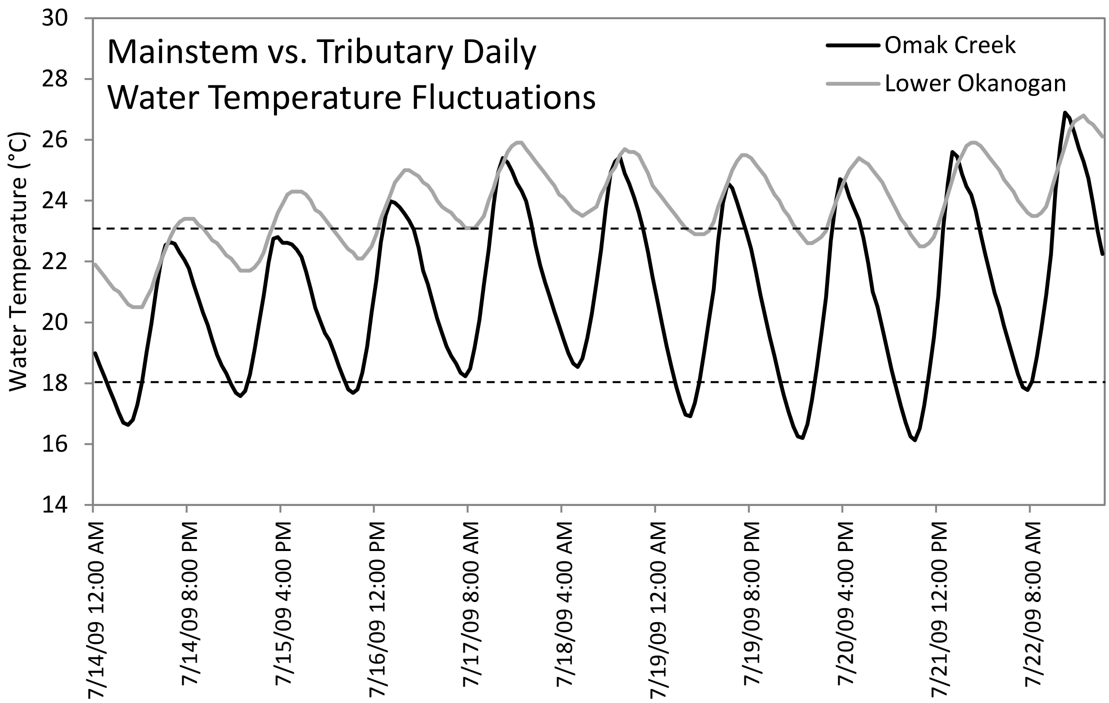


Figure 58. Difference in amplitude of hourly water temperature measurements in the lower Okanogan River and Omak Creek during mid-July.

Over-Winter Juvenile Steelhead Survival

The effects of low water temperature on over-winter survival have not been thoroughly examined specifically to the Okanogan subbasin. However, field studies are currently under way which may provide information to address this subject in future years.

Adult Steelhead Migration (in-subbasin review)

Adult summer steelhead migrate from the ocean upstream through the mainstem Columbia River hydro-system primarily from July through September. After passing over Wells Dam, adults tend to hold in the Wells Pool until summer-water temperatures drop in the Okanogan River. In a literature review, WDOE (2002) suggested that temperatures of 21-24°C may represent migration blockage and steelhead exhibit avoidance behavior. Likely due to elevated temperatures in the Okanogan during the late summer, many adults that pass Wells Dam wait to enter the Okanogan River until the fall. Additionally, a portion of the run also appears to hold in the Wells Pool until March, before entering the subbasin to spawn from March through May. The USEPA (2003) recommends that the 7DADM should not exceed 13°C for spawning. From October through early May, the timeframe when adult steelhead are holding, staging, and spawning, elevated water temperatures do not appear to significantly limit distribution, other than a potential migration blockage in early fall.

Other Salmonid Species

While not comprehensively discussed in this report, elevated water temperatures also have effects on behavior and survival of other species of salmonids in the Okanogan subbasin. A more in depth review can be found in the accompanying citations for returning adult Sockeye (Fryer et al. 2014), juvenile rearing Sockeye in the British Columbia Okanagan lakes (Fryer et al. 2014), and adult Chinook Salmon (CCT, unpublished data). Temperature monitoring sites funded by or data directly collected through OBMEP provide data for these and other ongoing studies in the subbasin.

Conclusions

Water temperature in the Okanogan River and tributaries remains an important variable affecting spatial and temporal distribution, growth rates, abundance, and survival of juvenile salmonids. In bioenergetics models, temperature directly affects metabolic responses by determining what portion of an organism's energy budget is available to either support basal and active metabolism or contribute to somatic growth, reproduction, or high-energy lipid storage (Beauchamp et al. 2007). Although temperature tolerances in laboratory studies depend on initial acclimation temperatures, peer-reviewed literature suggests the preferred temperature of rearing juvenile *O. mykiss* is approximately 18°C, incipient upper lethal temperature (IULT) is approximately 24°C and critical thermal maximum (CTMax) temperature is approximately 28°C (Wagner et al. 1997, Myrick and Cech 2000, Galbreath et al. 2004, and reviews in Currie et al. 1998, Beitinger et al. 2000, and Spina 2007). Results from the Okanogan showed that high summer temperatures in the mainstem, and to a lesser extent in some tributaries, could be adversely affecting salmonids directly, or indirectly causing behavior modifications and altering spatial distribution.

Many laboratory and field studies have quantified the acute and chronic effects of temperature on salmonids (reviews by Currie et al. 1998 and Beitinger et al. 2000). When temperatures exceed salmonids' biological tolerance, acute effects such as migration blockages, avoidance behavior, or death may occur. The EPA uses the maximum weekly maximum temperature (MWMT, the highest 7-day average of maximum daily temperature in a given year) to protect against acute effects because MWMT is not overly influenced by a single daily maximum, but it still describes maximum temperatures in a stream over a week-long period (USEPA 2003). Salmonids may tolerate temperatures higher than their optimal range, but sublethal effects may occur such as impacts to growth, increased incidence of disease, increased risk of predation, and potential delay of smoltification.

Although high maximum temperature values were being reached in the tributaries, the minimum daily values were much lower, and it is possible that these drops back to cooler temperatures may be buffering fish from further effects. According to Bjornn and Reiser (1991), the effects of acutely or chronically lethal and sub-lethal temperatures depend on acclimation temperature, duration of temperature increase, daily fluctuations, and ecological adaptations. When daily maximum temperatures approach lethal values in small streams but only for short durations, salmonids can still thrive if temperatures decline back to optimal ranges (Bjornn and Reiser 1991). Salmonids can also respond to high temperatures by moving upstream or downstream (Mabbott 1982), or seeking cold water refugia (reviews in USEPA 2001a). Daily behavioral movements and use of thermal refugia are not well understood and have not been specifically studied in the Okanogan subbasin to date.

As shown in the 10-year snorkel survey datasets (Appendix G), juvenile salmonids are consistently observed in greater numbers in small tributaries than in the mainstem Okanogan River, where they are infrequently observed. Thermal tolerances for juvenile salmonids suggest there should be few or no juvenile salmonids in the mainstem during high summer temperatures. However, concern exists over this apparent absence because approximately 50% of steelhead spawning occurs in the mainstem on a given year (OBMEP 2015). It is unknown if high summer water temperatures cause direct mortality to juveniles, alteration in behavior to avoid high temperatures, or if both are occurring, and to what degree. Juveniles may seek refuge in interstitial spaces between the gravels and snorkeling may not be as efficient for observing juveniles in the mainstem. Monitoring temperature in the mainstem Okanogan River and its tributaries will continue to play an important role in understanding life histories of steelhead in the Okanogan subbasin.

Appendix E. Water Quantity/Discharge

Introduction

The quantity of water available in streams plays a fundamental role in regulating the abundance and distribution of salmonid species, particularly in semi-arid regions of the Columbia Basin. The effects of extremely low discharge rates can be profound in the summer low flow period, which can contribute to increased competition for food resources, rearing space, and can contribute to elevated water temperatures. The Okanogan subbasin consists of two large mainstem rivers, the Okanogan and Similkameen, which combined have a substantial catchment area, roughly 21,000 km^2, more than twice the size of the Methow, Entiat, and Wenatchee subbasins combined (NPCC 2004, Morrison and Smith 2007). In the areas accessible to anadromous salmonids, additional habitat is found in relatively small tributaries, which in general, have a flashy runoff period, followed by very low base flow periods throughout the rest of the year. Many small tributaries flow subsurface in the lower reaches in mid-summer, which may result in disconnection of streams from the mainstem river. Primary causes may be attributed to the semi-arid climate of the Okanogan subbasin, minimal catchment area for some small watersheds, and water diversion/withdrawals for irrigation usage.

Methods

OBMEP - Water Quality Sampling (ID:5)
https://www.monitoringmethods.org/Protocol/Details/5
OBMEP - Habitat Monitoring (ID:9)
https://www.monitoringmethods.org/Protocol/Details/9

Discharge data were collected on the mainstem by the USGS and Canadian governmental organizations. Many of these monitoring sites were operated with funding from OBMEP, through the Fish and Wildlife Program. Tributary discharge monitoring in the U.S. was done cooperatively with the USGS and OBMEP employees and tributary discharge data were collected on Canadian tributaries through OBMEP. Discharge data collection included field work (measuring the velocity and volume of water passing a spot at a given time), automated data loggers (electronics located at the stream gage site that upload to the internet), and data analysis (creating stream discharge rating curves and quality control). Stage height data and discharge curves were incorporated into the EDT model to estimate suitability, carrying capacity, and fish abundance in the Okanogan subbasin.

Results

Discharge in the Canadian Okanagan mainstem is influenced by the Okanagan Basin Lake Regulation System, a series of dams located on the river. Discharge in the U.S. Okanogan mainstem are highly influenced by the Similkameen River, an unregulated, snowmelt-fed river, which contributes approximately three quarters of the flow to the US portion of the Okanogan River, and explains the different discharge trends in the US Okanogan mainstem (Figure 59) compared to the Canadian Okanagan mainstem (Figure 60). A low snowpack from the winter of 2014/2015 combined with above-normal temperatures and below-normal precipitation throughout 2015 resulted in low stream flow conditions in the Okanogan subbasin. The USGS has continuously operated the Okanogan mainstem stream gage at Tonasket for the last 86 years. The mean monthly discharge at this gage in July 2015 was only 26% of the July monthly mean for the full period of record.

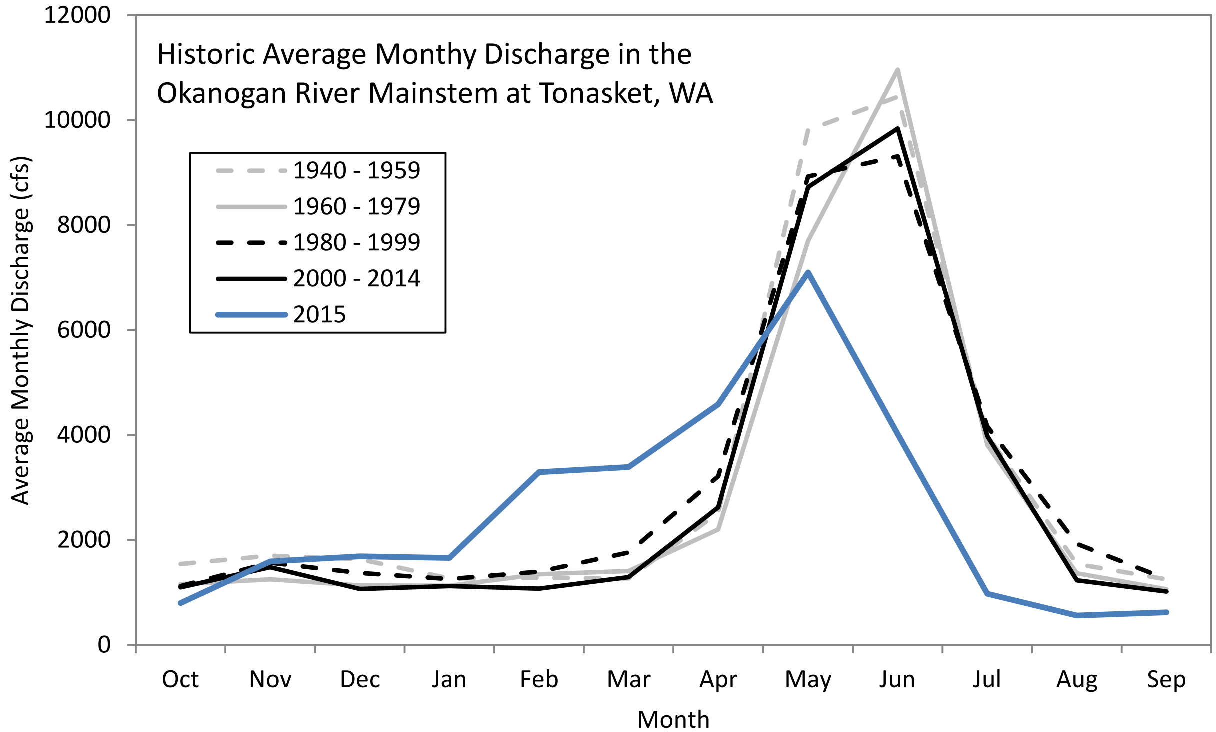


Figure 59. Average monthly discharge of the Okanogan River at Tonasket, WA (USGS Station 12445000, Okanogan River near Tonasket, WA).

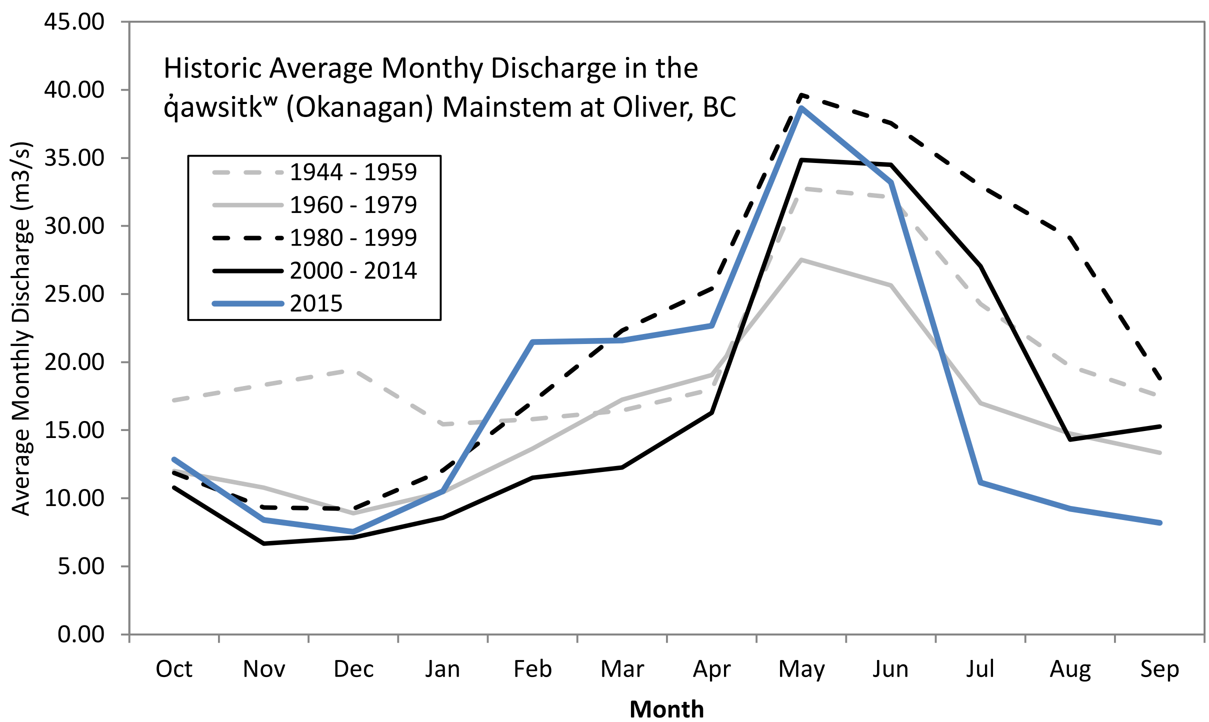


Figure 60. Historic mean monthly discharge recorded at Water Survey Canada station 08NM085 near sx̌ʷəx̌ʷnitkʷ (Okanagan Falls) from 1944 to 2015 (Environment Canada 2013).

Tributaries have seasonally flashy hydrographs, showing large spikes during freshet followed quickly by a drop back down to base flows. Tributary discharge in 2015 was characterized by an early February runoff period, returning to base flow by the end of June. The lower reaches of the majority of tributaries dried up completely during the 2015 base flow period. The mean monthly discharge at the Omak Creek stream gage in August 2015 was only 53% of the August monthly mean for a 10 year period of record.

Weblinks for temperature and discharge monitoring sites within the US Okanogan subbasin include:

- Okanogan River at Malott: http://waterdata.usgs.gov/nwis/uv?site_no=12447200
- Okanogan River near Tonasket: http://waterdata.usgs.gov/nwis/uv?site_no=12445000
- Okanogan River at Oroville: http://waterdata.usgs.gov/nwis/uv?site_no=12439500
- Ninemile Creek: http://waterdata.usgs.gov/wa/nwis/uv/?site_no=12438900
- Similkameen River near Nighthawk: http://waterdata.usgs.gov/wa/nwis/uv?site_no=12442500
- Antoine Creek near Ellisforde: http://waterdata.usgs.gov/nwis/uv/?site_no=12444290
- Johnson Creek near Riverside: http://waterdata.usgs.gov/nwis/uv/?site_no=12445500
- Omak Creek near Omak: http://waterdata.usgs.gov/nwis/uv/?site_no=12445900
- Salmon Creek above diversion near Okanogan: http://waterdata.usgs.gov/nwis/uv?site_no=12446995
- Loup Loup Creek at Malott: http://waterdata.usgs.gov/nwis/uv?site_no=12447285
- Bonaparte Creek at Tonasket: http://waterdata.usgs.gov/nwis/uv/?site_no=12444500

Conclusions

The quantity of water available in the semi-arid Okanogan River system plays a fundamental role in regulating the abundance and distribution of salmonid species, particularly in small tributaries. Effects of extremely low discharge rates are compounded by warm water temperatures during the summer base flow period, which contribute to increased competition for food resources and rearing space. Results of stream flow are further discussed in the EDT reports, where specific instances that water quantity may be limiting by life stage are clearly defined.

Although additional analyses have not specifically quantified effects outside of the EDT model, quantity of water in tributaries to the Okanogan River has been observed to have effects on various life stages of steelhead. For adult steelhead migrating into tributaries to spawn in the spring, low discharge rates have been noted to restrict access until discharge rates rise (OBMEP 2015). This is particularly evident in streams with large, wide alluvial fans at the confluence with the Okanogan River, most notably Antoine and Bonaparte creeks. Once spring flows increase water depth in the creek, or the mainstem Okanogan River rises to a level to submerge the broad alluvial fans, adult steelhead can enter those systems. For the juvenile life stage, discharge rates at the base flow period in tributaries have an inverse correlation with juvenile parr densities. For example, Bonaparte Creek has one of the highest densities of steelhead parr on an annual basis (refer to snorkel surveys, Appendix C), regularly 2-6 times the densities observed in lower Omak Creek. However, much of this cause may be influenced by very narrow wetted widths, rather than exceptional productivity of the system. Although much progress has been made over the past 10 years, habitat projects focusing on quantity of water in streams will continue to be an important focus, particularly during the summer base flow period and maintaining connectivity of tributaries with the mainstem Okanogan River. Projects should focus on tributaries that have a sufficient biological capacity to support juvenile rearing, including Loup Loup, Salmon, Omak, and Antoine Creeks in Washington State.