

Okanogan Basin Monitoring and Evaluation Program

2014 Annual Report

BPA Project # 2003-022-00

Report covers work performed under BPA contract #(s) 55926, BPA-6604

Report was completed under BPA contract #(s) 55926, BPA-6604

3/1/2013 - 2/28/2015

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February 2015

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

This report should be cited as follows:

OBMEP. 2015. Okanogan Basin Monitoring and Evaluation Program, 2014 Annual Report. Colville Confederated Tribes Fish and Wildlife Department, Nespelem, WA. Report submitted to the Bonneville Power Administration, Project No. 2003-022-00.

Executive Summary

The furthest upstream and northern-most extent of currently accessible anadromous salmonid habitat within the Upper Columbia River Basin is found in the Okanogan River. With the listing of several salmonid species within the Columbia River Basin as threatened or endangered under the Endangered Species Act (ESA), federal, state, tribal, and other entities have made considerable investments in salmon population monitoring and habitat restoration. Tracking status of salmon populations as they relate to habitat capacity and limiting factors is an important part of determining if conditions are improving. The Okanogan Basin Monitoring and Evaluation Program (OBMEP) conducted status and trend monitoring from 2004 through 2014 corresponding to abundance, productivity, and spatial/temporal distribution in the Okanogan subbasin. Monitoring efforts were primarily focused on Upper Columbia River summer steelhead (*Oncorhynchus mykiss*), which are listed as threatened (NMFS 2009). Additional monitoring tasks included 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 populations and respective habitats are improving. Future monitoring will continue to support trend analyses, while some modifications of protocols may be needed to evaluate identified uncertainties.

The overall outcome of monitoring strategies is to guide natural resource managers' decisions to minimize threats to salmon, choose restoration actions that will have the most positive impact, and set measurable salmon enhancement objectives to coincide with fiscal investments over multiple jurisdictions. Salmon 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 subbasin 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 analysis.

Adult Steelhead Monitoring, Key Findings and Recommendations:

- The 10-year mean (2005-2014) for total summer steelhead (hatchery plus natural origin) in the Okanogan subbasin was estimated at 1,818 and ranged from 899 to 3,496. The 10-year mean for natural origin summer steelhead was estimated at 309 and ranged from 146 to 728. The NOAA recovery goal of 1,000 natural origin spawners for the subbasin was not reached over the past 10 years (Figure ES1).

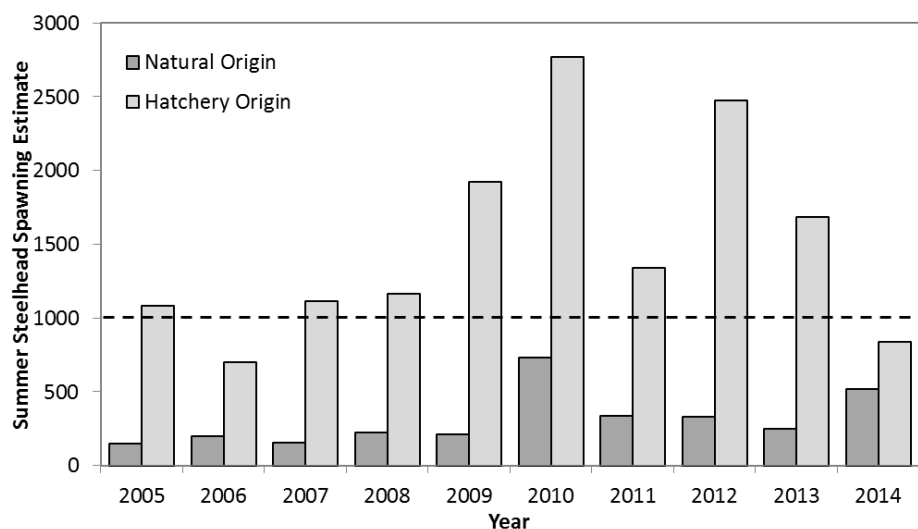


Figure ES1. Spawning estimates for hatchery and natural origin summer steelhead in the Okanogan subbasin, compared with NOAA natural origin recovery goals (dashed line).

- The 10-year average proportion of natural origin spawners (pNOS) was lower for the mainstem Okanogan River (0.10) compared with tributaries (0.23) in the Washington State portion of the subbasin. Summer steelhead spawning occurred throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities. The proportion of steelhead spawning in tributaries appeared to be regulated in part by stream discharge, which in turn is influenced by spring time precipitation in small creeks, timing of runoff in relation to run 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 10 years. Determining total abundance of spawners was also difficult, but improved with the installation of a PIT tag antenna array (OKC) above suwiws (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 2% for the past two years, however, average pNOS was much higher in British Columbia (0.75) than Washington State (0.24) during that timeframe. Continuing to expand the number of PIT tag interrogation sites in British Columbia will help increase knowledge concerning abundance and spatial and temporal distribution of summer steelhead in the subbasin.
- Steelhead redd surveys can document spawning distribution, timing, and an estimate of escapement in years when spring runoff occurs post-spawning. Defining the physical location of redds helps 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 is also important when considering locations for restoring and protecting habitat. Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on steelhead redd surveys for abundance 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), 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 Steelhead Monitoring, Key Findings and Recommendations:

- Outmigration (fish-out) monitoring of steelhead in the Okanogan subbasin was challenging in the early years of the project. New procedures were fully implemented in 2014 when OBMEP began conducting a U.S. tributary juvenile monitoring study to estimate abundance and outmigration of naturally produced juvenile steelhead. These studies assessed utilization of tributaries to the Washington State portion of the Okanogan River by juvenile steelhead with the use of electrofishing, mark-recapture events, remote PIT tagging, and in-stream PIT tag interrogations. These methods allowed the program to more accurately monitor annual abundance of juvenile steelhead in the Okanogan subbasin, estimate precision and bias associated with methods, and to determine trend in juvenile abundance, productivity, spatial/temporal distribution, and diversity through time. Results suggested great improvements for monitoring and understanding juvenile metrics and can aid fisheries managers in concentrating recovery efforts in drainages that have the biological capacity to support sufficient populations of juvenile steelhead.

- In all tributary stream reaches available to anadromous fish in the Washington State portion of the subbasin, three streams contained 90.7% of the juvenile *O. mykiss* (Loup, Loup Creek, Salmon Creek, and lower Omak Creek, Figure ES2). The trend in total observed densities of juvenile *O. mykiss* at annual snorkel monitoring sites increased in these three streams from 2004-2014, but remained near or at zero for nearly all mainstem Okanogan River survey sites during the summer base-flow period.

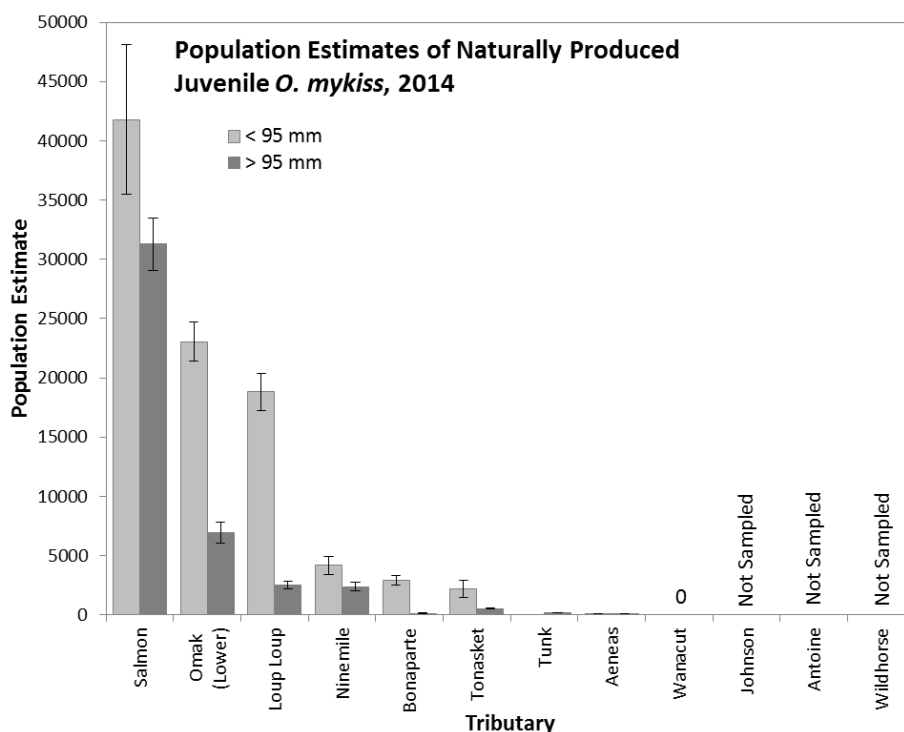


Figure ES2. Estimated population ($\pm 95\%$ CI) of natural produced juvenile *O. mykiss* in tributaries to the Okanogan River. Data are presented by *O. mykiss* fry (< 95mm) and juvenile+ (> 95mm).

- Research is needed to assess egg-to-fry/parr survival in mainstem habitats. Although a relatively large proportion of adult steelhead spawn in the mainstem reaches of the Okanogan subbasin in Washington State (10-year average of 63%), abundance of juvenile salmonids remained very low in those habitats. It is currently unknown if relatively few juvenile steelhead emerge from the gravel, or if they emerge but survival is adversely affected by high river temperatures. If they do survive to the fry/parr stage, other unknown life history pathways include migrating from the mainstem Okanogan into tributary habitats, utilize thermal refugia along the mainstem Okanogan, or migrate to the Columbia River. Preliminary small scale investigations are mapping patterns in temperature and dissolved oxygen in hyporheic water in select spawning areas, where eggs would be developing. Characterization of water conditions should be expanded, but remain focused on known areas used for spawning by summer steelhead.
- Predation was indicated as an important limiting factor in the EDT model results for the mainstem Okanogan River. There is no empirical data on predation in the Okanogan, so EDT modeling results are based on assumptions regarding the risk of predation due to overlap between predators and juvenile salmonids in time and space. Data should be collected to begin to understand the predator-prey relationships and the extent of the effects of predators on anadromous salmonids in the Okanogan subbasin.

Habitat Status and Trend Monitoring, Key Findings and Recommendations:

- In 2013, the integrated OBMEP/Ecosystem Diagnosis and Treatment (EDT) habitat status and trend report was completed for both summer steelhead and summer/fall Chinook for data collected through 2009. Results indicated that habitat conditions in the Washington State portion of the subbasin had capacity to support a viable population of summer steelhead (> 500) in the U.S. portion of the Okanogan. In 2015, a new EDT report using habitat data collected through 2013 will be completed.

- Specific habitat limitations identified and detailed by stream reach in EDT model results included: water temperature, water quantity, water management, fine sediments, and fish passage impediments, among others. Further research is needed to relate how surface water temperature data compares to actual temperature experienced by juvenile steelhead (e.g. diurnal movements and use of cold water refugia) and to properly identify when and where summer temperature may be limiting. Refinements in fine sediment data collection may be needed to more accurately quantify effects, as current methods use an average value to expand site data to a reach level, which likely resulted in fine sediment ratings greater than what was likely present in distinct spawning areas. To improve the quality of fine sediment data and directly link it to spawning habitat quality, refinements in methodology should be considered in future years.
- Over the past 10 years, the total number of stream kilometers available to anadromous fish in the Okanogan subbasin has increased considerably, primarily due to modification or removal of impediments and improvements in water management.
 - Examples where substantial improvements have occurred in the Washington State portion of the subbasin include: (1) Omak Creek, where habitat projects provided adult access above an impediment, first observed in the spring of 2014, and represents an approximate 81% increase in stream length for summer steelhead habitat in that sub-watershed. (2) In Salmon Creek, water negotiations between the CCT and the OID resulted in improved connection during the adult spawning and juvenile emigration season, and increases in the number of total and naturally produced adult steelhead have been observed. (3) In the Antoine Creek watershed, projects implemented in 2013 increased anadromous habitat from approximately 1.5 to 18 km. (4) In Loup Loup Creek, barriers and irrigation withdrawals were altered to restore perennial flows and access in 2012, resulting in dramatic increases in the abundance of juvenile rearing steelhead parr (Figure ES3).
 - In the British Columbia portion of the Okanogan subbasin, barrier removal actions have drastically increased the amount of habitat available to steelhead. These actions include: (1) re-design of McIntyre Dam (2009) – increased access to *np'əxłpiw'* (Vaseux Lake), approximately 7 km of mainstem habitat and one major tributary; (2) fish ladder at Skaha Dam (2014) – increased access to *qawstik'w't* (Skaha Lake), an additional 6 km of mainstem habitat (current upstream barrier is outlet dam of *kłusxnitk'w* (Okanagan Lake) and three major tributaries; and (3) removal of *akt'w'mina?* (Shingle Creek) dam (2014) – access to 35 km of tributary habitat.

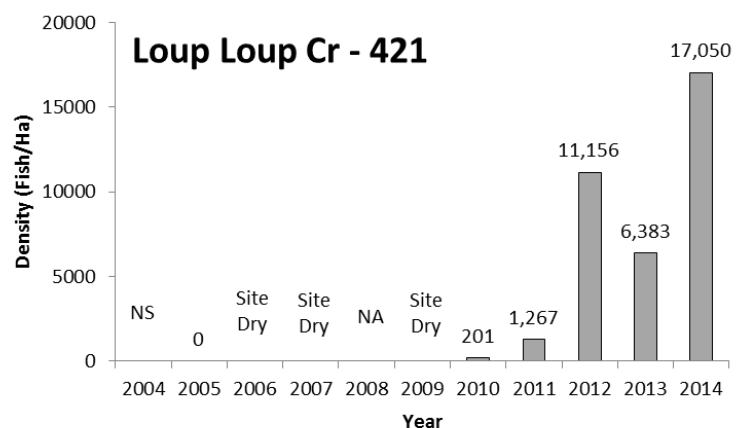


Figure ES3. Observed snorkel densities of juvenile *O. mykiss* (fish/ha) in Loup Loup Creek.

Coordination and Data Management

In 2014, OBMEP participated in the Coordinated Assessments project and was able to share the indicator of natural origin spawner abundance (NOSA) with Streamnet. OBMEP also sub-contracted with Sitka Technology, to continue assisting with tasks related to the Coordinated Assessment process and share relevant indicators while developing electronic methods for data collection, review, transfer, and storage. OBMEP continued to submit data types such as stream discharge, water temperature, fish passage, adult abundance, and snorkel

surveys to approved data repositories such as the United States Geological Survey (USGS) surface water discharge program, the NorWeST project, Data Access in Real Time (DART), Passive Integrated Transponder (PIT) Tag Information System (PTAGIS), and Streamnet. Finally, dissemination of some data types (GIS layers, EDT reaches, steelhead redd GPS coordinates, and water temperature at PIT tag arrays) occurred through the program website: http://www.colvilletribes.com/obmep_project_data.php. Managers should continue to support the development of whole data systems which include study design development, data collection, QA/QC of the data, storage of raw data, and automating standard calculations.

Acknowledgements

The Colville Confederated Tribes would like to acknowledge Edward Berrigan, Oly Zacherle, Vertis Campbell, Byron Sam, Mike Miller, Jack Roy, Oliver Pakootas, Wes Tibbits, Brooklyn Hudson, Rhonda Dasher, and Dennis Papa for their help in collecting, entering, and compiling field data for this report. Thanks also to Summit Environmental, ICF International, Washington State Department of Ecology, Washington Department of Fish and Wildlife, and the USGS for their collaboration on projects and data collection efforts. Thanks to Richard Townsend and John Skalski from the University of Washington Columbia Basin Research for reviewing, providing comments, and assisting in the development of juvenile abundance monitoring statistics. This work would not be possible without the cooperation of the many private landowners who have provided land access and enabled us to collect data within the Okanogan subbasin.

The Okanogan Nation Alliance Fisheries Department would like to acknowledge the Penticton Indian Band (PIB), the Osoyoos Indian Band (OIB), the townships of Oliver, Okanogan Falls and Penticton, the Lezard family, the Baptiste family (of OIB), Tony Thompson, The Nature Trust of BC and the South Okanogan Rehabilitation Center for Owls for access granted to sites of this ongoing study. Acknowledgements also go to Jamison Squakin, Cash Tonasket, Julie Brewer, Zoe Masters, Sheena Hooley, Jake Guerin, Skyeler Folks, Andrew Clark, Tammy Peterson, Colette Louie, Kari Alex, Camille Rivard-Sirois, Floyd Baptiste, Natasha Neumann, Hannah Sungaila and Saul Squakin for providing valuable technical assistance throughout the 2014 study.

Funding for the Okanogan Basin Monitoring and Evaluation Program was provided by Bonneville Power Administration.

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List of Okanogan Place Names

Columbia River	nǰʷəntkʷitkʷ
Ellis Creek	snpiŋyaʔtkʷ
Inkaneep Creek	akskʷəkʷant
Okanagan Falls	sǰʷəǰʷnitkʷ
Okanagan Lake	kłusxnitkʷ or kłusxənitkʷ
Okanagan River	ǰawsitkʷ
Osoyoos Lake	suwiw̓s
Penticton	snpintktn
Shingle Creek	akłxʷminaʔ
Skaha Lake	ǰawstikʷt
Vaseux Creek	snǰaǰəlqaxʷiyaʔ
Vaseux Lake	nǰəxłpiw̓
Similkameen River	nməlqitkʷ

1.0 Introduction

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) conducted status and trend monitoring from 2004 through 2014 to collect and analyze fish data corresponding to adult and juvenile abundance, as well as, spatial and temporal distribution throughout the Okanogan¹ subbasin. Much of these efforts were specifically focused on Upper Columbia River summer steelhead (*Oncorhynchus mykiss*), which are listed as threatened under the Endangered Species Act (NMFS 2009). Additional monitoring efforts included 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 populations and respective habitats are improving. Due to the trans-international boundary intersecting the Okanogan subbasin, the CCT began collaborating with the Okanogan Nation Alliance (ONA) Fisheries Department 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.

1.1 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 its confluence with the Columbia River (Figure 1). The total drainage area of the Okanogan subbasin is roughly 21,000 km², 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 lowlands. Often bordered by steep granite walls, water passes 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 (*Oncorhynchus mykiss*) which are ESA listed as threatened (NMFS 2009), and rare 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, which may cause adjustments in juvenile rearing location and adult migration during that timeframe. A number of small, cold water tributaries to the Okanogan offer additional habitat for steelhead, but access is often restricted by insufficient discharge and the total extent is often limited by natural 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

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

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

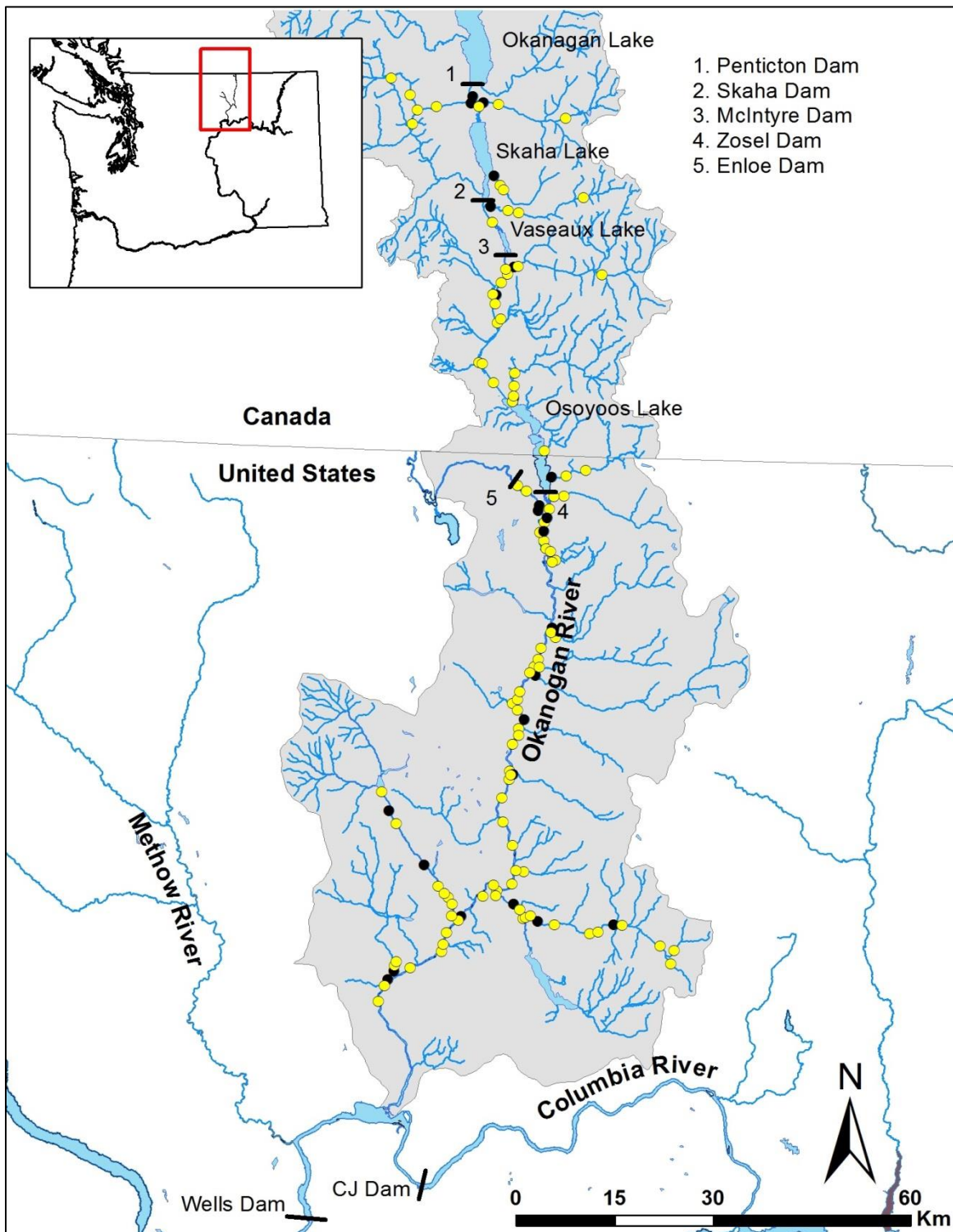


Figure 1. Study area, the Okanogan subbasin in north-central Washington State and southern British Columbia. Markers signify OBMEP habitat monitoring sites; black signifies annual panel sites sampled every year, and yellow signifies rotating panel sites sampled every four years.

In the Canadian portion of the Okanogan subbasin, man-made barriers are major constraints to current salmonid migrations. Dams exist at the outlets of Canadian Okanogan mainstem lakes including, suwiws (Osoyoos Lake), np'əxłpiw' (Vaseux Lake), qawstik'w't (Skaha Lake), and kłusxnitk'w (Okanagan Lake). In 2009, the outlet dam at np'əxłpiw' (Vaseux Lake), known as McIntyre Dam, was refitted to no longer obstruct fish migration outright. Currently, the kłusxnitk'w (Okanagan Lake) outlet dam at snpintktn (Penticton) is the upstream barrier for all anadromous salmon species and the qawstik'w't (Skaha Lake) outlet underwent improvements for fish passage in 2014. It is known that anadromous salmonids have previously occupied the entire qawsitk'w (Okanagan River) system (Ernst and Vedan 2000).

1.2 Goals and Objectives

OBMEP conducted status and trend monitoring in the Okanogan River subbasin to evaluate Upper Columbia River summer steelhead population in order to support the following Bonneville Power Administration (BPA) Fish and Wildlife management sub-strategies²:

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 to help support the following BPA Fish and Wildlife sub-strategy³:

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 the ecosystem including biological, physical habitat, and water quality parameters. Protocols were developed to assess 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>

2.0 Fish Population Status and Trend Monitoring

To assess presence or absence of meaningful change in biological factors at the population scale for summer steelhead, the Okanogan Basin Monitoring and Evaluation Program conducted surveys or sampling on the following status and trend metrics:

1. Adult Steelhead Monitoring
 - a. Assess the abundance, spatial distribution, and timing of adult return-migration and spawning.
 - b. Assess the abundance and proportion of natural origin to hatchery origin returning adults.
2. Juvenile Steelhead Monitoring
 - a. Assess the abundance, spatial distribution, and productivity of juveniles during rearing life-stages.
 - b. Assess the abundance and timing of juvenile out-migration.

2.1 Adult Steelhead Monitoring

2.1.1 Introduction

Within the Upper Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. Summer steelhead are listed as threatened in the Upper Columbia River ESU under the Endangered Species Act (ESA) (NMFS 2009). Recovering this ESU requires that all four populations (Wenatchee, Methow, Entitat, and Okanogan) meet minimum adult abundance thresholds, have positive population growth rates, and each population must be widely distributed within respective subbasins (UCSRB 2007). Within the Okanogan River subbasin, the Okanogan Basin Monitoring and Evaluation Program has monitored adult abundance attributes from 2005 through 2014.

In the Canadian portion of the Okanogan subbasin, previous studies have shown that, historically, steelhead were found throughout the Okanogan subbasin (Ernst and Vedan 2000). Prior to 2009, McIntyre Dam at the outlet of n̓əx̓lpiw̓ (Vaseux Lake) was the upstream barrier for returning anadromous salmonids. During this time, akskʷəkʷant (Inkaneep Creek) and sn̓ʔax̓əlqaxʷiyaʔ (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 klusxnitkʷ (Okanagan Lake) outlet dam at sn̓pintktn (Penticton). This allows steelhead access to at least four more major tributaries for spawning and rearing including Shuttleworth Creek, McLean Creek, sn̓piŋyaʔtkʷ (Ellis Creek) and ak̓xʷminaʔ (Shingle Creek). In 2012-2014, the only enumeration method used was a Passive Integrated Transponder (PIT) antenna array in the ɔ̓awsitkʷ (Okanagan River) mainstem just upstream of suwiw̓s (Osoyoos Lake) at Vertical Drop Structure (VDS) 3.

2.1.2 Methods

OBMEP - Adult Abundance - Redd Surveys (ID:192)

<https://www.monitoringmethods.org/Protocol/Details/192>

OBMEP - Adult Abundance - Adult Weir and Video Array (ID:6)

<https://www.monitoringmethods.org/Protocol/Details/6>

Estimate the abundance and origin of Upper Columbia steelhead (2010-034-00) v1.0 (ID:235)

<https://www.monitoringmethods.org/Protocol/Details/235>

Metrics and Indicators for adult summer steelhead monitoring are listed in Appendix B.

OBMEP developed redd survey protocols in 2004, derived from the Upper Columbia Monitoring Strategy (Hillman 2004), that called for a complete census of all steelhead spawning. Preliminary methods for implementing redd surveys were implemented in 2005 and these methods were later revised in 2007. From 2010 through 2014, OBMEP employed multiple methods to determine a total spawning estimate for the subbasin. Each method has been described in detail in the [monitoringmethods.org](https://www.monitoringmethods.org) links listed above. Counts of steelhead spawning downstream of anadromous fish migration barriers (Arterburn et al. 2007, Walsh and Long 2006) were attempted in the mainstem and all accessible tributaries of the Okanogan and Similkameen River drainages within the United States. Adult weir traps, PIT tag arrays, and underwater video enumeration were used to improve escapement estimates at locations where spawning habitat was extensive, environmental conditions were unfavorable for redd surveys to occur, and to coordinate with other ongoing data collection efforts. Enumeration of steelhead in the British Columbia portion of the subbasin relied solely on expanded PIT tag detections.

2.1.3 Results

In 2014, a total of 1,356 summer steelhead (838 hatchery and 518 natural origin) were estimated to have spawned in the Okanogan subbasin, including the Canadian portion. A summary of the estimated number of adult steelhead spawners in 2014, distributed by mainstem reach and individual tributaries, are presented in Table 1. From 2005 through 2014, the mean total number of steelhead spawners (hatchery and natural origin) in the Okanogan subbasin was 1,818 and the 10 year mean number of natural origin spawning steelhead was 309 (Table 2). The slope of the trend line from 2005 to 2014 suggests that the number of natural origin spawners increased at an average rate of 33 fish per year (Figure 2). The trend in hatchery origin spawners increased from 2005-2010, but declined from 2012-2014.

In 2010, 2011, and 2012, water availability in the Okanogan subbasin was above normal and subsequently, a larger proportion of steelhead spawned in tributaries to the Okanogan River than documented in previous years (Figure 3). Years such as 2006, 2008, and 2009 show how low tributary discharge can dramatically alter spawning location and reduce the available tributary habitat for steelhead to utilize (Figure 3). Spawning occurred throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities and has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River (Figure 4). Annual collection of adult summer steelhead data provided a comprehensive depiction of spawning distribution and minimum escapement within the Okanogan River subbasin. More details concerning escapement estimates can be found in the 2014 Okanogan Basin Steelhead Escapement and Spawning Distribution report (OBMEP 2015).

For the Canadian portion of the Okanogan subbasin, PIT tag detections on the q'awsitk^w (Okanogan River) at VDS 3 (Okanogan Channel - OKC) upriver of suwiw's (Osoyoos Lake) are listed in Appendix D from 2010 to 2014. In all years listed, a higher proportion of natural origin steelhead detected at Zosel Dam continued up the q'awsitk^w (Okanogan River) upriver of suwiw's (Osoyoos Lake) than hatchery steelhead. However, these proportions were based on extremely small sample sizes. In 2014, a temporary PIT array was installed in Shuttleworth Creek during the spawning season; however, no tag detections were observed. There were no data for 2011 to 2013 for the number of steelhead spawners entering Canadian tributaries.

Table 1. Estimated number of steelhead spawners in the Okanogan subbasin in 2014, by sub-watershed.

Category	Description/Reach	Estimated Total # Spawners	Estimated # Natural Origin
WA Mainstem	Okanogan River	302	50
	Similkameen River	123	21
WA Tributary	Loup Loup Creek	35	27
	Salmon Creek	163	51
	Omak Creek	393	207
	Wanacut Creek	0	0
	Johnson Creek	57	19
	Tunk Creek	48	11
	Aeneas Creek	3	1
	Bonaparte Creek	135	71
	Antoine Creek	0	0
	Wildhorse Spring Creek	0	0
	Tonasket Creek	49	28
	Ninemile Creek	9	9
Subtotal	Adult escapement into WA mainstem	425	71
Subtotal	Adult escapement into WA tributaries	892	424
Subtotal	Adult escapement into BC	39	23
Total	Okanogan subbasin	1,356	518

Table 2. Estimated number of steelhead spawners in the Okanogan subbasin, by year.

Year	Natural Origin	Hatchery Origin	Total
2005	146	1,080	1,226
2006	197	702	899
2007	152	1,116	1,268
2008	225	1,161	1,386
2009	212	1,921	2,133
2010	728	2,768	3,496
2011	333	1,341	1,674
2012	327	2,475	2,802
2013	250	1,687	1,937
2014	518	838	1,356
Average	309	1,509	1,818

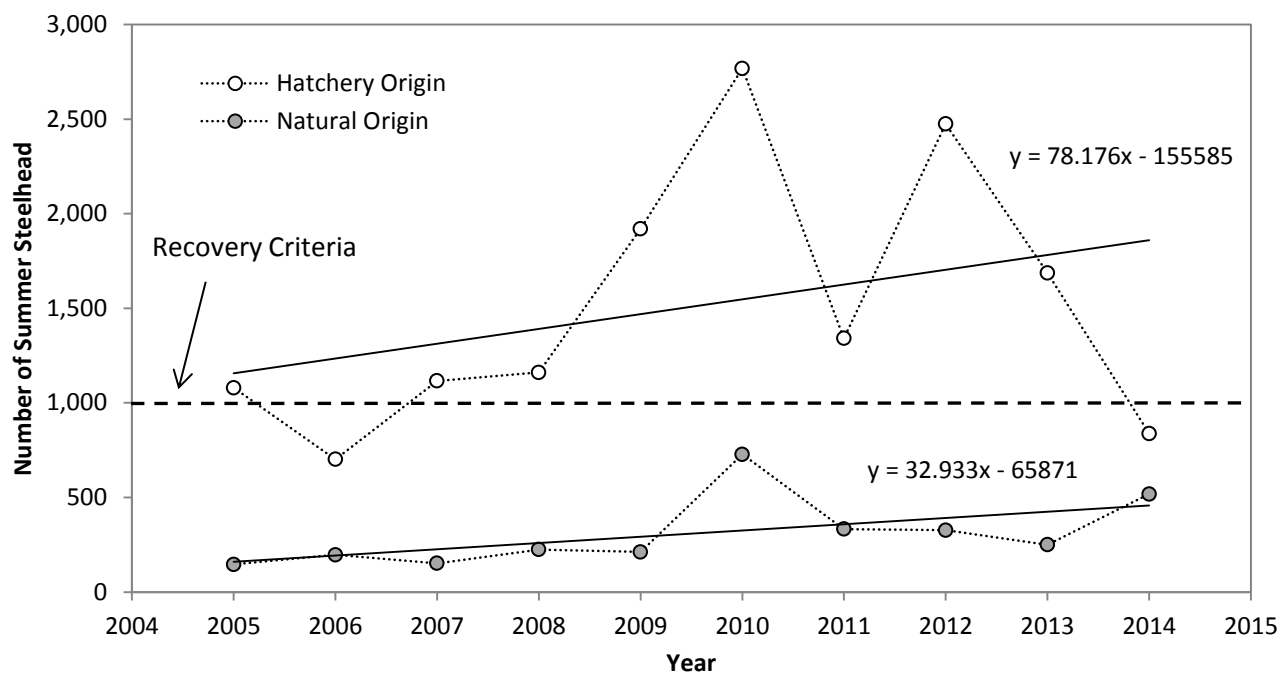


Figure 2. Trend of hatchery and natural origin summer steelhead in the Okanogan subbasin compared with the NOAA recovery goal⁴ (dashed line).

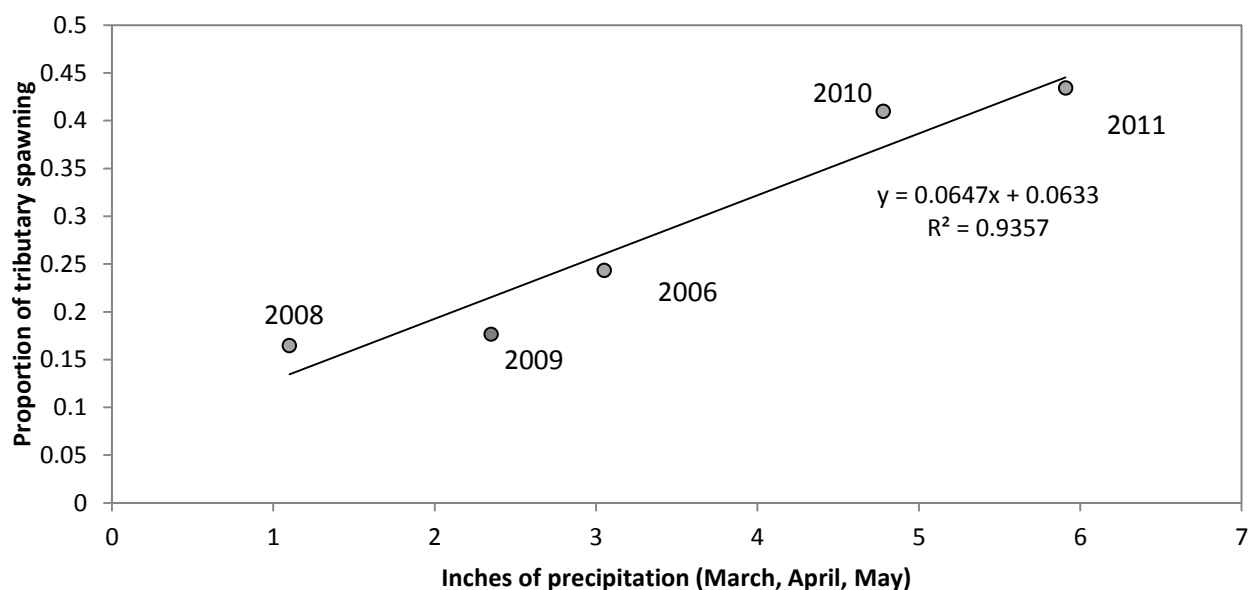


Figure 3. Correlation between precipitation occurring during March, April, and May and the proportion of steelhead spawning in tributaries to the Okanogan River in Washington State.

⁴ The Interior Columbia Basin Technical Recovery Team (ICBTRT) determined that 500 natural origin steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin. Including Canadian portion of the subbasin, minimum abundance recovery criteria would be 1,000 natural origin adults (UCSRB 2007).

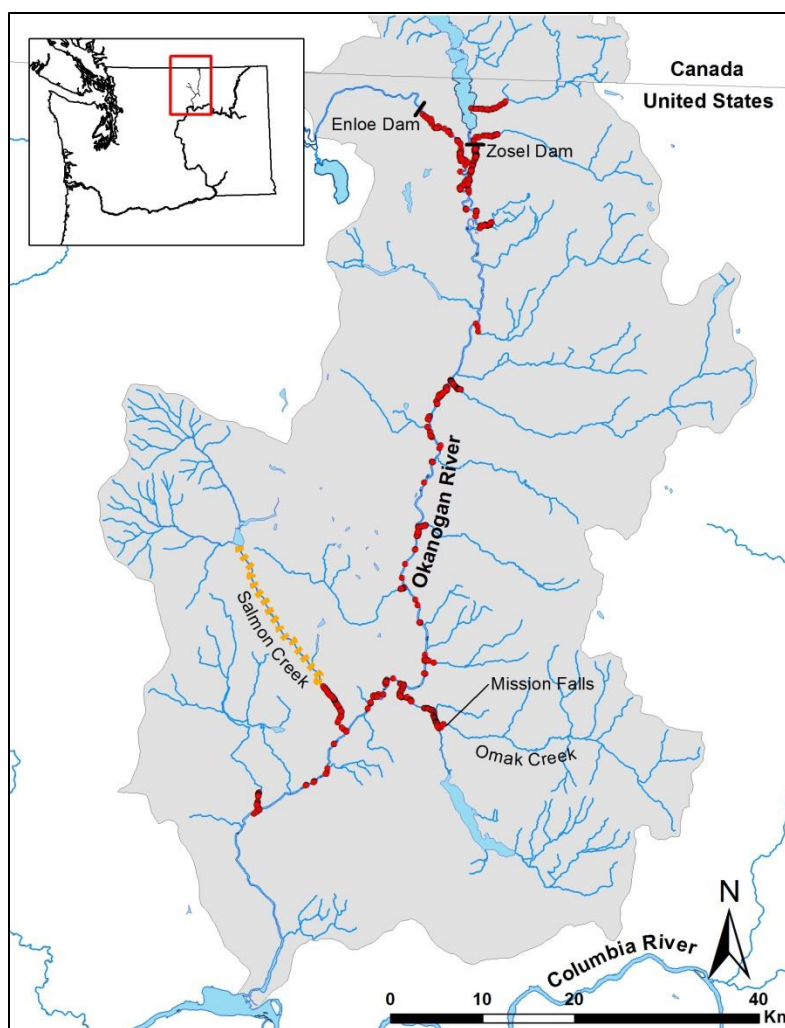


Figure 4. Spatial distribution of summer steelhead spawning in the Washington State portion of the Okanogan subbasin from 2005-2014 (n=5,162 georeferenced steelhead redds)⁵. Dashed line on Salmon Creek represents assumed spawning use⁶.

2.1.4 Conclusions

In the United States, summer steelhead are currently listed as “threatened” under the Endangered Species Act in the Upper Columbia River ESU (NMFS 2009). The OBMEP monitored adult Viable Salmonid Population (VSP) abundance attributes (McElhany et al. 2000) within the subbasin for Okanogan River summer steelhead through redd surveys, underwater video counts, and PIT tag expansion estimates. Detailed percent-wild information has been provided annually and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. However, these data should be used with caution, because it is difficult to

⁵ As of the spring of 2014, upper Omak Creek above Mission Falls was accessible to anadromous steelhead.

⁶ Assumed spawning use due to video observations and PIT tag detections, but no comprehensive redd surveys have been conducted on upper Salmon Creek.

define natal origin through visual observation alone (i.e. intact adipose fin), variability surrounding the estimate has not been quantified, and assumptions have been made which have not yet been validated. Occasionally, modeled escapement data were used when discharge rates were not conducive for visual surveys. Other methods, such as PIT tag estimates and redd expansion estimates, rely heavily on calculated escapement values. Additionally, relatively low returns in 2005 and 2006, when coupled with a very large return in 2010, likely skewed the trend data in an upward direction. Large variations in estimates exist in many reaches from year to year, but often, these accurately reflect real-world situations rather than survey bias or calculation error. Small creeks may have extremely low flows for two years, blocking access with no spawning occurring, and then experience a large run of fish the following year when sufficient flows exist (e.g. Loup Loup Creek escapement of 0, 0, and 125 for 2008, 2009, and 2010, respectively). This irregular nature of small scale population data frequently results in data being scattered loosely around a linear trend line. We have made every effort to ensure that the reported values are as accurate as possible, including using multiple data collection methods for validation, comprehensive on-the-ground surveys, and best professional judgment based on extensive local experience with the subbasin.

Annual variations of environmental factors can profoundly impact redd distributions in small tributaries to the Okanogan River. Changes in summer steelhead spawning distribution within tributaries appear to be driven by: 1) discharge and elevation of the Okanogan River; 2) discharge of the tributary streams; 3) timing of runoff in relation to run-timing of adult steelhead; and 4) stocking location of hatchery smolts. The first three factors are largely based upon natural environmental conditions, which can be altered dramatically by such things as water releases from dams, irrigation withdrawals, and climate change. Years such as 2006, 2008, and 2009 clearly show how low tributary discharge can dramatically alter spawning location and reduce the available tributary habitat for steelhead to utilize (Figure 3). Habitat alterations at the mouths of key spawning tributaries may improve access, provided that sufficient discharge is available. In 2010, 2011, and 2012, water availability in the Okanogan subbasin was above normal and subsequently, a larger proportion of steelhead spawned in tributaries than documented in previous years. Approximately 41% and 43% of steelhead were estimated to have spawned in tributaries to the Okanogan in 2010 and 2011, respectively. Because mainstem values were largely calculated and not directly counted for 2007 and 2012-2014 due to unfavorable mainstem redd survey conditions, no certain conclusions can be drawn for those survey years. Summer steelhead that spawn in tributary habitats of the Okanogan subbasin are more likely to find suitable environmental conditions and rearing habitats than those spawning in mainstem habitats. Therefore, habitat implementation programs should continue to focus on projects that address adequate flow in tributaries to the Okanogan River.

A multi-year restoration project on Omak Creek improved passage at a steep, boulder-choked falls and PIT tagged adult steelhead were documented above the falls for the first time in the spring of 2014. This restoration action should contribute to an increased spawner capacity in future years in Omak Creek by increasing the amount of available stream length by approximately 81%. Managers should continue funding projects that facilitate passage, but should also consider funding actions that improve stream habitat or increase instream flows, even before impediments are altered. For example, a barrier to a stream that dries up seasonally should probably not be removed until year-round flows are restored because steelhead may be able to access the creek to spawn, but eggs or parr would desiccate when the stream dries up in the summer.

The removal of barriers in the Canadian portion of the Okanogan 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 PIT tag detection sites further upriver and into tributaries would provide specific information related to spawning areas and run timing and could be coordinated with reintroduction programs. Adding more

antenna arrays in the Canadian Okanogan River subbasin could also be used to test assumptions about detection efficiency.

Summer steelhead redd surveys in the Okanogan subbasin can document spawning distribution and provide an estimate of escapement on years when spring runoff occurs post-spawning. However, modeling distribution and abundance of spawning on years with early runoff is less objective. Since OBMEP began collecting steelhead spawning data in 2005, the importance of not relying solely on redd surveys for abundance estimates has become evident. Implementation of an Upper Columbia Basin-wide PIT tag interrogation systems (Project # 2010-034-00), coupled with the representative marking of returning adults at Priest Rapids Dam, allowed managers an additional means to estimate abundance on years with poor water visibility. This project also provided a validation tool for redd survey efficiency, while describing spatial distribution and upstream extent of spawning where previously unknown. Continuing these efforts will allow managers to more accurately describe the spatial extent of steelhead spawning in tributaries to the Okanogan River and define spawning estimates when redd surveys cannot be conducted.

Lessons learned and recommendations for future monitoring of adult steelhead in the Okanogan subbasin:

1. Continue collection of steelhead redd data.
 - a. Defining the physical location of redds helps to inform managers about which, and to what extent, habitats are being used for spawning and allow for tracking of spatial status and trends through time. Detailed results are available in annual steelhead spawning reports.
2. Continue the representative marking of adult steelhead with PIT tags at Mid-Columbia facilities along with operation of PIT tag interrogation systems at the lower reaches of tributaries (Project # 2010-034-00).
 - a. The representative marking of returning adults at PRD has allowed researchers to expand unique detections into escapement estimates in distinct sub-watersheds within the Upper Columbia River. This project has helped to identify spawning areas that were previously unknown or undercounted, and define confidence intervals surrounding point abundance estimates.
 - b. Expand the number of PIT tag interrogation sites in the BC portion of the subbasin.
3. Examine feasibility of determining adult escapement estimates in the mainstem from mark-recapture PIT tag expansion estimates.
 - a. Spring redd surveys may produce reliable estimates on low water years or years with a delayed runoff period. However, the onset of runoff frequently coincides at or prior to the peak of steelhead spawning. In the Okanogan River, any meaningful rise in discharge equates to significant increases in turbidity which typically last through July.
 - b. Current redd survey expansion procedures provide a point estimate, but do not allow for determination of confidence intervals.
4. Ensure adequate flow exists in tributaries to the Okanogan River to allow adult fish access into creeks during the spawning timeframe.
 - a. The focus should be on sub-watersheds that retain sufficient flows throughout the summer to support fry/parr rearing (e.g. Loup Loup, Salmon, and Antoine Creeks).
5. Explore alternative adult enumeration techniques for Zosel Dam that will account for periods of high flows when the spillway gates are raised.
 - a. There are currently no methods used for quantifying fish passage when the spillway gates are raised to more than 12 inches, a height in which adult fish can pass underneath the spill gates.
 - b. Explore feasibility of installing PIT tag detection array near the dam that spans the entire channel, or upstream of the spillway gates to detect fish passing underneath.

2.2 Juvenile Salmonid Monitoring

2.2.1 Introduction

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, interpretation of migrational movements (i.e. resident vs. anadromous) can be challenging. The OBMEP operated a rotary screw trap (RST) from 2004 through 2011 on the mainstem Okanogan River to monitor outmigration of juvenile salmonids, but very few captures of naturally produced steelhead yielded highly variable and unreliable estimates for that species.

Snorkel surveys of juvenile salmonids can show changes in relative observed abundance at sites over time (Schill and Griffith 1984, Thurow 1994). Annual variation in observed abundance is calculable from the current long-term dataset for the Okanogan subbasin, but it remains unknown how these values relate to absolute abundance. Data collected from summer snorkel surveys conducted by OBMEP from 2004 (2005 in British Columbia) through 2014 show very low numbers of juvenile steelhead in the mainstem and considerably higher densities in tributaries. 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.

In 2014, new subbasin-wide juvenile monitoring studies were implemented 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 mark-recapture electrofishing, remote PIT tagging, and in-stream PIT tag interrogations. The primary study goals were to: (1) estimate abundance of juvenile *O. mykiss* in small streams, (2) determine precision of estimates, and (3) calculate an independent, stream-based emigration estimate from PIT tags. These methods allow the program to more accurately monitor annual abundance of juvenile steelhead in the Okanogan subbasin, estimate precision and bias associated with methods, and to determine trends in juvenile abundance, spatial distribution, and life history diversity through time.

2.2.2 Methods

In 2014, juvenile monitoring data collection occurred through the implementation of snorkel surveys, both in the U.S. and Canada, and a tributary-focused electrofishing and PIT tag mark-recapture study in the U.S. only.

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

To estimate abundance of juvenile steelhead within each ~150 m site, a two-pass Lincoln-Petersen mark-recapture study was performed. Site-based abundance was expanded to estimate the population of juvenile *O. mykiss* in each stratum (EDT reach). 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 during site based surveys. Therefore, the total population estimate for an individual creek was calculated by summing abundance estimates across reaches. The location of a parallel PIT tag array near the mouth of creeks may allow for determination of an emigration estimate. Efficiency of the PIT tag array was monitored throughout the period of the study based on detection probability of each antenna, which will be determined using marked release groups from the RST located near the mouth of Omak Creek and upstream hatchery plantings. Assuming that fish tagged upstream were representative 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. Detailed methods for the juvenile mark-recapture project are presented in Appendix F.

OBMEP - Juvenile Abundance - Snorkel surveys (ID:7)

<https://www.monitoringmethods.org/Protocol/Details/7>

Snorkel surveys have been conducted from 2005 through 2014 in the Okanogan subbasin. To minimize inter-crew observer bias, tributaries were snorkeled by the same observers from 2009 through 2014, and those who snorkeled the mainstem Okanogan and Similkameen Rivers in 2011 also snorkeled the following years. All observers were trained and had experience in fish observation techniques and species identification prior to snorkeling. Snorkel survey data have been presented as density of juvenile *O. mykiss*/ha, which was derived by dividing the observed number of fish less than 300 mm in each site by the wetted surface area of the survey site. Wetted surface area was calculated by measuring 22 evenly spaced wetted width measurements within the site and multiplying the average width by the total survey reach length. Metrics and Indicators for juvenile monitoring are listed in Appendix E.

2.2.3 Results

Mark-Recapture Abundance Estimates

During the 2014 field season, eight tributaries were representatively sampled to determine abundance of juvenile *O. mykiss* in stream reaches accessible to anadromous fish. Three streams were not sampled due to lack of access, minimal habitat, and/or limited remaining take on the electrofishing permit for the year. Estimated abundance ($\pm 95\%$ C.I.), capture efficiency of juvenile *O. mykiss*, and precision of estimates are presented in Table 3. In all tributary stream reaches available to anadromous fish in the Washington State portion of the subbasin, three streams contained 90.7% of the juvenile *O. mykiss* (Loup Loup Creek, Salmon Creek, and lower Omak Creek, Figure 5). Spatial distribution of juvenile *O. mykiss* varied within and between sub-watersheds, both by density and fork-length (FL) distribution (refer to Appendix F). A PIT tag was placed in all captured parr over 95 mm to monitor the proportion of fish that out-migrate during the following fall and spring. Detection and calculation of out-migration estimates will occur the following season, and thus, total emigration results will be reported in the following year.

A number of small creeks in the Okanogan subbasin contain flowing water in the upper reaches, but water frequently flows sub-surface before entering the mainstem Okanogan River. Salmon, Wanacut, Tunk, and Tonasket Creeks are all watersheds where adult spawning has been documented, but were dry in the lower reaches during the summer and fall of 2014. Wanacut Creek was dry in the lower ~3,000 m, but had flowing water from the falls (natural anadromous barrier) for ~300 m; however, zero fish were observed during sampling. Due to the wetted width being approximately 1 m during sampling, capture efficiency would have likely been high, therefore it is likely that Wanacut Creek contained little to no juvenile *O. mykiss* in 2014. Tunk Creek had a wetted length of ~700m below the anadromous barrier (falls) before going sub-surface for ~400 m to the confluence with the Okanogan River. Although a number of adult steelhead spawned in Tunk Creek in the spring of 2014, no fry were observed and many parr were in poor condition (many were thin with fungus on eyes and head), potentially due to very low flow and water temperatures exceeding 25°C during the summer. Tonasket Creek was dry in the lower ~2,500 m, but had flowing water from ~700 m below and up to the anadromous barrier (falls). Juvenile *O. mykiss* density appeared to be very high; however, the fish appeared to be in surprisingly good condition. All naturally produced juvenile *O. mykiss* that were 95 mm and larger were PIT tagged. Future outmigration data may be able to show if naturally produced *O. mykiss* in small disconnected streams contribute to returns of adult steelhead, or if contribution from these small watersheds is minimal relative to the number of adults that spawn in these streams.

Table 3. Abundance estimates of naturally produced *O. mykiss* in tributaries to the Okanogan River below assumed anadromous barriers (Arterburn et al. 2007) in the fall of 2014; ordered from south to north in the subbasin.

Tributary	< 95 mm <i>O. mykiss</i>				> 95 mm <i>O. mykiss</i>			
	Abundance Estimate	95% CI	Avg. Capture Eff.	C.V.	Abundance Estimate	95% CI	Avg. Capture Eff.	C.V.
Loup Loup Cr	18,806	1,567	39%	0.043	2,542	319	62%	0.064
Salmon Cr	41,803	6,339	25%	0.077	31,269	2,245	48%	0.037
Omak Cr	23,045	1,647	31%	0.036	6,958	886	46%	0.065
Wanacut Cr	0	0	-	-	0	0	-	-
Tunk Cr	0	0	-	-	193	31	81%	0.080
Aeneas Cr	86	14	44%	0.081	106	20	47%	0.096
Bonaparte Cr	2,922	368	45%	0.064	127	20	60%	0.082
Tonasket Cr	2,192	716	7%	0.167	526	51	58%	0.049
Ninemile Cr	4,184	756	67%	0.092	2,393	375	43%	0.080
Total or Average	93,038	11,407	37%		44,114	3,947	56%	

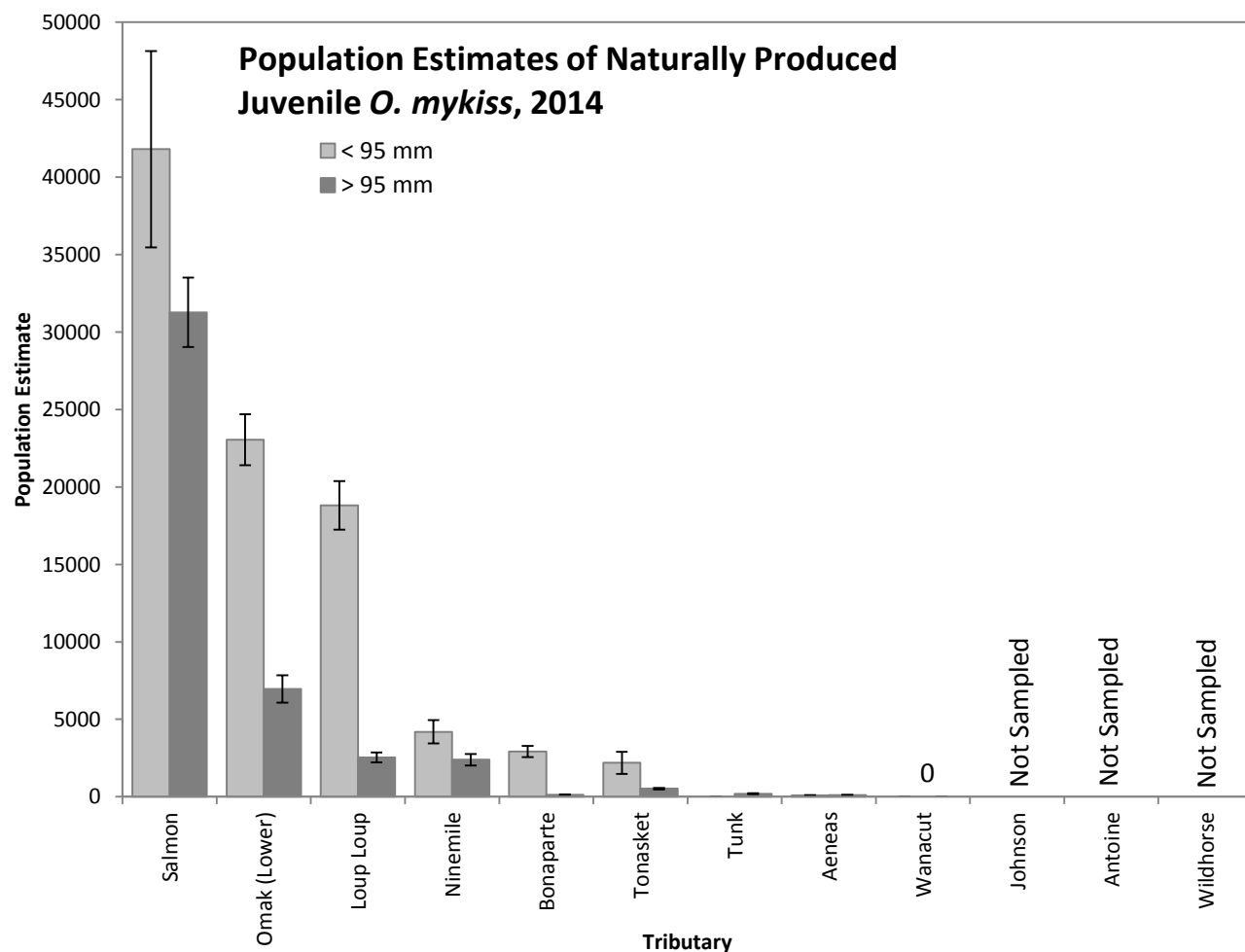


Figure 5. Estimated population of natural produced juvenile *O. mykiss* in tributaries to the Okanogan River in the fall of 2014. Data are presented by *O. mykiss* fry (< 95 mm) and juvenile+ (> 95 mm).

Snorkel Surveys

In the Washington State portion of the subbasin, the highest densities of juvenile *O. mykiss* observed at any single site on a creek was on Loup Loup Creek (17,050 fish/ha), followed by Tonasket Creek (14,252 fish/ha), and Bonaparte Creek (12,123 fish/ha). Three sites were sampled on Salmon Creek, and densities among these sites ranged from 178 to 2,466 fish/ha. Three sites below the anadromous barrier (Mission Falls) on Omak Creek had densities of 2,654 to 8,874 fish/ha. In contrast, the density of juvenile *O. mykiss* at four sites above the anadromous barrier on Omak Creek ranged from 0 to 1,560 fish/ha. No juvenile *O. mykiss* were observed in 8 out of 12 sites total sites on the mainstem Okanogan River. Average observed density in the Okanogan mainstem was 0.12 fish/ha and 1.21 fish/ha in the Similkameen River, compared to an average density of 4,292 fish/ha in all tributaries. The trend in total observed densities of juvenile *O. mykiss* at annual snorkel monitoring sites increased in three major streams from 2004-2014 (Loup Loup, Salmon, and Omak creeks), but remained near or at zero for nearly all mainstem Okanogan River survey sites during the summer base-flow period. Results over the past 10 years continued to show very low numbers of juvenile steelhead in the mainstem and considerably higher densities in tributaries (ex. Figure 6). Quantity of water (i.e. dry creeks, as noted in the figures contained in Appendix G) appeared to limit distribution of juvenile *O. mykiss* in many small streams. Tributaries that support adult steelhead spawning, but were most notably affected by low summer discharges included Tonasket, Wildhorse Spring, Tunk, lower Salmon, and Loup Loup creeks in Washington.

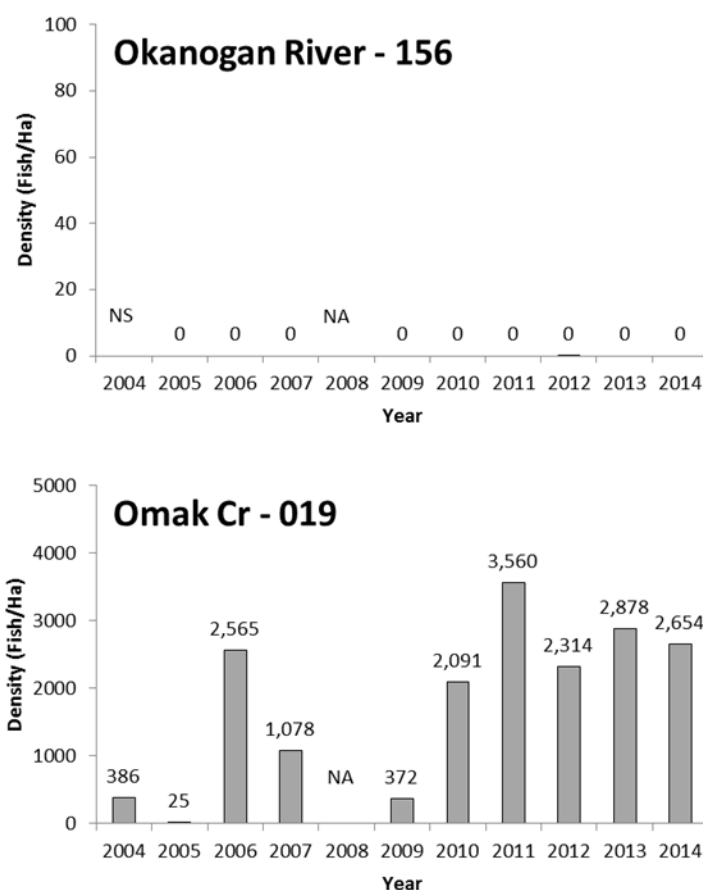


Figure 6. Comparison of observed densities of juvenile *O. mykiss* (< 300mm) in the mainstem Okanogan River (near Malott, WA) and in a tributary to the Okanogan River (Omak Creek).

In the British Columbia portion of the Okanagan subbasin, 11 out of the 12 tributary sites were snorkeled in 2014. One site on Haynes Creek (OBMEP-471) was dry at base flow. Juvenile *O. mykiss* were observed at 8 of the 11 sites. No juvenile *O. mykiss* were observed in lower snpin'ya?tkw (Ellis Creek, OBMEP-470), Testalinden Creek (OBMEP-1252) and Wolfcub Creek (OBMEP-1260). The highest average density of juvenile *O. mykiss* (fish/ha) was observed in McLean Creek (2,561 fish/ha). The highest total number of juvenile *O. mykiss* were observed in snḡaxəlqaxw'iya? (Vaseux Creek) and aksk'ək'ant (Inkaneep Creek). All four ḡawsitkw (Okanagan River) mainstem sites were sampled in Canada and *O. mykiss* were observed at all four sites. The average density of juvenile *O. mykiss* was lower in the mainstem (6 fish/ha) compared to tributaries with *O. mykiss* (1,169 fish/ha).

Refer to Appendix G for additional detail on observed abundance estimates from snorkel surveys.

Snorkel Surveys Verification

In 2014, snorkel surveys in small streams in Washington State were coupled with mark-recapture electrofishing in attempts to determine potential relationships between snorkel observation and total abundance of juvenile *O. mykiss* in 150 m survey sites. The number of observed fish during snorkel surveys was compared with mark-recapture abundance estimates in order to define detection rates of fish during snorkeling and the accuracy of total snorkel counts. Although the number of data points used in the comparison is relatively small at this time (n=19), initial results suggest that snorkel surveys are fairly precise and can detect relative change in density of juvenile salmonids. However, observed snorkel survey estimates are not accurate, in that density of fish were under-reported in every instance. There was a strong correlation between mark-recapture estimated site abundance and the total snorkel count ($p < 0.001$) (Figure 7) and number of < 100 mm FL *O. mykiss* ($p < 0.001$) observed during snorkel surveys. There was a noticeable decrease in observation rate of > 100 mm FL *O. mykiss* ($p = 0.057$) (Appendix H).

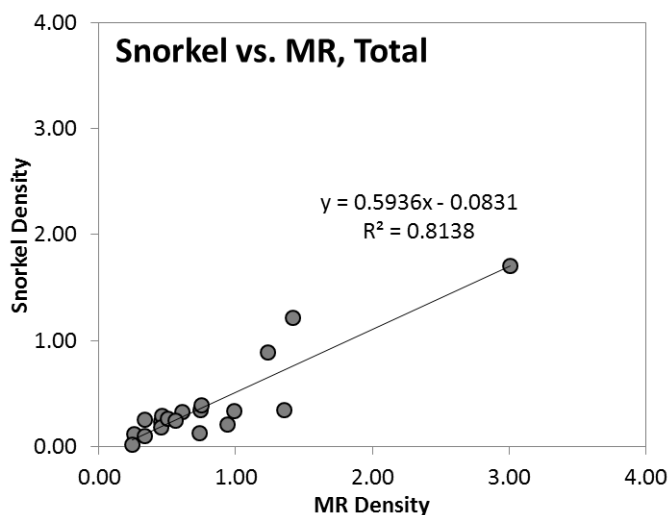


Figure 7. Comparison of snorkel survey observation and mark-recapture densities (fish/m²) within 150 m monitoring sites (n=19).

2.2.4 Conclusions

Snorkel surveys conducted in the Okanogan subbasin continued to show a distinct difference between densities of *O. mykiss* in the mainstem compared to the tributaries. In the mainstem Okanogan, summer water temperatures commonly exceed 24°C in most years, which potentially limits the seasonal distribution of juvenile salmonids during that timeframe (refer to Section 3.2 Water Temperature). The apparent absence of juvenile salmonids in the mainstem during the summer months may be attributed to mortality, avoidance behavior, or low observation rates during snorkel surveys.

Results from snorkel surveys indicate that annual site-based observed fish abundance were highly variable. Additionally, it is unknown how observed numbers related to the total abundance, given varying site conditions. With the addition of mark-recapture abundance estimates, initial results suggest great improvements by the means in which OBMEP monitored juvenile parameters. Additional years of data for Omak Creek and other tributaries to the Okanogan River can serve as an indicator for trends in juvenile abundance and emigration from the Okanogan subbasin. Data collection methods conform to existing monitoring approaches within the Okanogan and among other major monitoring programs in the Columbia River Basin and provide precision of estimates, as outlined by NOAA (Crawford and Rumsey 2011).

Spatial distribution of fish throughout the creek may vary by age and size class (Roper et al. 1994). For example, density of age-0 steelhead may be linked to spawning location of adults from 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 initial study period, it will be possible to explore this hypothesis in the future, due to the fact that these abundance data were collected at existing habitat monitoring sites. Determining the 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.

Representatively marking a known proportion of the population upstream of the PIT tag array may enable the program to estimate emigration, even in the absence of an RST. This method can also be applied to small watersheds where monitoring of juvenile production was previously infeasible. Dividing the creek into distinct biologic reaches allowed for subsampling to occur at a finer scale and site-based abundance of juvenile steelhead were only expanded within similar habitat types. Annual outmigration estimates will 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 a small watershed with a high degree of precision.

Lessons learned and recommendations for future monitoring of juvenile steelhead in the Okanogan subbasin:

1. Continue implementing mark-recapture population assessments on tributaries to the Okanogan River.
 - a. Methods align with recommendations from BPA and guidance from NOAA (Crawford and Rumsey 2011).
 - b. Focus primary efforts on larger tributaries to the Okanogan River (e.g. Salmon, Omak Creeks), although attempt to get abundance and trend data on all tributaries if time and funding allow.
 - c. Continue to link juvenile monitoring with habitat monitoring sites in attempts to correlate juvenile abundance to habitat factors.
2. Continuing marking naturally produced juvenile steelhead with PIT tags to address knowledge gaps in juvenile survival, outmigration, and smolt-to-adult return rates of naturally reared steelhead in the Okanogan subbasin.

3. Continue conducting snorkel surveys on the mainstem Okanogan and Similkameen Rivers.
 - a. Current juvenile abundance electrofishing procedures cannot be conducted in the large mainstem habitats, therefore, continue conducting snorkel observation in mainstem reaches.
 - b. Snorkel surveys are currently conducted at the summer base flow period; however, this time period overlaps with the warmest water conditions of the year which frequently exceed 24°C.
 - i. Consider conducting a secondary subset snorkel surveys in the mainstem outside the highest temperature period in attempts to discern if juvenile steelhead are truly absent, or if seeking refuge from high temperatures precludes observation.
4. Research is needed to assess egg-to-fry survival in mainstem habitats.
 - a. A relatively large proportion of adult steelhead spawn in the mainstem reaches of the Okanogan subbasin (55-80% on given years). However, snorkel observations of juvenile steelhead remain highly infrequent in those habitats (refer to Appendix F).
 - b. It is currently unknown if juveniles are succumbing to high river temperatures, or if relatively few alevin are emerging from the gravels.
5. Examine predation of juvenile steelhead by smallmouth bass and northern pike minnow.
 - a. The majority of fish species observed during mainstem snorkel surveys are smallmouth bass.
 - b. The extent of predation by native and non-native piscivorous fishes on juvenile salmonids in the Okanogan subbasin is currently unknown, but may be significant.
 - c. Refer to draft predation study.
 - i. <http://www.colvilletribes.com/media/files/TechnicalSupporttoOBMEP-PredatorPreyMethodsfinaldraft091202.pdf>

3.0 Habitat Status and Trend Monitoring

To monitor the current status and possible trends in steelhead habitat capacity and identify limiting factors, the Okanogan Basin Monitoring and Evaluation Program developed the following measurement objectives:

1. Assess the quantity and quality of habitat available to steelhead and summer Chinook by monitoring physical habitat parameters;
2. Assess the quality of environmental factors impacting steelhead and summer Chinook productivity including water quality, temperature and discharge parameters; and
3. Assess the quality of biological community factors impacting steelhead and summer Chinook productivity including benthic macroinvertebrates and non-native fish species.

To assess and report on the status and trend of these wide-ranging parameters, OBMEP has worked towards integrating long-term empirical datasets as inputs into the Ecosystem Diagnosis and Treatment (EDT) model, implemented by ICF International. The EDT model is used at a watershed or stream reach scale and can be used to quantify the expected impacts of long-term changes in habitat capacity and limiting factors on summer steelhead productivity. EDT assesses multiple theoretical salmonid life history trajectories within a hierarchically arranged, spatially explicit model, which can be used by natural resource managers to investigate constraints on salmonid production.

3.1 Physical Habitat Monitoring

3.1.1 Introduction

OBMEP's habitat monitoring program "systematically collects quantitative habitat status and trends data on multiple habitat parameters at fixed- and rotating-panel survey locations distributed throughout the subbasin. The monitoring data are managed in a SQL Server database and undergo routine QA/QC review during collection and database entry. This information is supplemented with data collected in the Rapid Assessment protocol which targets specific data gaps identified as critical for characterizing the environment." (CCT 2013, p. 2-2)

With the combined inputs from the transect-based habitat monitoring sites and the Rapid Assessment habitat sampling program, the EDT model can generate theoretical salmonid productivity outputs. However, the completeness of the inputs that feed the model is an ongoing process and will become more robust as additional data are collected. Specific information requests can be directed to the Colville Tribes' Fish and Wildlife Department, Anadromous Fish Division, 25B Mission Road, Omak, WA 98841, (509) 422-7424.

3.1.2 Methods

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>

Two data collection methodologies have been utilized by OBMEP to obtain salmonid habitat metrics. Transect-based data are gathered at 50 habitat monitoring sites (25 Annual Panel sites, 25 Rotating Panel sites) for the entire Okanogan subbasin, per year. In total, for a four-year iteration, 85 reaches contain habitat monitoring sites in the U.S. portion of the Okanogan subbasin, and in Canada, 40 reaches contain habitat monitoring sites. For the remaining stream reaches accessible to anadromous salmon, populating the EDT model relies on data collected through the GIS mapping-based Rapid Assessment program. The EDT model can integrate a wide range of data types such that the aquatic habitat for salmonids may be depicted in a generalized manner (Lestelle et al. 2004). The protocols developed for both data gathering methodologies are listed at the Monitoring Methods links above. Metrics and Indicators for habitat monitoring are listed in Appendix I.

ICF International developed a series of procedures and equations for processing and transforming OBMEP data on each habitat attribute into EDT inputs. Other methods and data sources, including federal and provincial government flow and water quality data, GIS-based analyses, report documentation, and best-professional judgment, were used to develop some remaining attributes. Habitat monitoring site data are managed in a Microsoft SQL Server database, where data are uploaded digitally and managed by CCT and Sitka Technology. Rapid Assessment data are stored as GIS shapefiles and are managed on CCT and ONA servers. With regards to Quality Assurance and Quality Control (QA/QC), habitat monitoring site data are double-checked for completeness in the field and analyzed in the database by data managers. QA/QC protocols for Rapid Assessment data are detailed in [Monitoringmethods.org](https://www.monitoringmethods.org).

3.1.3. Results

In 2014, data were collected from all transect-based habitat monitoring sites and Rapid Assessment reaches. An example of maps and data produced for the Okanogan mainstem and tributary reaches through the Rapid Assessment program are also presented in Appendix J. The data collected under both habitat monitoring

methodologies are analyzed using the EDT model. Analyzed data are then compiled into technical reports with data collected through 2009 currently available for:

Summer Steelhead:

http://www.colvilletribes.com/media/files/2013SteelheadHabitatStatusandTrendReport_ElectronicOnly.pdf

Chinook Salmon:

http://www.colvilletribes.com/media/files/2013ChinookHabitatStatusandTrendReport_ElectronicOnly.pdf

(Note: Downloading may take several minutes due to large file size.)

In 2015, new reports using data collected through 2013 will be made available at the OBMEP web page.

The EDT report cards present ‘results’ of OBMEP habitat analysis and include a selection of bar graphs, pie graphs, and summaries. “...report cards describe habitat performance and identify the survival factors having the greatest impact on population success at this intermediate scale and the priority reaches for habitat protection and restoration within [specific habitat units]. The reach-level report cards characterize the estimated effect of reach-level survival factors on life-stage productivity...” (CCT 2013, p. 1-3)

Results from the EDT status and trends report concerning steelhead habitat in the Okanogan subbasin are summarized in the excerpt below:

“The population-level results for the U.S. and Canadian steelhead subpopulations indicate that both halves of the subbasin have considerable habitat potential under 2009 conditions. However, these results should be considered preliminary until anomalous results are investigated and data discrepancies and information needs are addressed. Specific guidance in this regard is provided in the data quality summary and summary of findings and recommendations provided in the following sections. A summary of EDT results and comparison to observed escapement and CCT recovery objectives is provided in Table 92 [in CCT 2013].

The EDT-estimated equilibrium abundance⁷ of the U.S. subpopulation is 662 adults, or approximately 26% of the template equilibrium abundance of 2,574. The 6-year geomean (2005-2010) observed total escapement was 1,365, of which 132 were natural-origin. The 2010 natural-origin escapement was 616 fish. The high level of hatchery outplantings confounds comparison of EDT-estimated and observed abundance, as hatchery-origin fish are capable of exploiting available habitat capacity during juvenile rearing and migrant life stages that is more productive than the habitats available to natural-origin fish during spawning, incubation, and early rearing.

One apparent finding of the EDT analysis is that the U.S. mainstem diagnostic units account for the majority of restoration opportunity in this portion of the subbasin, driven primarily by the large size and therefore high capacity of mainstem reaches. Restoration of all mainstem diagnostic units to template conditions would increase current steelhead abundance by 46.6%, with each contributing to a 5 to 9% effect. This suggests that habitat restoration efforts should focus on the Okanogan River proper. In reality, the opportunities in the mainstem are limited by a variety of social and environmental factors to

⁷ Equilibrium abundance: “The EDT-estimated theoretical population size that the quantity and quality of habitat provided by the model habitat environment can support.” (CCT 2013, p. 1-9)

the extent that it is unlikely these reaches could be restored to an approximation of historical function. This does not mean that restoration opportunities in the mainstem should be ignored, but that costs, benefits, and expectations for success must be viewed realistically when deciding how to allocate available resources.” (CCT 2013, p. 5-1)

3.1.4 Conclusions

Key recommendations from the EDT status and trends report have been summarized for Okanogan (U.S.) mainstem and tributary diagnostic units, which can be found in Table 96, in CCT 2013.

“The 2009 habitat status and trend analysis provides a detailed assessment of steelhead habitat potential in the Okanogan subbasin, characterizes the reliability of these results by diagnostic unit, and identifies key information needs. Based on these findings, ICF has developed a list of recommendations for prioritization of habitat protection and restoration, and for improving OBMEP / EDT integration to improve the reliability and utility of these model results in the 2013 habitat status and trends report. These include general recommendations for addressing broad-scale information needs, and specific recommendations for addressing critical information needs and / or model configuration issues in high priority diagnostic units.” (CCT 2013, p. 5-5)

Fish passage barriers are a limiting factor for steelhead in tributaries to the q̓awsitkʷ (Okanogan River) in British Columbia, as well as, Washington State. Rapid Assessment data identified previously unknown fish passage barriers, validated locations of known passage impediments, and measured potential for passage for multiple life stages of salmonids. These data are important to restoration practitioners to inform their actions. Ensuring access to historic stream kilometers in tributaries to the Okanogan remains a significant factor for the recovery of summer steelhead.

The length of stream reaches has largely been calculated using GIS map layers that often underestimate sinuosity, and subsequently, total reach length. Reach lengths are currently known to underrepresent the actual amount of stream habitat available in the Okanogan River subbasin. Rapid assessment surveys document the actual thalweg stream reach; these values will be used to update stream length calculation in future reporting cycles.

Through the past nine years of habitat monitoring, it has become evident that monitoring at the subbasin level may not be answering questions asked at the restoration practitioner scale or at a scale directly related to biological responses of fish species. For example, monitoring of fine sediments at sites randomly distributed in the subbasin may be able to answer the question “is sedimentation increasing or decreasing in the subbasin,” but it may not be able to answer “is sedimentation in key spawning areas increasing or decreasing, thus potentially impacting salmonids?” To answer the latter question, collection of fine sediment data should be focused to specific locations, such as pool tail outs, where salmonids frequently spawn and eggs develop.

In the Okanogan River subbasin, the OBMEP reach scale habitat data collection and subsequent EDT analysis can provide meaningful guidance for restoration practitioners. For example, the EDT model identified that in Salmon Creek, unregulated spill after reservoir fill in the spring results in scouring of steelhead redds. To reduce this, data are being collected to build a reservoir fill model that can reduce, if not eliminate unregulated discharge after steelhead eggs have been laid in the gravels. Over winter habitat has also been found to be limiting due to low stream flows in the winter. Improving water management in Salmon Creek could benefit both over winter survival while also reducing spring scour.

3.2 Water Temperature Monitoring

3.2.1 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 4 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 4 were considered appropriate for this preliminary analysis.

Table 4. 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 4). 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.

3.2.2 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 2014, 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 qawsitk^w (Okanogan 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 A. Water temperature data are compiled on the OBMEP server located at the Colville Tribes, Fish and Wildlife office in Omak, WA. 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).

3.2.3 Results

Steelhead Incubation

The water temperature at time of incubation is shown in Figure 8 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 9, 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. Research is currently being 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. Results from the initial study period should be available in the following year.

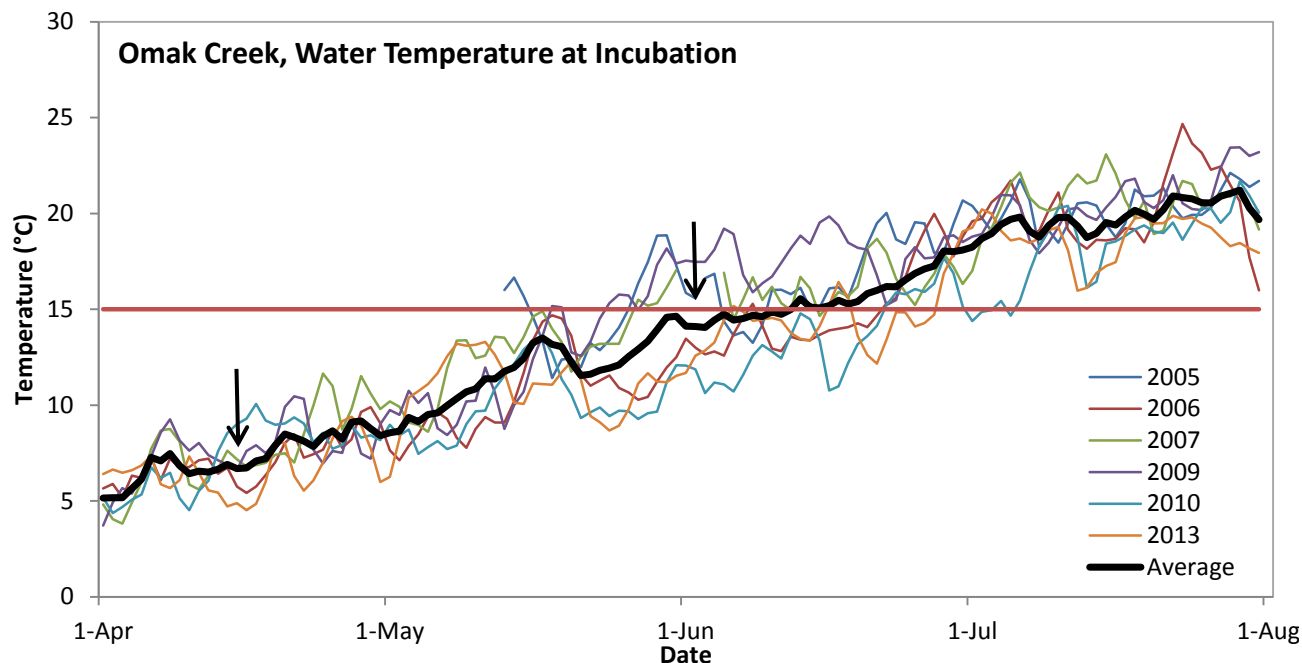


Figure 8. Mean daily water temperature for lower Omak Creek (data from OBMEP habitat site 019). Myrick and Cech (2001) define 15°C as a temperature in which increased mortality has been noted to occur during egg incubation. Markers signify the approximate time after peak spawn timing that steelhead eggs or alevin may be in the gravel.

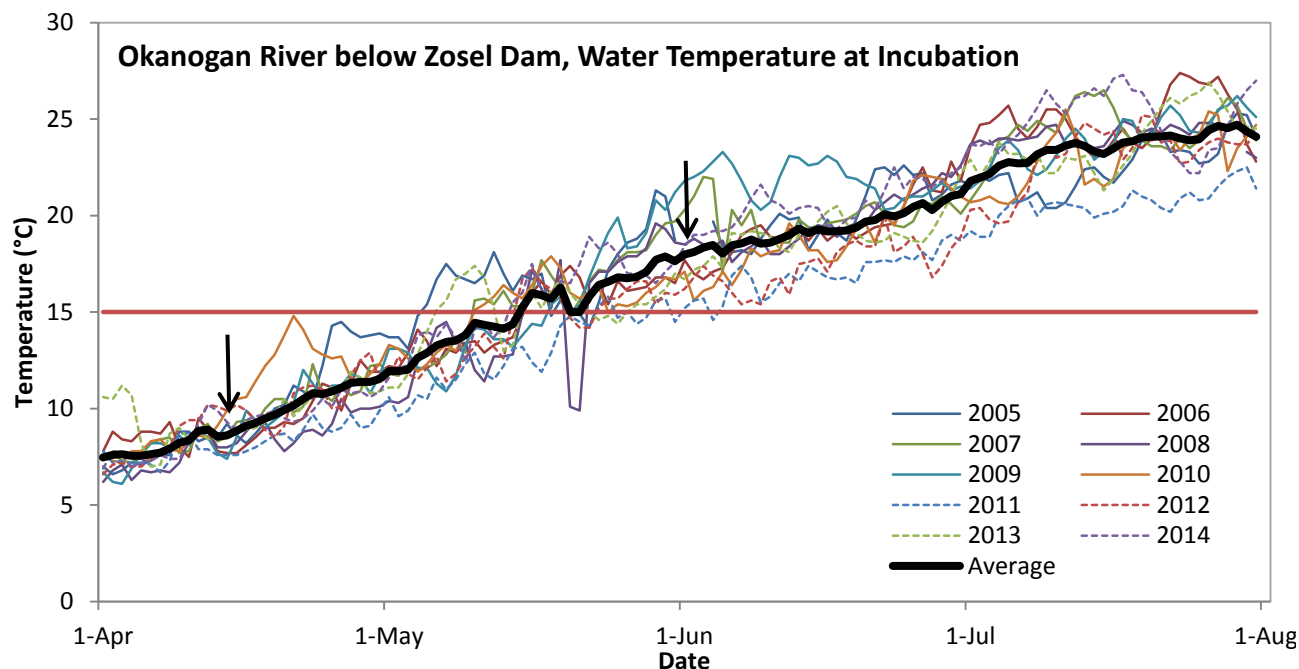


Figure 9. Mean daily water temperature of the Okanogan River below Zosel Dam (USGS Station 12439500, Okanogan River at Oroville, WA). Myrick and Cech (2001) define 15°C as a temperature in which increased mortality has been noted to occur during egg incubation. Markers signify the approximate time after peak spawn timing that steelhead eggs or alevin may be in the gravel.

Juvenile Steelhead Rearing

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 2013, 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 10). However, 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 11), and it is possible that these cooler nighttime temperatures may be buffering fish from further negative effects. Based on long-term monitoring data and known limitations of cold-water salmonid species (reviews by Currie et al. 1998 and Beiting et al. 2000), water temperature represents a limiting factor for rearing steelhead parr in the Okanogan River.

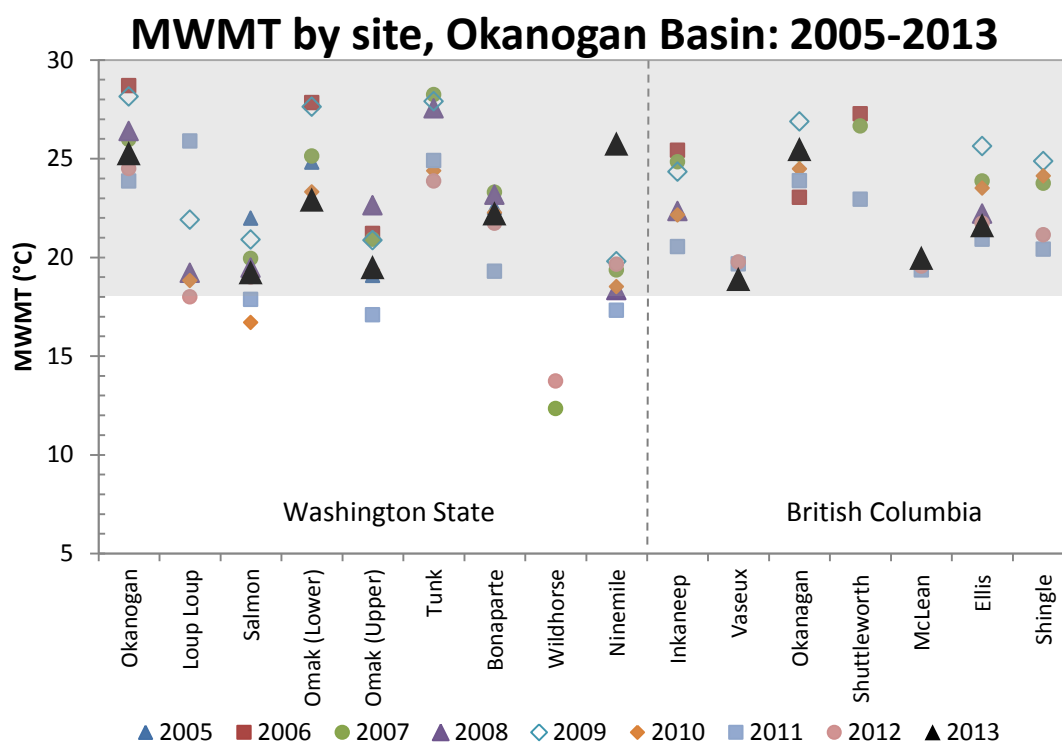


Figure 10. Maximum weekly maximum water temperatures in the Okanogan subbasin from 2005-2013. Shaded area represents the 18°C exceedance (EPA 2003).

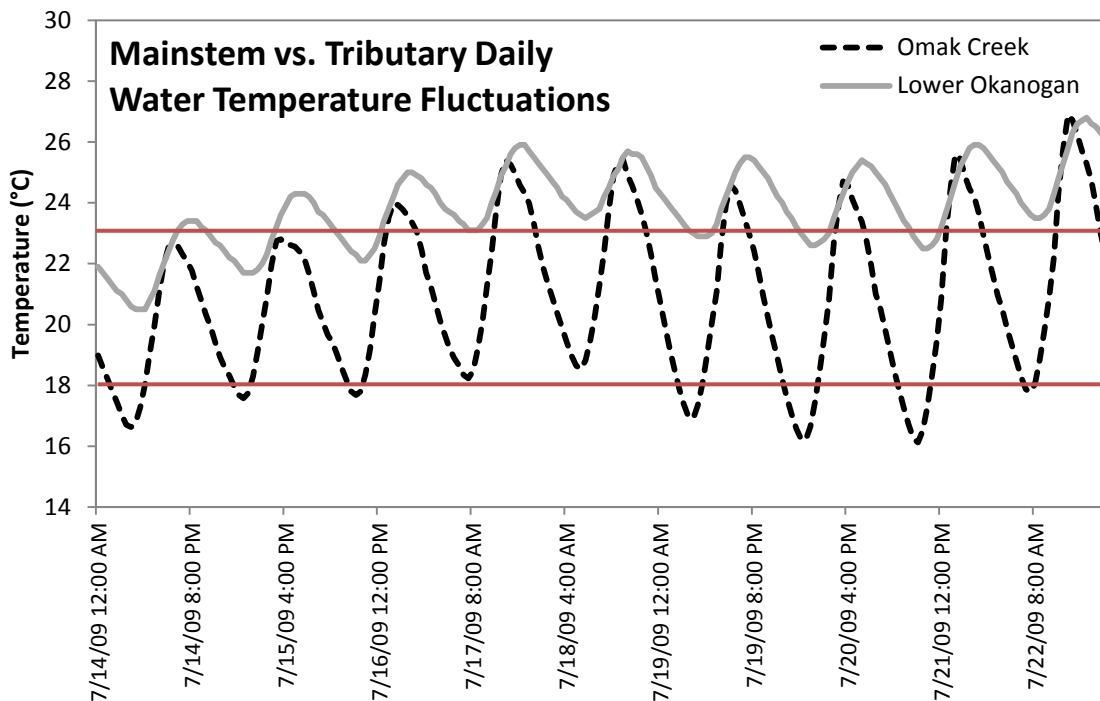


Figure 11. Daily temperature fluctuations of the lower Okanogan and Omak Creek during mid-July. Temperature thresholds (horizontal lines) are described in Table 4; > 18°C represents above preference and elevated disease risk (USEPA 2001a,b); > 23°C represents lethal 1-week temperatures (USEPA 2001c).

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 at temperatures of 21-24°C, steelhead exhibit avoidance behavior and may represent migration blockage. 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 Okanogan 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.

3.2.4 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. Therefore, the EPA recommends a MWMT of 18°C that protect fish from both acute and sublethal effects, especially for populations that are endangered or threatened.

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.

3.3 Water Quantity/Discharge Monitoring

3.3.1 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 km², 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.

3.3.2 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. These results may also be verified and compared to field data collected through snorkeling and electrofishing. Further discussion on the EDT model can be found in section 3.1.3. (Habitat Status and Trend Monitoring Results), which contain links to EDT results for each subwatershed and discuss specific instances where water quantity may be limiting and at which life stage.

A list of discharge monitoring sites in the Okanogan subbasin is available in Appendix A.

3.3.3 Results

Discharge in the Canadian Okanogan mainstem is influenced by the Okanogan 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 12) compared to the Canadian Okanogan mainstem (Figure 13). In the Canadian portion of the Okanogan subbasin, results also show periods of time in late summer when more water is removed from the river than contributed (Figure 14).

Tributaries have seasonally flashy hydrographs, showing large spikes during freshet followed quickly by a drop back down to base flows. Results from EDT modeling suggest that quantity of water in many of the tributaries to the Okanogan River were found to be limiting. While each unique sub-watershed is not individually discussed in this document, further information can be found in the link to the EDT report below, which contain data through 2009. Since 2009, significant improvements in connectivity of streams have been made. In future years, these are expected to be evident in the EDT results, which will compare data from 2005-2009 to data from 2010-2013; a final report will be available in 2015.

Summer Steelhead:

http://www.colvilletribes.com/media/files/2013SteelheadHabitatStatusandTrendReport_ElectronicOnly.pdf

Chinook Salmon:

http://www.colvilletribes.com/media/files/2013ChinookHabitatStatusandTrendReport_ElectronicOnly.pdf

3.3.4 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 (Appendix G), 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 (refer to Section 2.2 Juvenile Salmonid Monitoring).

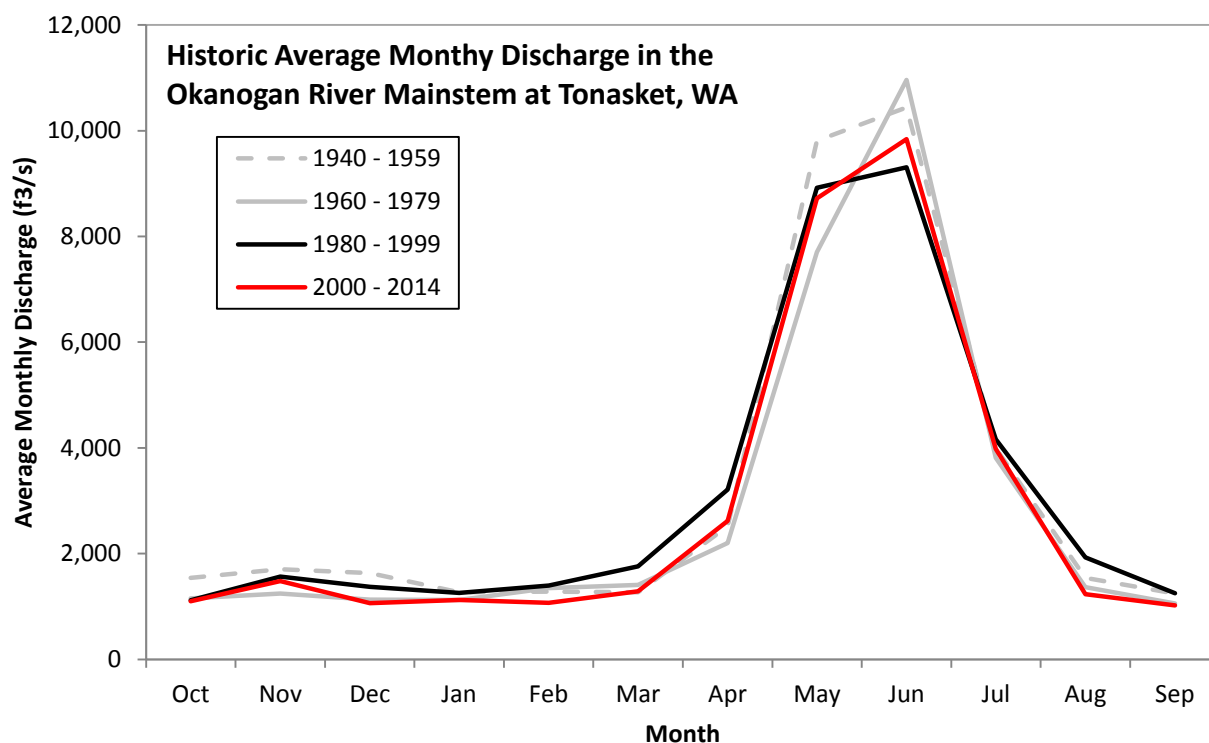


Figure 12. Average monthly discharge of the Okanogan River at Tonasket, WA (USGS Station 12445000, Okanogan River near Tonasket, WA).

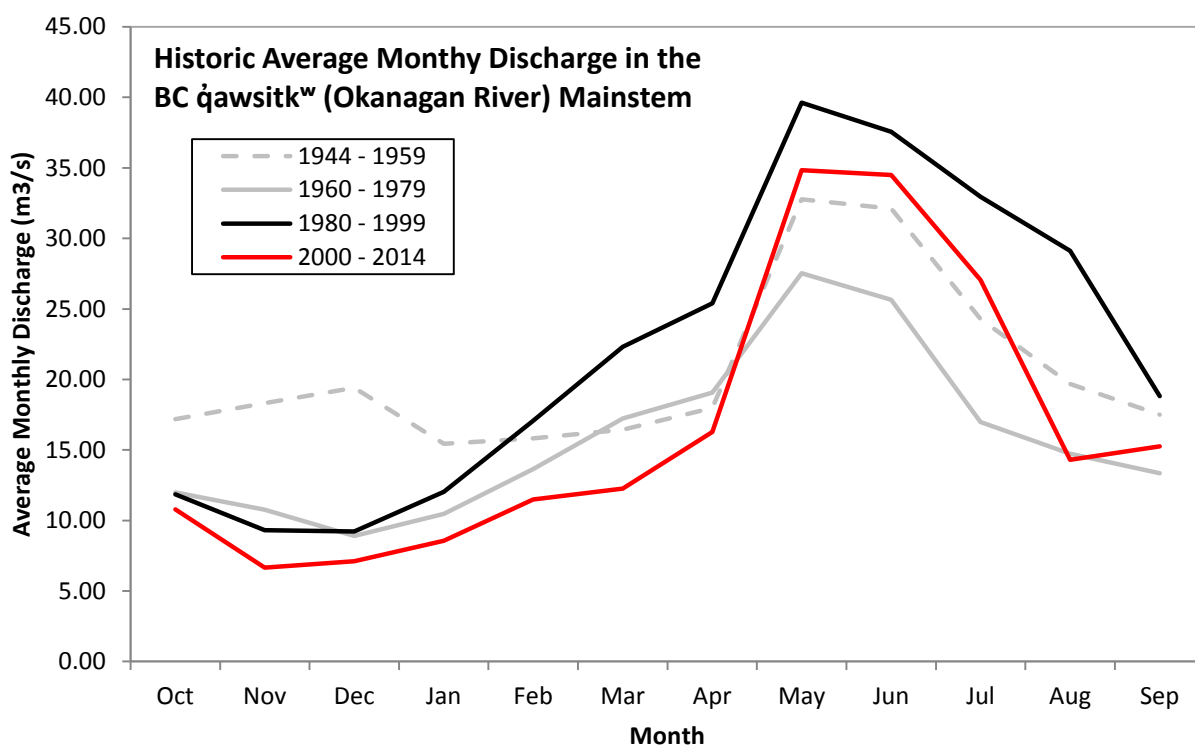


Figure 13. Historic mean monthly discharge recorded at Water Survey Canada station 08NM085 near sḵʷəḵʷnitkʷ (Okanagan Falls) from 1944 to 2014 (Environment Canada 2013).

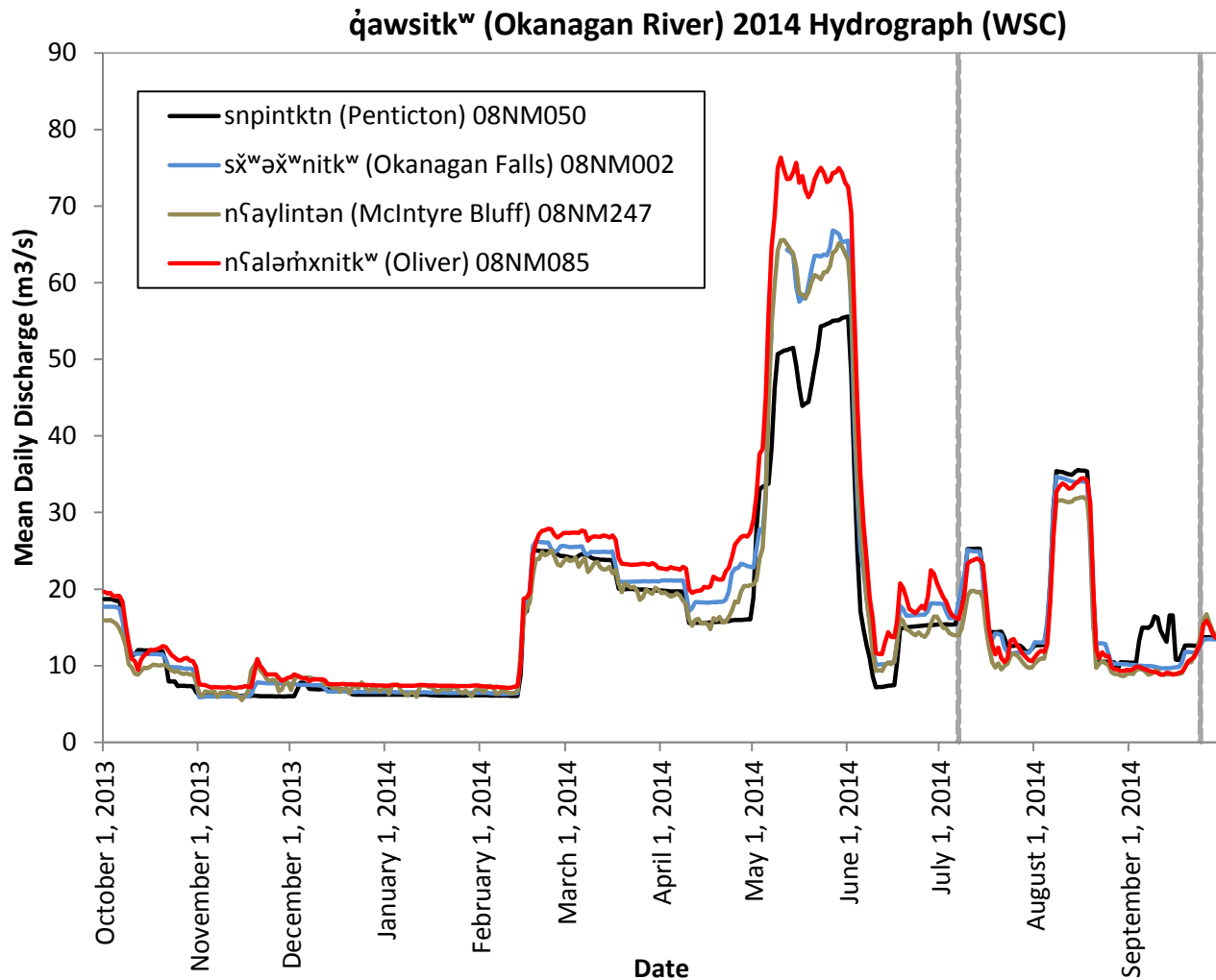


Figure 14. 2014 water year discharge measurements at four discharge gauge sites on the Okanagan River in British Columbia, legend arranged from upstream to downstream sites. The discharge between the dashed lines represents a period when more water is removed from the system than is contributed.

3.4 Water Quality Monitoring

3.4.1 Introduction

Salmonid health, performance, and survival are dependent on a number of environmental factors. When water quality parameters such as dissolved oxygen, pH, nutrients, or total dissolved gases are at suboptimal levels, salmonids can experience adverse effects such as increased susceptibility to disease, reduced growth, increased competition, and potentially death. Dissolved oxygen is one of the most important water quality parameters controlling fish health (Noga 2011) and can impact development and survival at various life stages from the egg to fry stage (Geist et al. 2006), which can impact growth (Brett and Blackburn 1981, Herrmann et al. 1962) and swimming behavior of juveniles and adults (Davis et al 1963).

3.4.2 Methods

OBMEP - Water Quality Sampling (ID:5)

<https://www.monitoringmethods.org/Protocol/Details/5>

OBMEP – Rapid Habitat Assessment (ID:8)

<https://www.monitoringmethods.org/Protocol/Details/8>

In 2014, water chemistry parameters were collected by OBMEP through the protocols listed above and incorporated into the EDT model. The EDT inputs require a number of water chemistry attributes that were previously not collected at habitat monitoring sites (Table 5) and, consequently, methods were developed to collect those attributes as part of the Rapid Assessment habitat sampling program. Water chemistry testing was also conducted monthly from 2010 through 2012 at 18 sites in the U.S. Okanogan River, Similkameen River, and major tributaries in the subbasin, to obtain baseline readings.

As inputs to the EDT model, a number of water quality “environmental attribute” parameters were collected in previous years using field sampling designs that were not suitable either in terms of seasonal timing or collection methods. In the Canadian portion of the Okanagan, pilot studies were developed for two parameters (dissolved oxygen and turbidity) to assess different sample design options and suitability of results. Dissolved oxygen (DO) was collected at two sites (OBMEP-1251 and OBMEP-535) using two Onset HOBO® U26-001 DO loggers recording at hourly intervals over summer months. Logger results were then compared to results taken from the HANNA HI 9828 Multiparameter taken during the day once a week during the same period (similar to previous years’ methods). Turbidity was collected at 12 sites on six tributaries during spring freshet using two collection methods. Grab samples were collected and sent to a lab (Maxxam) to assess levels of Total Suspended Solids (TSS); at the same time, turbidity was collected using a LaMotte 2020 turbidity meter to collect turbidity in terms of Nephelometric Turbidity Units (NTU). Levels of TSS are required as inputs into the EDT model and the relationship between NTU and TSS varies between watersheds. Turbidity meters and NTUs are generally used due to their ease of use and relatively low cost.

3.4.3 Results and Conclusions

Water quality data were incorporated in the EDT model, and thus, specific results and a comprehensive review will not be presented in this document. Results from DO and turbidity pilot studies are presented in Appendix K.

To date, most collected water quality readings have been within the surface water quality standards set by the Washington State Department of Ecology. The only values that might pose a concern during certain times of the year were nitrates, which are not thoroughly monitored currently. This finding was not surprising given the amount of agriculture, orchards, and livestock in the subbasin. Peer-reviewed literature suggests nitrate levels as low as 2.3-7.6 mg/L-N may induce mortality of Chinook salmon and Rainbow Trout in the egg and fry life stages (Kincheloe et al. 1979). Additionally, sub-lethal effects may include decreased ability of the blood to carry oxygen (anemia), which results in decreased fitness and health. The EDT analysis will include water quality data and assess impacts of the various water quality parameters to Chinook salmon and steelhead at various life stages.

Table 5. List of water quality, temperature, and discharge attributes used to populate the Ecosystem Diagnosis and Treatment (EDT) model and associated measurement status obtained through OBMEP.

	Water Quality (Chemistry) Attribute	Habitat Monitoring Sites	Rapid Assessment
EDT Attribute	<i>Alkalinity</i>	Not measured	Measured
	<i>Dissolved Oxygen</i>	Measured	Not measured
	<i>Metals (in water column)</i>	Not measured	Not measured
	<i>Metals/pollutants (in sediments/soils)</i>	Not measured	Not measured
	<i>Toxic pollutants (in water column)</i>	Not measured	Not measured
	<i>Nutrient enrichment</i>	Not measured	Not measured
Water Temperature Attributes			
EDT Attribute	<i>Daily maximum and minimum</i>	Measured at habitat monitoring sites and discharge sites	Not measured
	<i>Spatial variation</i>	Not measured	Not measured
Water Discharge Attributes			
EDT Attribute	<i>Flow characteristics and hydrologic regime</i>	Measured at established discharge stations (not at habitat monitoring sites and not on all tributaries)	Not measured
	<i>Water withdrawals</i>	Noted	Measured

3.5 Biological Community Monitoring

Two attributes that are associated with the biological community and measured through OBMEP are 1) benthic macroinvertebrate diversity and 2) introduced fish species abundance. In 2014, benthic macroinvertebrate assemblages were collected and assessed at all annual and rotating panel habitat monitoring sites that were not dry. The benthic macroinvertebrate collection methods are listed on [monitoringmethods.org](https://www.monitoringmethods.org) at: <https://www.monitoringmethods.org/CustomizedMethod/Details/11512>. Currently, 2014 samples are still being processed in the lab; however, 2013 data have been processed. A summary of 2013 *Ephemeroptera*, *Plecoptera* and *Trichoptera* (EPT) taxa richness compared to fish species composition, habitat, human influence, and water quality attributes is shown for Canadian sites in Figure 15. Results from macroinvertebrate sampling show that EPT taxa richness was lower in stream reaches with elevated summer water temperatures. Non-native fish species are also more prevalent in streams with lower EPT taxa richness and higher average summer water temperatures.

Introduced fish species abundance was observed through snorkel surveys and electrofishing in 2014. The snorkel sampling methods used are listed above in Section 2.2.2. While results are not listed in this report, specific information requests can be directed to the Colville Tribes' Fish and Wildlife Department, Anadromous Fish Division, 25B Mission Road, Omak, WA 98841, (509) 422-7424.

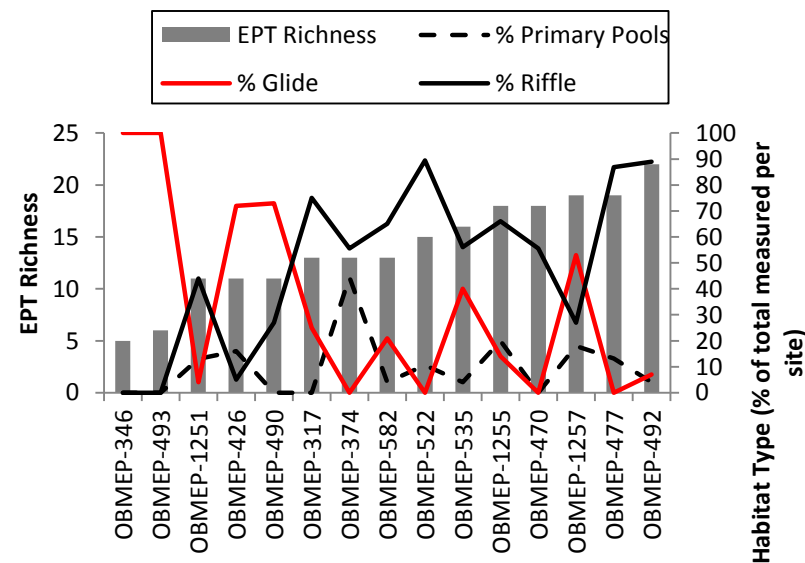
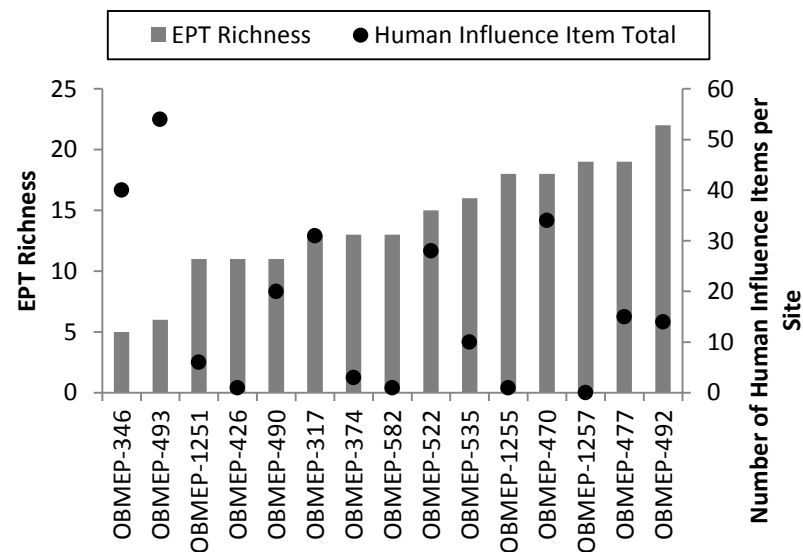
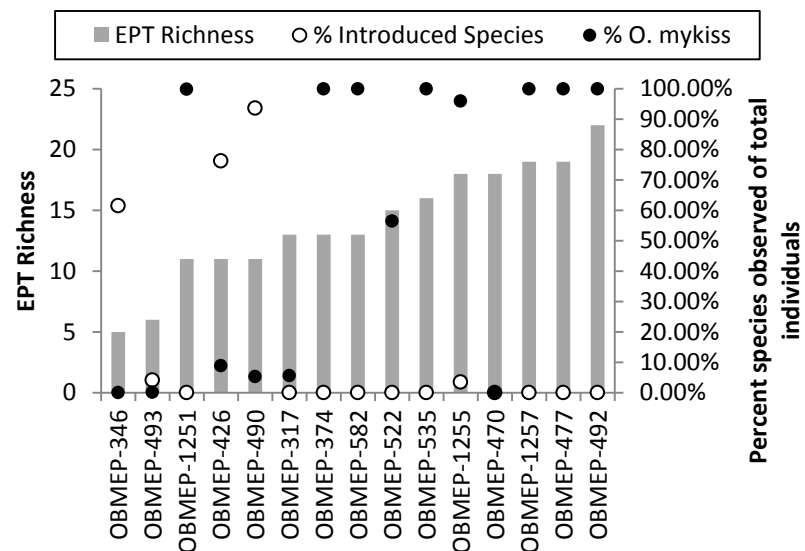
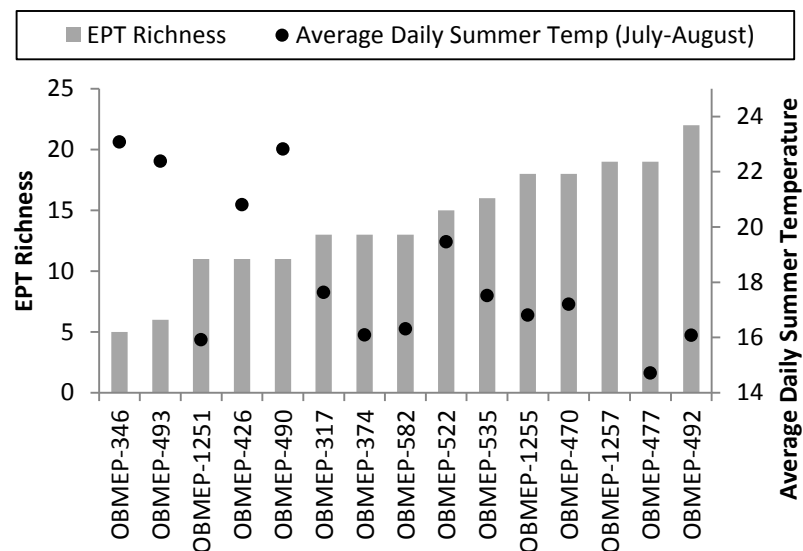


Figure 15. Graphs summarizing benthic macroinvertebrate taxa (Ephemeroptera, Plecoptera and Trichoptera (EPT)) richness compared to fish species composition, habitat, human influence, and water quality parameters for Canadian sites in 2013.

Lessons learned and recommendations for future monitoring of habitat in the Okanogan subbasin:

1. Examine comparability of two current methods of collecting habitat data (transect based and larger scale rapid assessment methods).
 - a. Conduct both methods in a subset of reaches, compare results.
 - b. Examine precision, accuracy, and biases of empirical habitat data.
2. Conduct a focused study on fine sediments in the Okanogan and effects on life stages of steelhead.
 - a. Determine % fines in key spawning reaches using McNeil core samples or other quantifiable methods.
 - b. Document to what degree high % fines in the Okanogan River are limiting factors to mainstem steelhead juvenile production.
3. Collaborate with Intensively Monitored Watershed (IMW) studies to determine if the data from Rapid Habitat Assessments (also known as fluvial audits) and OBMEP Rapid Assessment data are compatible.
 - a. Aligning protocols with other monitoring programs conducting Rapid Assessments may enable the methods to be more widely used across the Columbia Basin.
4. Identify sources of cold water refugia in mainstem reaches of the Okanogan River.
 - a. It is unknown to what extent cold water refugia are utilized by juvenile or adult salmonids during the summer months.
 - b. Does the presence of refugia affect survival?
 - c. Monitor sources and temperature differential of hyporheic flows and identify utilization by salmonids.
5. Identify other analytical tools to assess benthic macroinvertebrate communities and stream health to compare to EDT outputs.
 - a. Currently, benthic macroinvertebrate collection is limited to transect-based habitat sites. There may be a need to expand benthic macroinvertebrate collection to reaches outside of habitat panel sites to include rapid assessment reaches.

4.0 Coordination and Data Management (RM&E)

OBMEP supported the BPA Fish and Wildlife Program data management strategy⁸ to “Work with regional federal, state and tribal agencies, and non-governmental entities to establish a coordinated, standardized, web-based distributed information network and a regional information management strategy for water, fish, and habitat data. Establish necessary administrative agreements to collaboratively implement and maintain the network and strategy.”

BPA Fish and Wildlife Program management question:

How has your work supported exchange and dissemination of fish and wildlife data or the development of a database to manage data that may be shared regionally, relative to the RM&E data management strategies roadmap?

⁸ Coordination and Data Management RM&E - <http://www.cbfish.org/ProgramStrategy.mvc/Summary/8>

1. Identification of Management Questions and Strategies
2. Documentation of Protocols
3. Data Collection and Generation
4. Data Entry
5. Agency Data Storage
6. Regional Sharing
7. Reporting

OBMEP also supported the two following coordination and data management RPAs:

RPA 71.4 - <http://www.cbfish.org/BiologicalOpinionSubAction.mvc/Summary/71/4>

How has your project worked with regional monitoring agencies to track and report on the status of regional fish improvement and fish monitoring projects?

RPA 72.1 - <http://www.cbfish.org/BiologicalOpinionSubAction.mvc/Summary/72/1>

How did your project contribute to the coordination and standardization of information to support the RM&E program and related performance assessments?

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. As a BPA-funded project, OBMEP has been keeping pace with these goals by utilizing tools such as www.monitoringmethods.org to document and standardize protocols, developing electronic methods for data collection, review, transfer, and storage. A data steward was hired to integrate common data elements developed in the Coordinated Assessments with OBMEP's internal database. 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 at PIT tag arrays) are made available on the OBMEP website at:

http://www.colvilletribes.com/obmep_project_data.php

OBMEP has made significant gains in coordinating, standardizing, and disseminating data which support the RM&E program. When OBMEP began in 2004, data were collected almost entirely on paper data sheets, entered into Microsoft (MS) Excel and stored on local computers. At the end of 2006, OBMEP was using a MS Access database to archive and run basic queries on the data. Some data were collected on Trimble handheld GPS units or hand-written data forms and entered in to the database through custom entry forms or by appending MS Excel tables to the database tables. However, data flow was not automated and contained many opportunities for translation errors to occur. Towards the end of 2011, OBMEP began implementing a comprehensive data management system (DMS) to automate data flows and improve efficiencies, and enable a web-based distributed information system. The DMS includes software for web-accessible data storage (MS SQL Server 2008) and custom templates and interfaces (MS ASP.NET) for data collection, QA/QC of the data, and analysis and reporting.

In 2014, OBMEP continued to use a custom habitat data collection template installed on Trimble Yuma ruggedized tablet computers. Data were entered in the template as they were being collected in the field, and the data were then synchronized with the database when the Yuma was connected to CCT's network. Once in the database, data were QA/QC'd by biologists in a custom desktop interface application, which displayed the habitat data in tabular format, similar to a MS Excel spreadsheet. Within the desktop interface, there are multiple options for sorting and querying the data, with an option to export data into other formats such as MS Excel or Adobe PDF. This interface was intended to be further developed into a web-accessible interface available to outside agencies, who may wish to query and obtain portions of OBMEP data.

In working with regional monitoring agencies to track and report the status of regional fish monitoring projects, OBMEP submitted data such as adult steelhead fish passage, redd survey escapement estimates, and snorkel survey juvenile abundance estimates to regional data forums including DART, PTAGIS, and Streamnet. Additionally, OBMEP has been involved since 2010 in the Coordinated Assessment process, whose goal is to involve agencies and Tribes who collect salmon and steelhead data in the management and use of their data when used in higher-level, population assessments and regional reporting efforts (i.e. NOAA's Salmon Population Summary and BPA's BiOp Annual & Comprehensive Evaluation). In 2014, OBMEP's data steward was able to share the indicator of natural origin spawner abundance (NOSA) with Streamnet, making the CCT the first Tribe or agency to do so. OBMEP also sub-contracted with Sitka Technology to continue assisting with tasks related to the Coordinated Assessment process and share relevant indicators, develop electronic methods for data collection, review, transfer, and storage. OBMEP will continue to fully participate in the Coordinated Assessments project as other types of data undergo compilation, transformation, and exchange. Managers should continue to support the development of whole data systems which include study design development, data collection, QA/QC of the data, storage of raw data, and automating standard calculations.

OBMEP staff have frequently been involved in local and regional meetings, conferences, and workshops. Data collected by the program have been commonly requested to be presented at these events, which are used for both informative and management decisions. Some of the forums in which OBMEP staff contributed to in 2014 included:

- Columbia Cascade Regional Fisheries Enhancement Group
- Upper Columbia Regional Technical Team
- Canadian Okanagan Basin Technical Working Group (COBTWG)
- Bilateral Okanagan Basin Technical Working Group (BOBTWG)
- Okanogan Irrigation District board meetings
- Regional Fisheries Enhancement Group Advisory Board and Coalition
- PNAMP Habitat Metric meetings
- American Fisheries Society, WA-BC
- Presentations to NPCC related to habitat status and trend reporting tool
- Lake Osoyoos Board of Control Fisheries Advisory meeting
- PNAMP Steering Committee
- Okanogan River Watershed Action Team meetings
- PNAMP Data Management Leadership Team
- Action Agencies Expert Panel
- Regional Coordinated Assessment Project
- Collaboration with WDFW on Okanogan PIT tag interrogation system
- Upper Columbia Science Conference
- PITAGIS Remote Array Subcommittee
- USGS Stream Gaging and GRSAT software training

- American Water Resources Association, Annual Water Resources Conference
- Presentations to local clubs, groups, and organizations

OBMEP has learned some valuable lessons in electronic data collection that others should consider, before investing significant time and effort in developing customized solutions to meet their needs. For example, if a particular device (i.e. and Apple iPad) is being considered, it is important to consider if it will be used to collect only one kind of data, or if multiple types of data will be collected and if the device is compatible with currently-owned solutions or equipment. For example, OBMEP collects a variety of data for various program goals (i.e. habitat data via a custom template, temperature logger downloads with Onset Hoboware Pro, PIT tag array diagnostics through Campbell Scientific Loggernet Remote, Vemco VUE software for acoustic tags, PTAGIS P3 software for remote electrofishing and PIT tagging studies). A benefit was found in using Trimble Yuma tablets with Windows 7 software, because many OBMEP projects use out-of-the-box software designed only for Windows platforms. Furthermore, integration of currently-owned Trimble GeoXT GPS's (with sub-centimeter accuracy) or Destron-Fearing PIT tag readers, was possible with the Yuma, which has Bluetooth, USB, and COM ports to accommodate peripheral devices. Other programs should weigh the cost/benefit of purchasing a less expensive device and then paying for customized software versus purchasing a more expensive device that can run existing software and can meet multiple program needs.

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.

5.0 Synthesis of Findings: Discussion/Conclusions

Status and trend monitoring in the Okanogan subbasin was conducted to support the Bonneville Power Administration (BPA) Fish and Wildlife management sub-strategies. These strategies help provide answers to key Fish and Wildlife Program management questions, which are listed below, along with a summary of indicators and findings from monitoring activities over the past 10 years.

1. *What are the status and trend of abundance of natural and hatchery origin fish populations?*
 - The 10-year mean (2005-2014) for total summer steelhead in the Okanogan subbasin was estimated at 1,818 and ranged from 899 to 3,496.
 - The 10-year mean (2005-2014) for natural origin summer steelhead was estimated at 309 and ranged from 146 to 728.
 - The NOAA recovery goal of 1,000 natural origin spawners for the subbasin was not reached over the past 10 years.
 - From 2005 to 2014, the trend in number of natural origin spawners increased at an average rate of 33 fish per year.
 - The trend in hatchery origin spawners increased from 2005-2010, but declined from 2012-2014.

- The proportion of natural origin spawners (pNOS) averaged 0.15 from 2005 through 2013, but increased to 0.38 in 2014.
2. *What are the status and trend of juvenile abundance and productivity of fish populations?*
- In Washington State, from 2004 to 2014, 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 a slight upward trend in Bonaparte Creek), but remained near or at zero for nearly all mainstem Okanogan River survey sites.
 - In British Columbia, from 2005 to 2014, the trend in total abundance of juvenile *O. mykiss* at annual tributary monitoring sites increased in Shingle Creek, had a slight upward trend in Inkaneep Creek, Shuttleworth Creek, and Vaseux Creek, remained level in McLean Creek, and decreased slightly in Ellis Creek. Abundance at annual survey sites in the British Columbia mainstem Okanogan River remained low, averaging only 3.6 fish/ha, which was higher than in the Washington State portion of the Okanogan River.
 - 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, but very few captures of naturally produced steelhead yielded highly variable and unreliable estimates for that species. Due to this, outmigration (fish-out) monitoring was challenging.
 - A new long-term monitoring research project began in 2014 in the Washington State portion of the subbasin designed to address abundance, distribution, and productivity of steelhead (outlined in Section 2.2.3). In future years, this project may also be expanded to the British Columbia portion of the subbasin. Preliminary analyses of the data appear to be promising and final results will be made available in future reports.
3. *What are the status and trend of spatial distribution of fish populations?*
- a. Adult Steelhead
- Summer steelhead spawning occurs throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities.
 - The proportion of steelhead spawning in tributaries appeared to be regulated in part by stream discharge, which was influenced by spring time precipitation in small creeks, timing of runoff in relation to run timing of steelhead, surface water diversions, and corresponding changes in flows.
 - The 10-year average proportion of natural origin spawners was lower for the mainstem Okanogan River (0.10) compared with tributaries (0.23) in the Washington State portion of the subbasin.
 - A relatively small proportion of the total adult steelhead pass into British Columbia, averaging 2% for 2013 and 2014; however, average pNOS was much higher in British Columbia (0.75) compared with Washington State (0.24) during that timeframe.
- b. Juvenile Steelhead
- Snorkel surveys conducted during summer base-flow periods show considerably higher densities of juvenile *O. mykiss* in tributaries compared with the mainstem Okanogan River. This finding remained constant over 10 years of data collection.
 - Preliminary PIT tag data suggest that juvenile *O. mykiss* may utilize the mainstem in the fall, winter, and spring seasons, although these findings are not quantifiable at this time.
 - In all tributary stream reaches available to anadromous fish, three streams contained 90.7% of the juvenile *O. mykiss* in the Washington State portion of the subbasin in 2014 (Loup Loup Creek (15.5%), Salmon Creek (53.3%), and lower Omak Creek (21.9%)). The six remaining streams sampled contained a combined 9.3%.

4. *What are the status and trend of diversity of natural and hatchery origin fish populations?*
 - For adult steelhead during the spring, combined PIT tag data from 2011-2014 suggest that the date when 50% of the run passed into British Columbia occurred three weeks earlier for natural origin steelhead when compared with hatchery steelhead (interrogation site OKC).
 - PIT tag detections suggest that adult steelhead enter Omak Creek two to three weeks earlier in the spring, compared with all other tributaries.
 - Investigations through mark-recapture electrofishing and PIT tags are attempting to quantify anadromous and resident life history strategies and migration timing of juvenile *O. mykiss* in the U.S. portion of the subbasin. These results will be made available in future reports.
5. *What are the tributary habitat limiting factors (ecological impairments) or threats preventing the achievement of desired tributary habitat performance objectives?*
 - Fine sediments represented a limiting factor in the EDT model in most mainstem reaches in the Okanogan subbasin.
 - EDT results suggested that stream flows in Salmon Creek were impaired by 69%, which represented the most heavily weighted limiting factor for that diagnostic unit. Uncontrolled water releases can scour redds and low over-winter flows limit habitat for juvenile rearing steelhead. The Salmon Creek is frequently dry in the lower reach, from the OID diversion to the confluence with the Okanogan River, which limits adult access and juvenile emigration timing.
 - Physical barriers or impediments limit the extent of stream kilometers available to anadromous fish in the subbasin. Streams that are most affected by impediments include Johnson and Antoine Creeks in Washington State.
 - 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. High water temperatures in the mainstem, which can exceed 24°C during the summer months, likely limits distribution during that timeframe. Water temperature may also be limiting to a lesser extent in some tributaries.
 - Predation was indicated as an important limiting factor in the EDT model results for the mainstem Okanogan River, although empirical data related to predator abundance and salmonid consumption have not been collected to date.

With the listing of several salmonid species within the Columbia River Basin as threatened or endangered under the Endangered Species Act (ESA), federal, state, tribal, and other entities have made considerable investments in salmon population monitoring and habitat restoration. Tracking status of salmon populations as they relate to habitat capacity and limiting factors remains an important part of determining if conditions are improving. From 2005 to 2014, biological data corresponding to adult and juvenile steelhead abundance and spatial and temporal distribution have been collected, which greatly increased the amount of information available for the Okanogan subbasin. Additional monitoring efforts included physical habitat measurements, water quality, temperature, and discharge data, which were used to identify specific limiting factors for salmonids. Over the long-term, status data are used to examine trends, which may indicate if salmon populations and respective habitats are improving. Future monitoring will continue to support validation of trends, while some modifications of protocols may be needed to evaluate identified uncertainties.

The overall outcome of monitoring in the Okanogan subbasin is to guide natural resource managers' decisions to minimize threats to salmon, choose restoration actions that will have the most positive impact, and set measurable salmon enhancement objectives to coincide with fiscal investments over multiple jurisdictions. Salmon 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 analysis.

5.1 Overview of Recommendations for Management Programs

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. Outlined in this document and the accompanying EDT reports are a number of factors that may be limiting recovery of salmonids within the Okanogan subbasin, although the specific focus of this research has been primarily on summer steelhead. Subsequent recommendations to habitat practitioners are included throughout these documents, which were derived from 10 years of monitoring data, analyses, and extensive professional experience working in the field. Due to the length of these reports, an overview of recommendations by sub-watershed has been assembled in Table 6. This summary table is not all-inclusive, but rather, it provides a starting place for readers to pursue further information within the Okanogan subbasin EDT reports and supplementary analyses. The Colville Tribes recently submitted a Hatchery Genetic Management Plan (HGMP) for a proposed summer steelhead conservation program (Broodstock Acclimation Program). Extensive analysis and recommendations concerning hatchery management are covered in the HGMP, and therefore, hatchery related recommendations discussed in this document are limited to high-level statements.

Although monitoring results and indicators 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). Monitoring staff can be contacted directly if more specific data or analyses are needed.

Table 6. Summary recommendations for management programs, by sub-watershed.

Sub-watershed	Approx. num. of stream KM (GIS) available to anad. salmonids *	Estimated number of total steelhead spawners (natural origin)			Estimated template summer steelhead capacity from EDT (CCT 2013)	Observations and Monitoring Recommendations
		Min.	Avg.	Max.		
Chiliwist Creek	0.6	NA	NA	NA	2	No actions should be taken at this time. Benefits are uncertain and landowners may be unwilling to participate in restoration.
Loup Loup Creek	3.4	0	38 (9)	125 (27)	26	Past projects to restore perennial flow by changing the point of diversion in 2012 appear to have been successful. The number of juvenile steelhead observed in the creek has been greatly increasing over the past five years, likely due to recent flow and passage improvements. From this, increases in natural origin adults may be anticipated in the future. Recommendations focus around continuing to pursue projects that maintain and enhance year-round flow. Additionally, improvements to instream complexity would enhance spawning and rearing habitat quality.
Salmon Creek	27.9	0	160 (28)	308 (53)	326	<p>Salmon Creek contains a significant amount of the tributary habitat found in the US portion of the Okanogan subbasin; projects should continue to facilitate instream flows below the Okanogan Irr. Dist. diversion, which is paramount for adult and juvenile migration. Additional improvements to water management could improve egg incubation success and increase overwintering habitat in the upper reaches. There may be a need to evaluate effectiveness of the irrigation diversion fish screens, which currently may allow juveniles to become entrained in the irrigation canal.</p> <p>The number of hatchery and natural origin adult steelhead entering Salmon Creek has been increasing over the past 10 years of monitoring. Although hatchery programs are continuing to plant hatchery raised juveniles into the creek to accelerate habitat usage, the number of natural origin adult steelhead entering the creek should continue to be monitored annually. When recovery goals are being approached, stocking should be proportionally reduced or ceased to reduce competition with natural origin fish. Alternatively, operation of a weir trap could facilitate management of returning hatchery origin adults.</p>
Omak Creek (below Mission Falls)	9.2	71 (6)	204 (67)	393 (220)	93	No specific recommendations for habitat implementation programs at this time. See Omak Creek (above Mission Falls). Recommendations for hatchery origin steelhead management in Omak Creek are specifically detailed in the HGMP. Management programs should continue to reduce influence of hatchery adults through the adult weir trap.
Omak Creek (above Mission Falls)	38.8	9	NA	NA	NA	In 2014, adult steelhead were documented above Mission Falls for the first time. The habitat above the falls represents an approximate 81% increase in stream length available to anadromous fish in the watershed. Upper Omak Cr was not analyzed in the last EDT model run; however, habitat data collected over the past 10 years suggest sufficient habitat likely exists. Habitat projects should focus on fine sediment reduction and protection actions. Although hatchery programs are stocking locally

						adapted WxW juveniles into the creek, the number of natural origin adults should continue to be monitored annually. When recovery goals are being approached, stocking should be proportionally reduced or ceased to reduce competition with natural origin fish.
Wanacut Creek	2.5	0	3 (1)	12 (4)	16	No actions should be taken at this time.
Johnson Creek †	0.5 or 16.1	18 (2)	34 (8)	57 (19)	21	Past habitat surveys were limited to the lower canyon portion of the creek, no systematic habitat surveys have occurred upstream to date. Two probable impediments have been documented on lower Johnson Creek. Other potential impediments upstream have not been surveyed at this time.
Tunk Creek	1.2	2 (0)	42 (10)	109 (44)	6	No actions should be taken at this time.
Aeneas Creek	0.4	NA	NA	3 ‡ (1)	13	After habitat implementation projects occurred in 2012, adult steelhead redds were observed in the creek for the first time in 2014. The current extent of upstream passage is likely at the highway culvert, approx. 0.4 km from the confluence. Juvenile surveys, conducted for the first time in 2012, noted low densities of salmonids. This may be due to newly utilized habitat after recent habitat projects. No additional actions should be taken at this time.
Bonaparte Creek	1.7	12 (6)	96 (30)	204 (71)	16	No actions should be taken at this time.
Siwash Creek	2.9	0	0	0	44	No actions should be taken at this time.
Antoine Creek (Lower)	1.4	0	4 (1)	31 (8)	10	Over the past 9 years of monitoring, very few adult steelhead have been documented in the creek, potentially due to an impediment near the confluence of the creek, or low spring time instream flows. To increase steelhead abundance in this stream, projects should focus on instream flow issues and the fish passage impediment (head-cut) near the mouth of the creek. Also see Antoine Creek (Upper).
Antoine Creek (Upper)	17.7	NA	NA	NA	80	A passage impediment (diversion dam) was retrofitted in 2013, greatly increasing the number of stream km's available to anadromous fish. However, utilization of this new habitat is expected to be low until instream flows and other impediments are addressed.
Wildhorse Spring Creek	1.8	0	57 (9)	278 (48)	6	Out of all surveyed tributaries, WHS Creek has been documented to have the lowest summer-time water temperatures; however, very limited habitat exists during summer base-flow, including lower reaches that dry-up annually. On years when the creek has sufficient spring flows to allow adult access, significant numbers of adults have been documented spawning in this creek. Because of its ephemeral nature in the lower reaches and the over-allocation of adults that can spawn in the creek, proportionally, this system is not expected to produce many out-migrants. No stocking should occur, but in years with sufficient spring time flows, broodstock could be collected here to prevent spawners from stranding their progeny and help transition the hatchery program to 100% natural origin broodstock (refer to the HGMP).
Whitestone Creek §	NA §	NA	NA	NA	NA	Comprehensive habitat surveys have not been conducted on Whitestone Creek to date; the upstream extent is not known. This creek is known to have particularly high spring and summer water temperatures. Aside from monitoring, no additional actions should be taken at this time.
Tonasket Creek	3.3	0	34 (7)	75 (28)	17	Tonasket Creek dries up annually in the lower reaches, although adult and juvenile steelhead are known to exist in the upper reaches. Based on the stream flows observed over the past years of monitoring, this creek has little summer rearing habitat, relative to the number of adult spawners annually. If any habitat projects are to occur, instream flow would have to be a focus.

Ninemile Creek	8.4	3 (1)	29 (8)	77 (18)	87	A long section in the middle reaches of this creek go dry or flow subsurface annually, which likely limits any significant contribution to steelhead populations. It is unknown if this is a natural occurrence, although it should be noted that the catchment size of the watershed is a relatively small 55 km ² in a semi-arid shrub-steppe. Ninemile Creek was identified in the HGMP as a creek to measure natural colonization rates and is not scheduled to receive direct supplementation in the foreseeable future. No actions should be taken at this time.
Okanogan River (US only)	143.6	302 (27)	742 (72)	1,327 (120)	2,551 ¶	The mainstem Okanogan River has persistently high summer water temperatures, which may limit salmonid habitat use during that season. The mainstem is also dominated by fine sediments; potential habitat projects could focus on fine sediment management, including projects that build islands or reconnect floodplains, particularly in reaches near spawning areas. Mainstem hatchery supplementation has been limited to the Similkameen River; no actions should be taken at this time.
Similkameen River	16.5	123 (13)	300 (30)	514 (47)	431	Potential habitat projects could focus on fine sediment management, including projects that build islands or reconnect floodplains, particularly in reaches near spawning areas. Current management calls for all hatchery steelhead not planned for release into a tributary stream to be released in the vicinity of the WDFW Acclimation Site on the Similkameen River; no additional actions should be taken at this time.
All US habitat	282.6	666 (63)	1,653 (263)	2,672 (616)	3,743 ¶	Habitat implementation projects over the past few years has reconnected or made accessible a significant amount of habitat for anadromous fish. The focus should continue to be on tributary habitats, particularly those with a sufficient biological capacity to support juvenile rearing, including Loup Loup, Salmon, Omak, and Antoine Creeks (refer to Section 2.2, Juvenile Salmonid Monitoring). The NOAA recovery criteria of 500 natural origin adults for the US portion or 1,000 natural origin adults for the entire subbasin has not been reached. Although hatchery programs are continuing to plant hatchery raised juveniles, the number of natural origin adults entering priority creeks has been increasing and should continue to be monitored annually. When recovery goals are being approached, stocking should be reduced proportionally or ceased, as outlined in the HGMP, to reduce competition with natural origin fish.

* Total habitat available as of 2014, calculated through a GIS shapefile; GIS stream lengths are known to be bias low, so actual lengths are likely longer.

† Only three years of data available, 2012-2014.

‡ Only two years of data available, 2013-2014, but no assumed spawning before this year due to large impediments near the mouth.

§ Whitestone Creek has not been systematically surveyed to date.

¶ The total mainstem summer steelhead capacity is likely an over estimate because the model is not currently factoring juvenile steelhead response to water temperature accurately; this issue will be addressed in the next EDT report.

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Appendix A: Use of Data & Products

1. Identify the database, web-links, or documented sources for related data sets for the project.

Data collected under the Okanogan Basin Monitoring and Evaluation Program are stored in a MS SQL Server database. Data requests can be referred to Jennifer Miller (509-422-7733). Additional information about the OBMEP database can be found in chapter 4.0: Coordination and Data Management (RM&E).

- Redd survey and snorkel survey data available at www.streamnet.org
- Redd survey shapefiles, GIS files, and temperature files from PIT tag arrays are available at http://cctobmep.com/obmep_project_data.php
- Fish counts at Zosel Dam have been occasionally uploaded to the D.A.R.T. webpage at <http://www.cbr.washington.edu/dart>
- Juvenile and adult steelhead PIT tag detections are immediately uploaded and available at www.ptagis.org

Website links 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
- WA DOE gage at Bonaparte Creek at Tonasket: <https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?sta=49F070>

2. Identify citations for other technical reports produced/published using data collected or evaluated by this project in the calendar year that could be included in potential review.

OBMEP. 2015. 2014 Okanogan Subbasin Steelhead Escapement and Spawning Distribution. Colville Confederated Tribes Fish and Wildlife Department, Nespelem, WA. Report submitted to the Bonneville Power Administration, Project No. 2003-022-00.

Appendix B: Adult Abundance Metrics and Indicators

Adult Abundance Metrics

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Fish	Abundance of Fish	Fish Life Stage: Adult Fish	Fish Origin: Both	Fish Abundance
Fish	Density of Fish Species	Fish Life Stage: Adult Fish	N/A	Fish Abundance
Fish	Distribution of Fish Species	Fish Life Stage: Adult Returner	N/A	Fish Abundance
Fish	Distribution of Fish Species	Fish Life Stage: Adult Spawner	N/A	Fish Abundance
Fish	Length: Fish Species	Fish Life Stage: Adult Fish	N/A	Fish Length
Fish	Migration Pathways: Fish	Fish Life Stage: Adult Returner	N/A	PIT Tag Detections
Fish	Origin		N/A	Origin
Fish	Presence/Absence: Fish	Fish Life Stage: Adult Returner	N/A	Adult Distribution
Fish	Sex Ratio: Fish	Fish Life Stage: Adult Returner	N/A	Fish Sex
Fish	Sex Ratio: Fish	Fish Life Stage: Adult Spawner	N/A	Fish Sex
Fish	Timing of Life Stage: Fish	Fish Life Stage: Adult Returner	N/A	Run Timing
Fish	Tissue Sample: Fish	Fish Life Stage: Adult Fish	N/A	Scale Sample
Other	Location	Fish Origin: Both	N/A	Redd GPS Location
Time	Date	N/A	N/A	Date

Adult Abundance Indicators

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Fish	Abundance of Fish	Fish Life Stage: Adult Spawner	Fish Origin: Both	Spawner Abundance

Appendix C: Underwater Video Monitoring at Zosel Dam

Introduction

Underwater video can be used to enumerate fish passing certain points in a river system without having to handle them, which is an ideal solution for monitoring fish without causing further handling stress. Underwater video observations allow the program to monitor seasonal run timing of salmonids and estimate run abundance, in certain species, by sex and origin. OBMEP operates several underwater video counting stations, primarily focused to enumerate adult steelhead, although all species of fish are recorded passing monitoring sites.

Methods

OBMEP - Adult Abundance - Adult Weir and Video Array (ID:6)

<https://www.monitoringmethods.org/Protocol/Details/6>

Underwater video monitoring was conducted on the mainstem Okanogan River at Zosel Dam, just south of the Canadian border, and the tributaries of Salmon and Antoine creeks. For Chinook Salmon, fish estimated at 22 inches or under relative to the known size of an object in the counting box were considered jacks (i.e. same length used at Bonneville Dam fish viewing window). Salmon were also classified as natural or hatchery origin when the presence or absence of an adipose fin was identified. Results for steelhead are summarized in the annual Okanogan Subbasin Steelhead Escapement and Spawning Distribution report (OBMEP 2015), and will not be presented here.

There were several ways fish observations were missed, resulting in inaccurate counts. Video systems may have been temporarily removed for short durations during the mid-winter (a time when very limited or no fish movement occurs) or for routine maintenance and cleaning. To estimate missed fish during this time, an average was taken of passage events during the hour before and after the boxes were removed. Additionally, when the undershot spillway gates at Zosel Dam were raised to a height of more than 12 inches, an unknown number of fish may have swam through the spillways and bypassed the fishway monitoring systems.

Fish may also be overestimated when individuals ascend the fishway, fall back through the spillway, and ascend through the fishway again. An adult fallback and re-ascension adjustment was calculated using an algorithm on the DART website, developed by Brian Burke at the Northwest Fisheries Science Center, NOAA. A successful ascension was determined when a PIT tagged fish was detected on both the downstream and upstream antenna in a fishway in that order. If the same fish was detected again ascending 15 minutes later, it was considered a separate ascension. If the fish was detected multiple times on both upstream and downstream antennas within a 15 minute period, and was last detected on the downstream antenna, it was not considered an ascent. If the fish was only detected once or multiple times on one antenna, it was not considered an ascent. An adult fallback adjustment (AFA) was calculated as the ratio of the number of unique PIT tagged fish (N_{PIT}) ascending the fishways, divided by the total number of their ascents:

$$\widehat{AFA} = \frac{N_{PIT}}{\sum_{i=1}^{N_{PIT}} a_i}$$

where,

N_{PIT} = number of unique PIT-tagged fish ascending the ladder(s),

a_i = number of ascents made by the i th PIT-tagged fish ($i = 1, \dots, N_{PIT}$).

The video count (C) multiplied by the AFA provided an estimate of the total adult passage abundance (N):

$$\hat{N} = C \cdot \hat{AFA}$$

In 2014, a record Sockeye run was enumerated at Zosel Dam using a subsample counting technique. Instead of viewing all footage, viewers watched 20 minutes of each hour in evenly spaced, 5-minute increments. Counts were then expanded for the entire hour. A linear regression comparing complete hourly counts to subsample estimates suggested the subsample estimate was an excellent predictor of the true count ($p < 0.001$) (Figure C1).

Underwater video data are compiled on the OBMEP server located at the Colville Tribes, Fish and Wildlife office in Omak, WA. Specific information requests can be directed to the Colville Tribes' Fish and Wildlife Department, Anadromous Fish Division, 25B Mission Rd., Omak, WA 98841, (509) 422-7733.

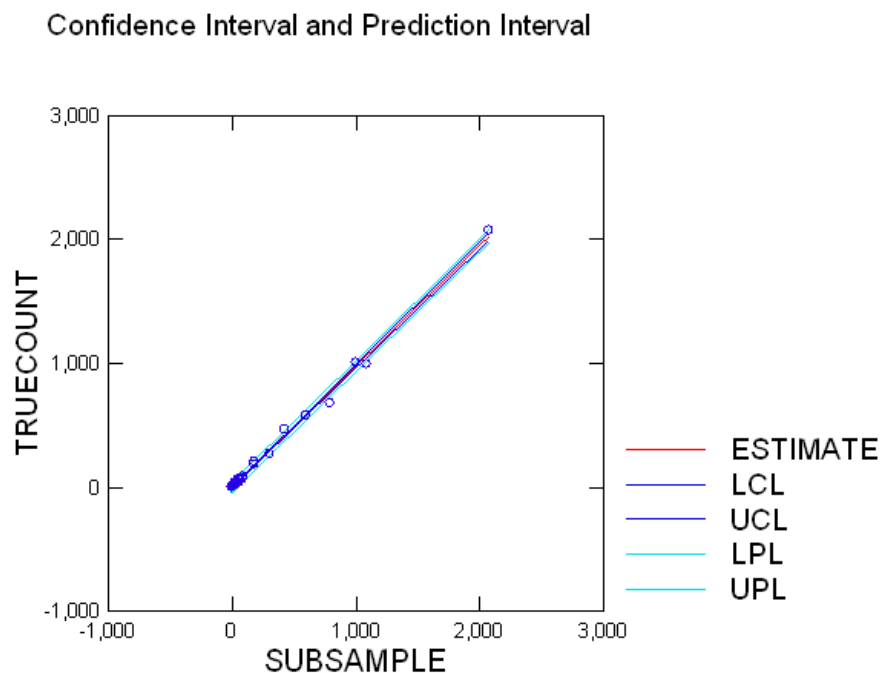


Figure C1. Linear regression analysis for Zosel Dam Sockeye subsampling. LCL and UCL stand for lower and upper confidence level, and LPL and UPL stand for lower and upper prediction limit.

Results

Over the past 10 years of underwater video monitoring, the most common *Oncorhynchus* sp. observed passing Zosel Dam include Sockeye and Chinook salmon, steelhead/Rainbow Trout, and Coho salmon (first observed in 2011). Various frequently counted non target species include northern pikeminnow (*Ptychocheilus oregonensis*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*M. salmoides*), carp (*Cyprinus* sp.), suckers (*Catostomus* sp.), bluegill (*Lepomis macrochirus*), mountain whitefish (*Prosopium williamsoni*), peamouth (*Mylocheilus caurinus*), chiselmouth (*Acrocheilus alutaceus*), yellow perch (*Perca flavescens*), and extremely rare observations of Bull Trout (*Salvelinus confluentus*). No sturgeon or pacific lamprey have been observed in the Zosel Dam underwater video array.

A total of 1,976 Chinook Salmon were observed passing Zosel Dam in 2014, of which 1,614 were adults and 362 were jacks (Figure 7). When adjusted for fallback, the total count was adjusted to 1,253. An estimated 22 fish were missed when video equipment was pulled out of the water for weekly cleaning, so the final adjusted count was 1,275 Chinook. Figure C2 represents observed counts unadjusted for fallback rates from all years, as they were reported to DART.

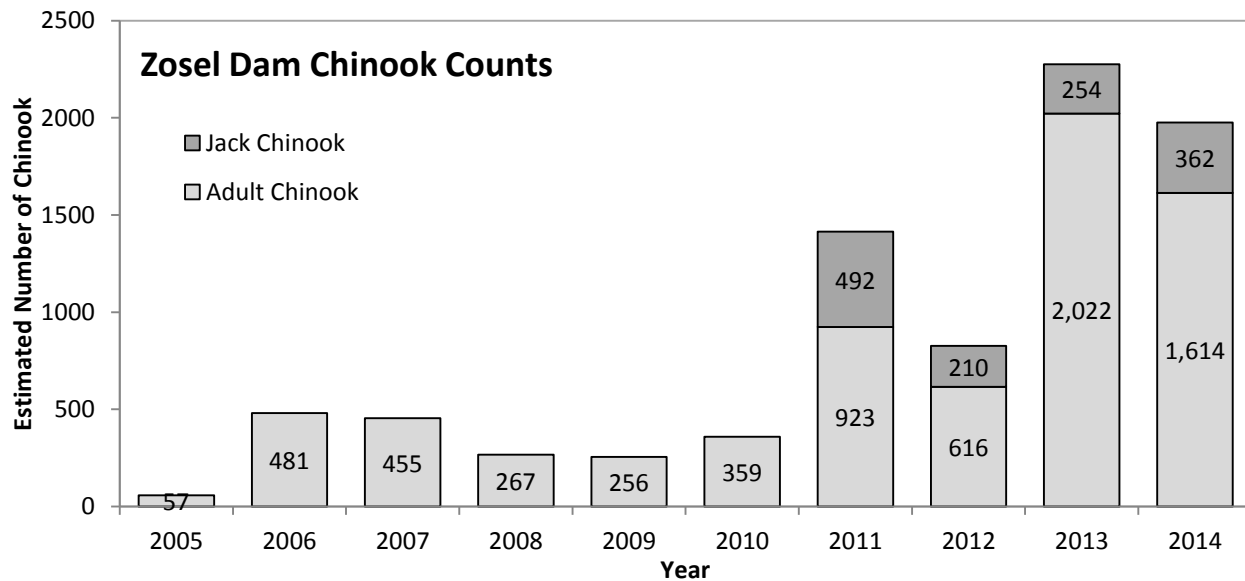


Figure C2. Zosel Dam Chinook counts for the years 2005 through 2014. Beginning in 2011, viewers divided observations into adult Chinook and jack Chinook.

The Sockeye run peaked on July 25, when 72,245 Sockeye were observed passing Zosel Dam (Figure C3), more than double a single day's count at all other dams on the Columbia River. The total number of fish observed passing the system was 325,277. After adjusting for recension, the corrected count was 312,166 passing upstream. Additionally, an estimated 2,696 sockeye passed when video equipment was pulled out of the water for weekly cleaning and an estimated 2,000 Sockeye were missed on July 24 when the spillway gates were opened for 15 minutes to allow for unimpeded passage. Therefore, a total of 316,862 Sockeye were estimated to have passed Zosel Dam. Daily passage presented in Figure C3 represents observed counts unadjusted for fallback rates.

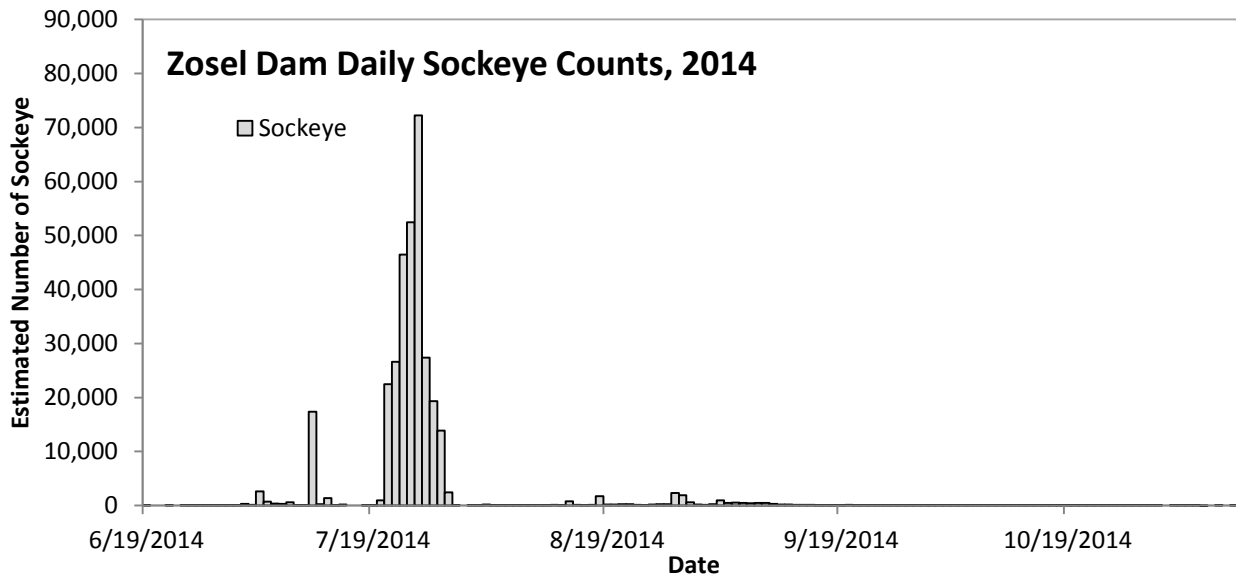


Figure C3. Zosel Dam underwater video counts for Sockeye, 2014; the run peaked on July 25.

Coho Salmon have been observed in the Zosel Dam underwater video system, but only since 2011 (Figure C4). In 2014, 80 Coho were observed passing upstream through the Zosel Dam video array and the peak occurred on October 24. When adjusted for fallback, a total of only 46 Coho passed upstream. Figure C4 includes Coho counts which have been adjusted for fallback/re-ascension. Coho have been extirpated from the Okanogan subbasin for many years and are only reappearing recently due to a hatchery reintroduction program in the Methow River. It is unknown if adults are spawning successfully and producing offspring.

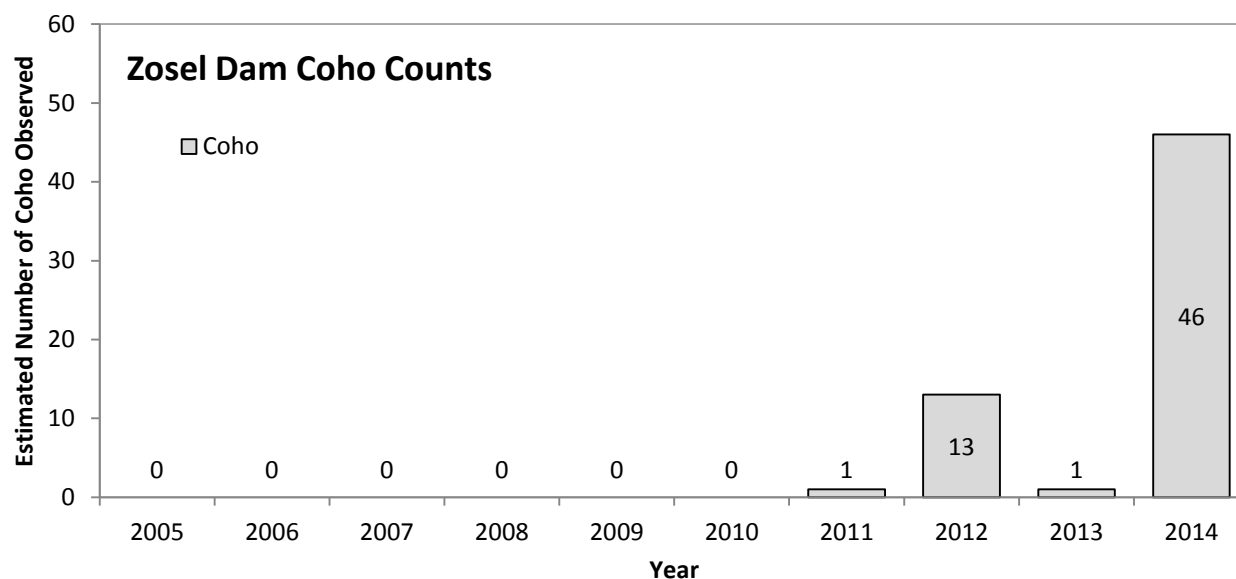


Figure C4. The Zosel Dam underwater video Coho counts adjusted for fallback/re-ascension for the years 2005 through 2014.

Conclusions

Underwater video observation provided a means to easily identify fish, in some species by sex and origin, and to document salmonid run timing in the subbasin. Video counts are used in combination with other methods of enumeration and can provide fish counts in case other methods fail. Underwater video has the capability to document fish that are not tagged and where no other means exist to document abundance. This method can also be used to validate PIT tag expansion estimates. However, in-river conditions some years have resulted in not all fish being observed due to turbid water conditions. When this occurs, census counts are incomplete. In addition, fallback rates are only now beginning to be factored in to the results at Zosel Dam.

Appendix D: Adult Steelhead Enumeration in Canada

Calculation of adult steelhead spawners in the Canadian portion of the Okanogan subbasin

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 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 D1. Abundance estimates of steelhead passage at OKC antenna array on the qawsitk^w (Okanogan River) upstream of suwiws (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

* 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.

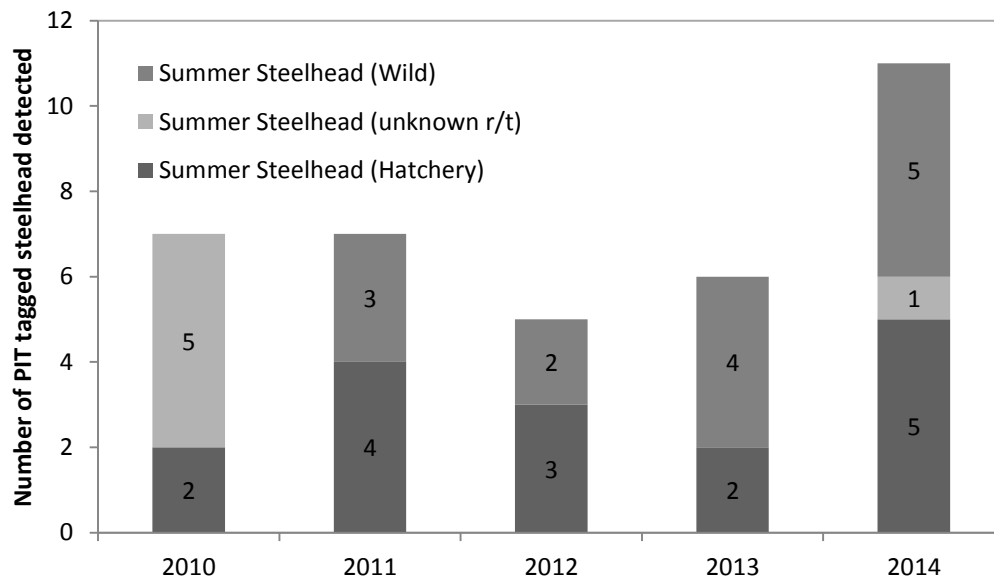


Figure D1. Graph of steelhead PIT tag detections by year at Okanagan Channel (OKC) at VDS 3 broken down for hatchery and wild fish.

Table D2. 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

*Data from the Fish Passage Center website, fpc.org

**Data provided by WDFW (Ben Truscott, WDFW, pers com)

Appendix E: Juvenile Abundance Metrics and Indicators

Juvenile Abundance Metrics

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Fish	Abundance of Fish	Fish Life Stage: Juvenile Fish	Fish Origin: Both	Abundance of Fish
Fish	Abundance of Fish	Fish Life Stage: Adult Fish	Fish Origin: Both	Abundance of Fish
Fish	Density of Fish Species	Fish Life Stage: Juvenile Fish	N/A	Density of Fish Species
Fish	Density of Fish Species	Fish Life Stage: Adult Fish	N/A	Density of Fish Species
Fish	Genetics: Fish Diversity, Fitness or Variation	Fish Origin: Both	N/A	Scale Sample
Fish	Length: Fish Species	Fish Life Stage: Juvenile Fish	N/A	Length
Fish	Length: Fish Species	Fish Life Stage: Juvenile Fish	N/A	Length Categories
Fish	Length: Fish Species	Fish Life Stage: Adult Fish	N/A	Length Categories
Fish	Mark/Tag Application		N/A	Marking
Fish	Mark/Tag Recovery	Habitat Type: Channel: Pools	N/A	Recapture
Fish	Origin		N/A	Origin
Fish	Presence/Absence: Fish	Fish Life Stage: Juvenile Fish	N/A	Presence/Absence
Fish	Presence/Absence: Fish	Fish Life Stage: Adult Fish	N/A	Presence/Absence
Fish	Timing of Life Stage: Fish	Fish Life Stage: Juvenile Fish	N/A	Life Stage
Landscape Form &	Length/Width/Area	Habitat Type:	N/A	Channel Length

Geomorphology		Channels		
Other	Location	N/A	N/A	GPS Location
Time	Date	N/A	N/A	Date
Time	Time: Duration	N/A	N/A	Duration
Water Quality	Conductivity	N/A	N/A	Conductivity
Water Quality	Water Temperature	N/A	N/A	Water Temperature

Juvenile Abundance Indicators

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Fish	Carrying Capacity	N/A	N/A	Carrying Capacity
Fish	Migration Pathways: Fish	Fish Life Stage: Juvenile Fish	N/A	Outmigration
Landscape Form & Geomorphology	Length/Width/Area	Habitat Type: Channels	N/A	Area

Appendix F: Juvenile *O. mykiss* Mark-Recapture Population Assessment

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). However, estimating the population size of naturally produced juvenile steelhead in the Okanogan subbasin continues 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) since 2004 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 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. However, 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 tags. 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 Loup Loup Creek surface water to the mainstem Okanogan River. A noticeable increase in juvenile abundance was noted from 2010 to 2014 (refer to Appendix G, snorkel density of juvenile *O. mykiss* in Loup Loup Creek).

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 F1). 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.

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 F2). 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.

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 F3). 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.

Wanacut Creek

Wanacut Creek is a small ephemeral stream that meets the Okanogan River at approximately RKM56, between Omak and Riverside, WA (Figure F4). The 51 km² 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.

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 km², only the lower ~1.2 KM are accessible to anadromous fish, due to a natural falls (Figure F5). 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.

Aeneas Creek

A small creek with a drainage area of only 25 km², 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 F6). 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.

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 km²; 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 F7). 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.

Tonasket Creek

Tonasket Creek is a third order stream that has a drainage area of 153 km². 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 F8). A single seasonal PIT tag antenna is operated near the confluence of the creek with the Okanogan River.

Ninemile Creek

The drainage area of Ninemile Creek is 55 km², 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 F9). 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.

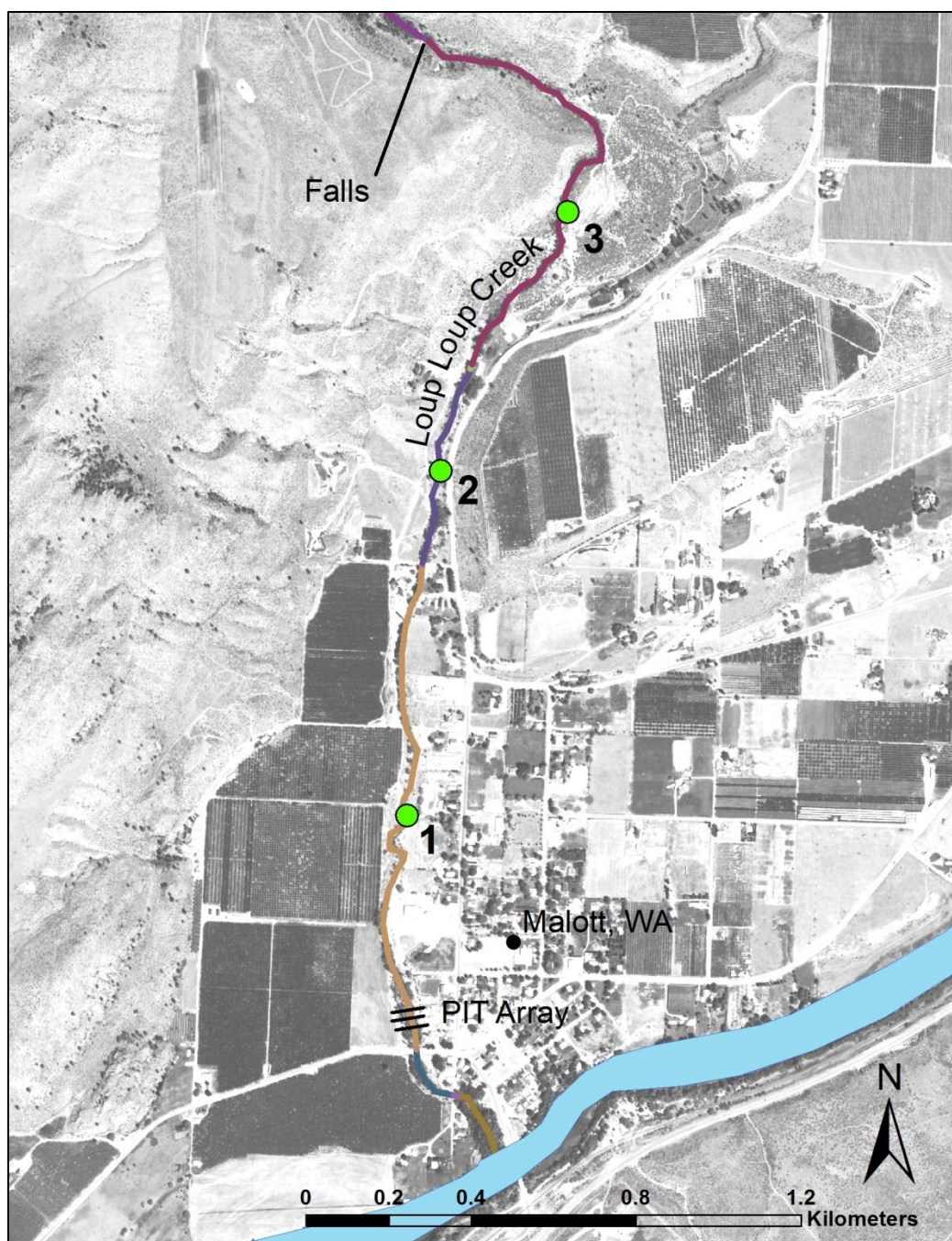


Figure F1. Loup Loup Creek juvenile *O. mykiss* mark-recapture study sites and strata.

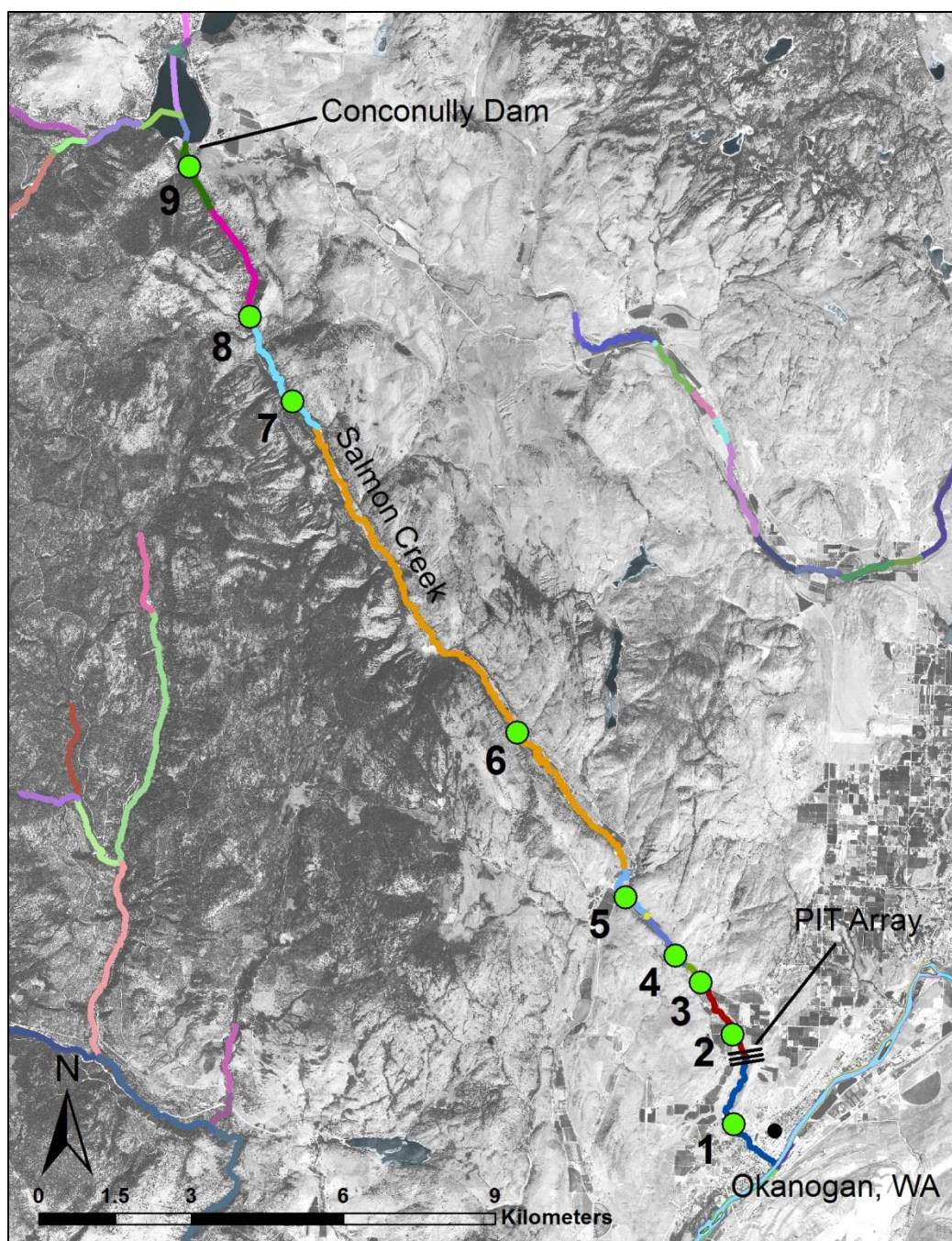


Figure F2. Salmon Creek juvenile *O. mykiss* mark-recapture study sites and strata.

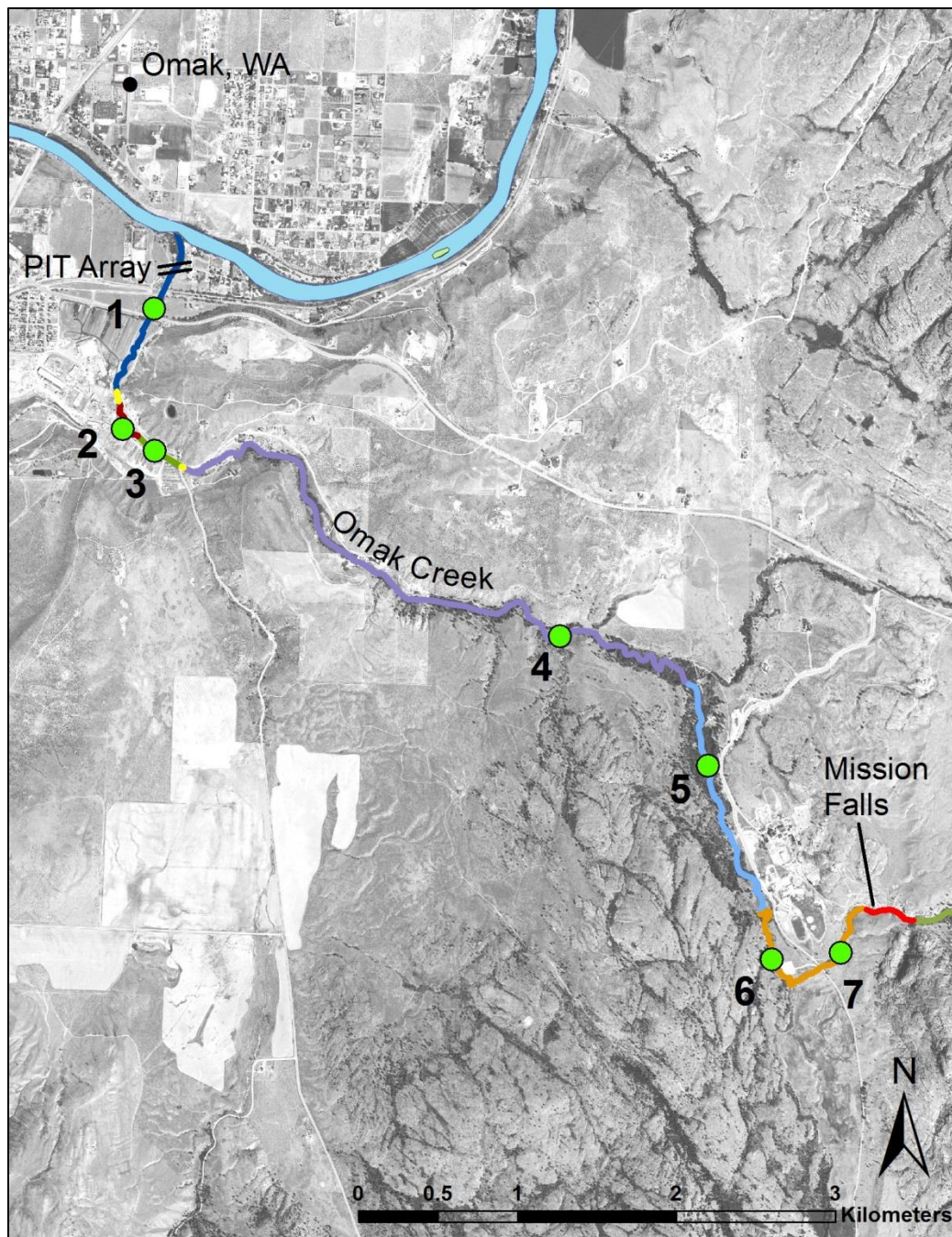


Figure F3. Omak Creek juvenile *O. mykiss* mark-recapture study sites and strata.

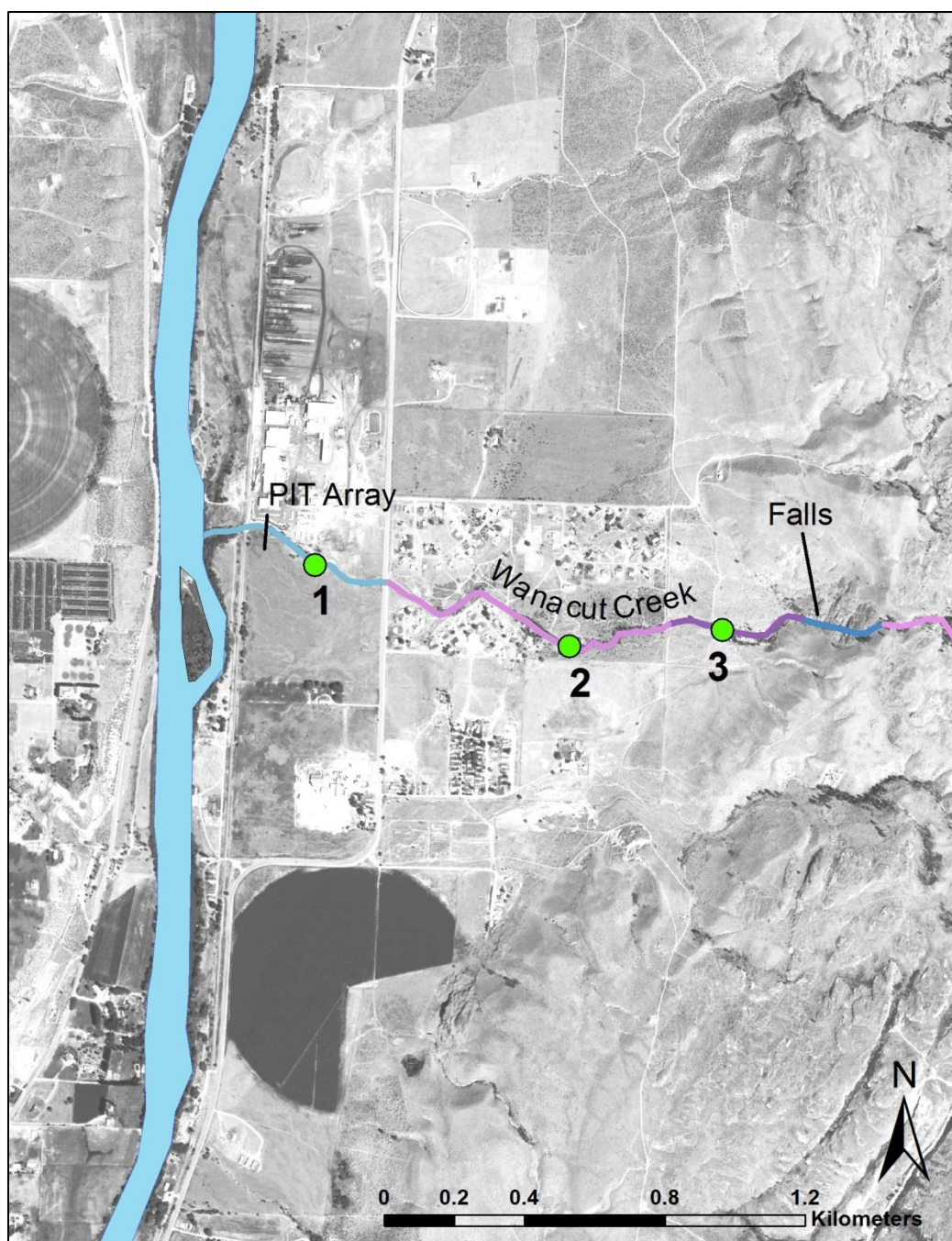


Figure F4.. Wanacut Creek juvenile *O. mykiss* mark-recapture study sites and strata.

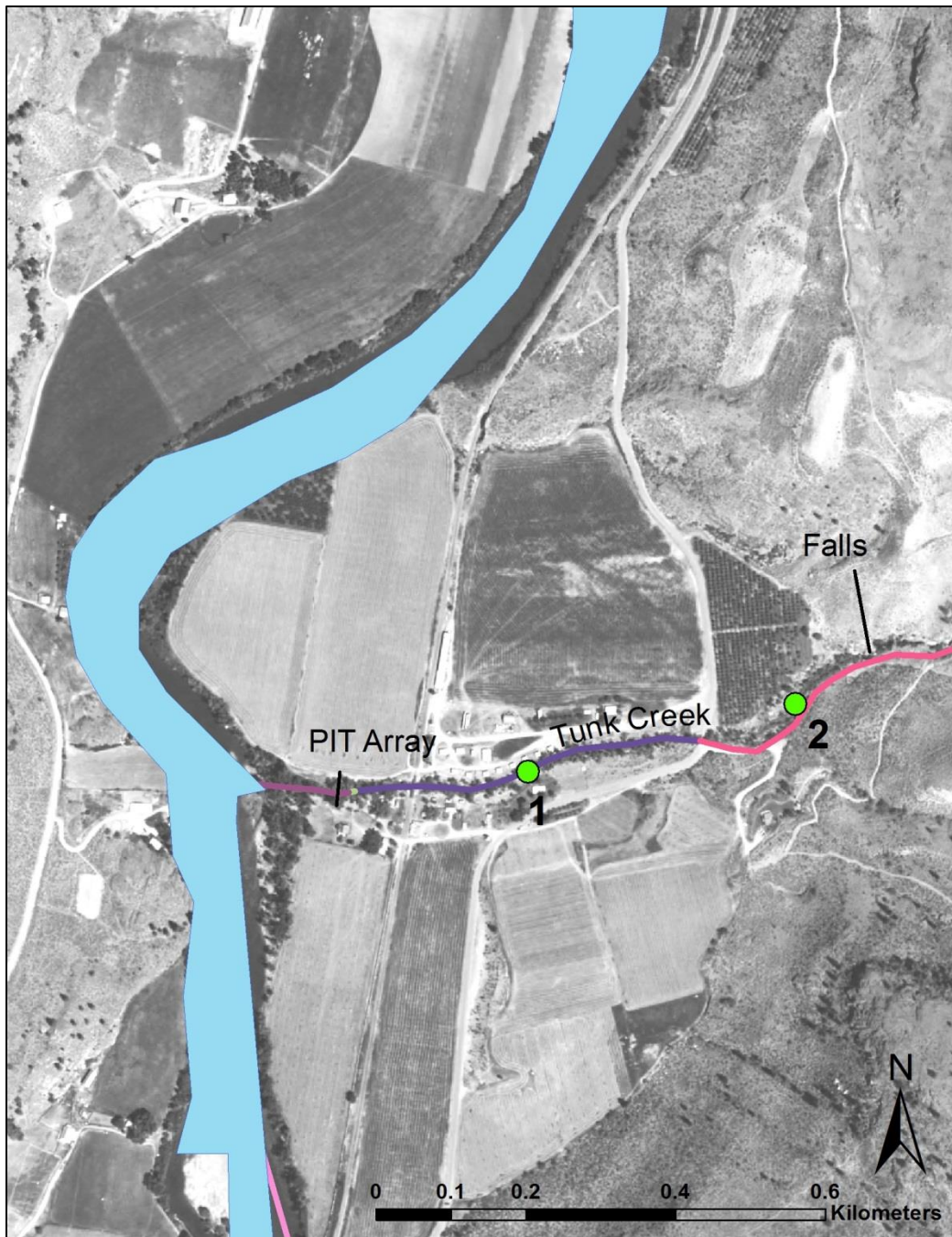


Figure F5. Tunk Creek juvenile *O. mykiss* mark-recapture study sites and strata.

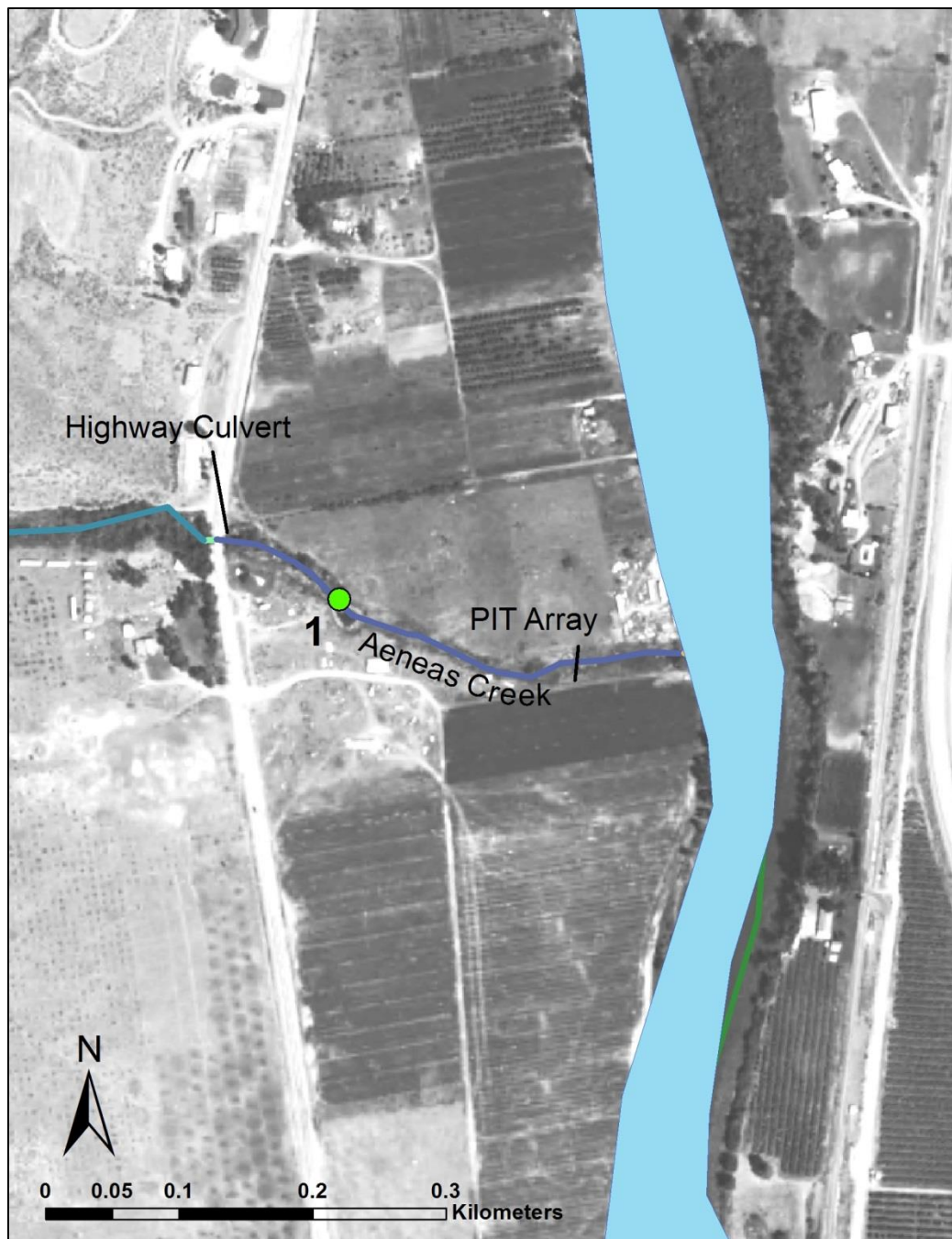


Figure F6. Aeneas Creek juvenile *O. mykiss* mark-recapture study sites and strata.

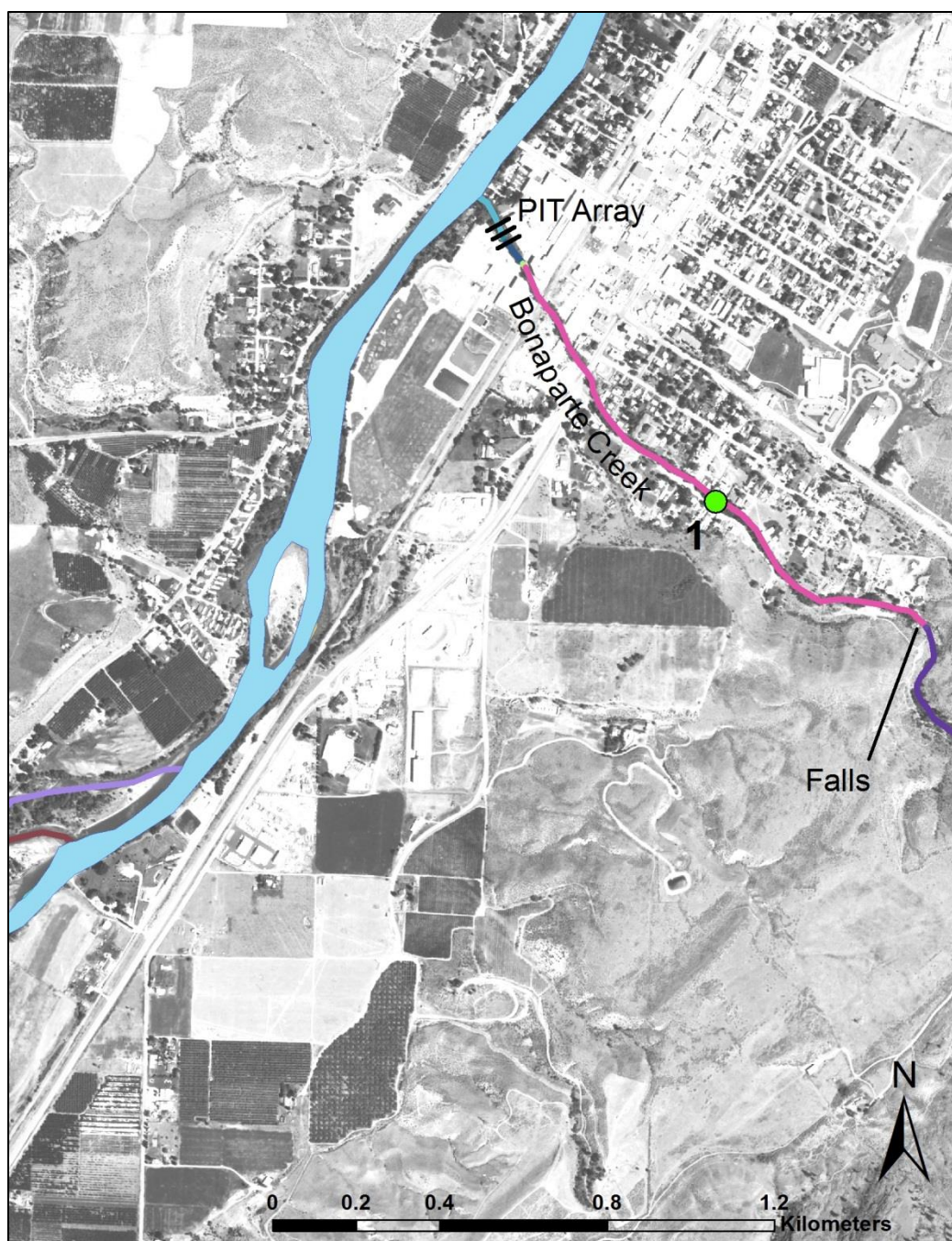


Figure F7. Bonaparte Creek juvenile *O. mykiss* mark-recapture study sites and strata.

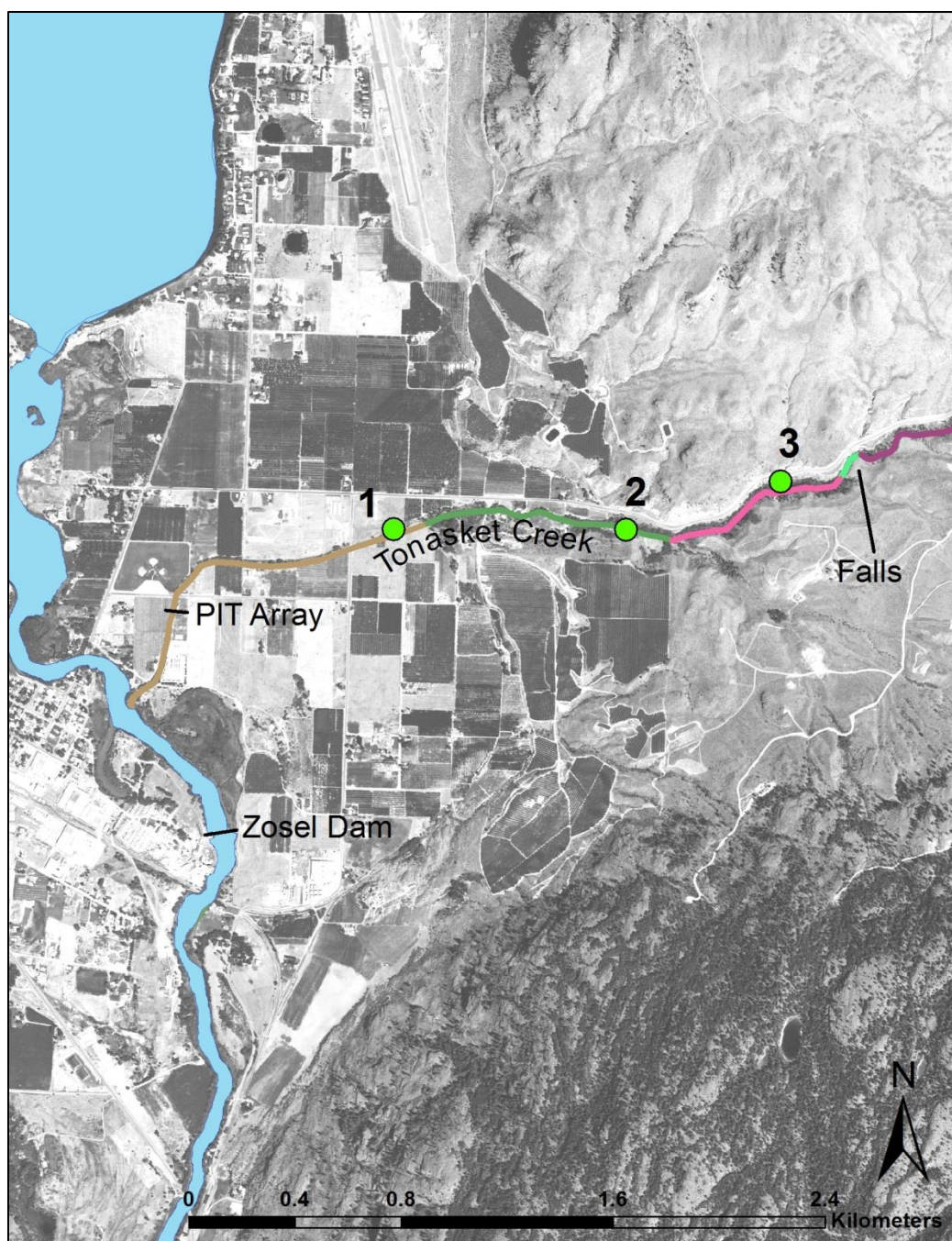


Figure F8. Tonasket Creek juvenile *O. mykiss* mark-recapture study sites and strata.

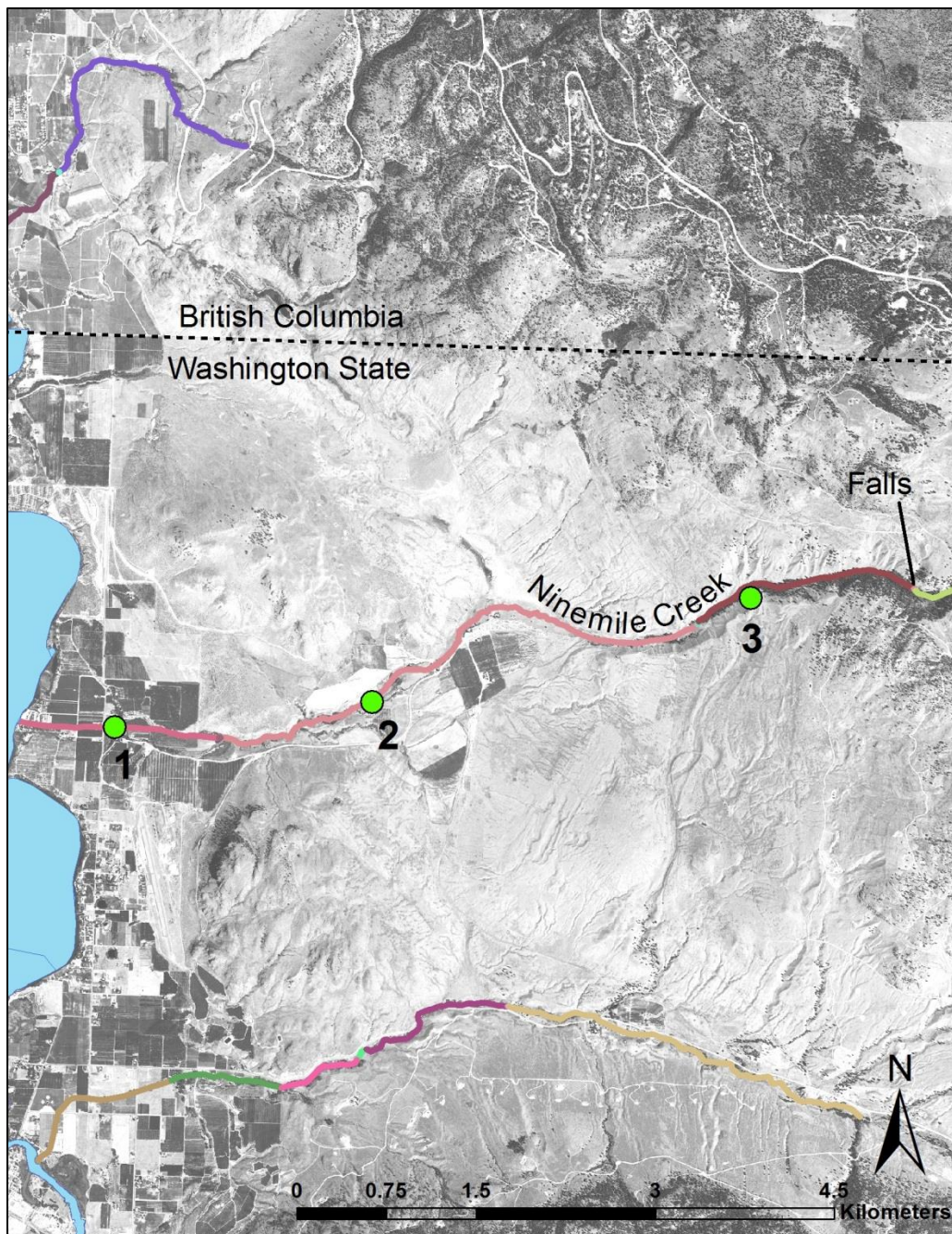


Figure F9. Ninemile Creek juvenile *O. mykiss* mark-recapture study sites and strata.

b. 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):

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

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:

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

c. 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, \hat{N}_i for $i = 1, \dots, 7$). 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),

$$R_i = \frac{\text{Reach Length}_i}{\text{Sample Site Length}_i}.$$

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

$$\hat{N}_i = N_i R_i .$$

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

$$\hat{N} = \sum_{i=1}^7 \hat{N}_i R_i ,$$

with variance of

$$\widehat{\text{Var}}(\hat{N}) = \sum_{i=1}^7 R_i^2 \times \widehat{\text{Var}}(\hat{N}_i) ,$$

and a 95% confidence interval (CI) of

$$\hat{N} \pm 1.96 \sqrt{\widehat{\text{Var}}(\hat{N})} .$$

The coefficient of variation (CV) was calculated as:

$$\text{CV}(\hat{N}) = \frac{\sqrt{\widehat{\text{Var}}(\hat{N})}}{\hat{N}} .$$

d. Out-Migration Estimates Based on Tagged Fish

The location of parallel PIT tag arrays near the mouth of creeks may allow for determination of an emigration estimate. Efficiency of the PIT tag array will be monitored throughout the period of the study based on detection probability of each antenna, which will be determined using marked release groups from the RST and upstream hatchery plantings. Although multiple methods exist to calculate detection efficiency of antennas, one method to calculate the overall probability of detection (\hat{P}) may be as follows:

$$\hat{P} = 1 - (1 - \hat{p}_1)(1 - \hat{p}_2)$$

or

$$\hat{p} = 1 - \left(1 - \frac{m}{n_2}\right) \left(1 - \frac{m}{n_1}\right)$$

where,

n_1 = number of fish detected at the upstream array,
 n_2 = number of fish detected at the downstream array,
 m = number of fish detected at both arrays,
 p_i = probability of detection at i th array.

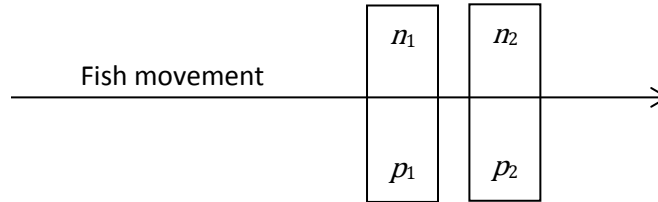


Figure F10. Diagram for probability of detection and estimated number of PIT tags past a parallel array.

Assuming that the fish tagged upstream are representative 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.

e. 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+”, primarily 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 in obvious bi-modal distributions. Length frequency distributions are much more distinctive 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. Detection and calculation of out-migration estimate (step d.) will occur the following season, and thus, total emigration results will be reported in the following year.

During the 2014 field season, eight tributaries were representatively sampled to determine abundance of juvenile *O. mykiss* in stream reaches accessible to anadromous fish. Three streams were not sampled due to

lack of access and/or limited remaining take on the electrofishing permit for the year. Estimated abundance ($\pm 95\%$ CI), capture efficiency of juvenile *O. mykiss*, and precision of estimates are presented in Table F1.

The largest number of fry and juvenile *O. mykiss* were found in Salmon Creek, followed by Omak and Loup Loup Creeks (Figure F11). A number of small creeks in the Okanogan subbasin contain flowing water in the upper reaches, but water frequently flows sub-surface before entering the mainstem Okanogan River. Salmon, Wanacut, Tunk, and Tonasket Creeks are all watersheds where adult spawning has been documented, but were disconnected from the mainstem river (dry in the lower reaches) during the summer and fall of 2014.

Wanacut Creek was dry in the lower ~3,000 m, but had flowing water from ~300 m below and up to the anadromous barrier (falls); however, zero fish were observed during sampling. Due to the wetted width being approximately 1 m during sampling, capture efficiency would have likely been high, and it is likely that Wanacut Creek contained little to no juvenile *O. mykiss* in 2014. Tunk Creek had a wetted length of ~700m below the anadromous barrier (falls) before going sub-surface for ~400 m to the confluence with the mainstem. Although a number of adult steelhead spawned in Tunk Creek in the spring of 2014, no fry were observed and many parr were in poor condition (many were thin with fungus on eyes and head), potentially due to very low flow and water temperatures reaching $> 25^{\circ}\text{C}$ during the summer. Tonasket Creek was dry in the lower ~2,500 m, but had flowing water from ~700 m below and up to the anadromous barrier (falls). Juvenile *O. mykiss* density appeared to be very high in this reach due to narrow wetted widths and shallow depths; however, the fish appeared to be in surprisingly good condition. All naturally produced juvenile *O. mykiss* that were 95 mm and larger were PIT tagged. Future outmigration data may be able to show if naturally produced *O. mykiss* in these small, disconnected streams contribute to returns of adult steelhead, or if contribution from these small watersheds is minimal, relative to the number of adults that spawn in these streams.

Table F1. Abundance estimates of naturally produced *O. mykiss* in tributaries to the Okanogan subbasin, below assumed anadromous barriers; ordered from south to north in the subbasin.

Tributary	< 95 mm <i>O. mykiss</i>				> 95 mm <i>O. mykiss</i>			
	Abundance Estimate	95% CI	Avg. Capture Eff.	C.V.	Abundance Estimate	95% CI	Avg. Capture Eff.	C.V.
Loup Loup Cr	18,806	1,567	39%	0.043	2,542	319	62%	0.064
Salmon Cr	41,803	6,339	25%	0.077	31,269	2,245	48%	0.037
Omak Cr	23,045	1,647	31%	0.036	6,958	886	46%	0.065
Wanacut Cr	0	0	-	-	0	0	-	-
Tunk Cr	0	0	-	-	193	31	81%	0.080
Aeneas Cr	86	14	44%	0.081	106	20	47%	0.096
Bonaparte Cr	2,922	368	45%	0.064	127	20	60%	0.082
Tonasket Cr	2,192	716	7%	0.167	526	51	58%	0.049
Ninemile Cr	4,184	756	67%	0.092	2,393	375	43%	0.080
Total or Average	93,038	11,407	37%		44,114	3,947	56%	

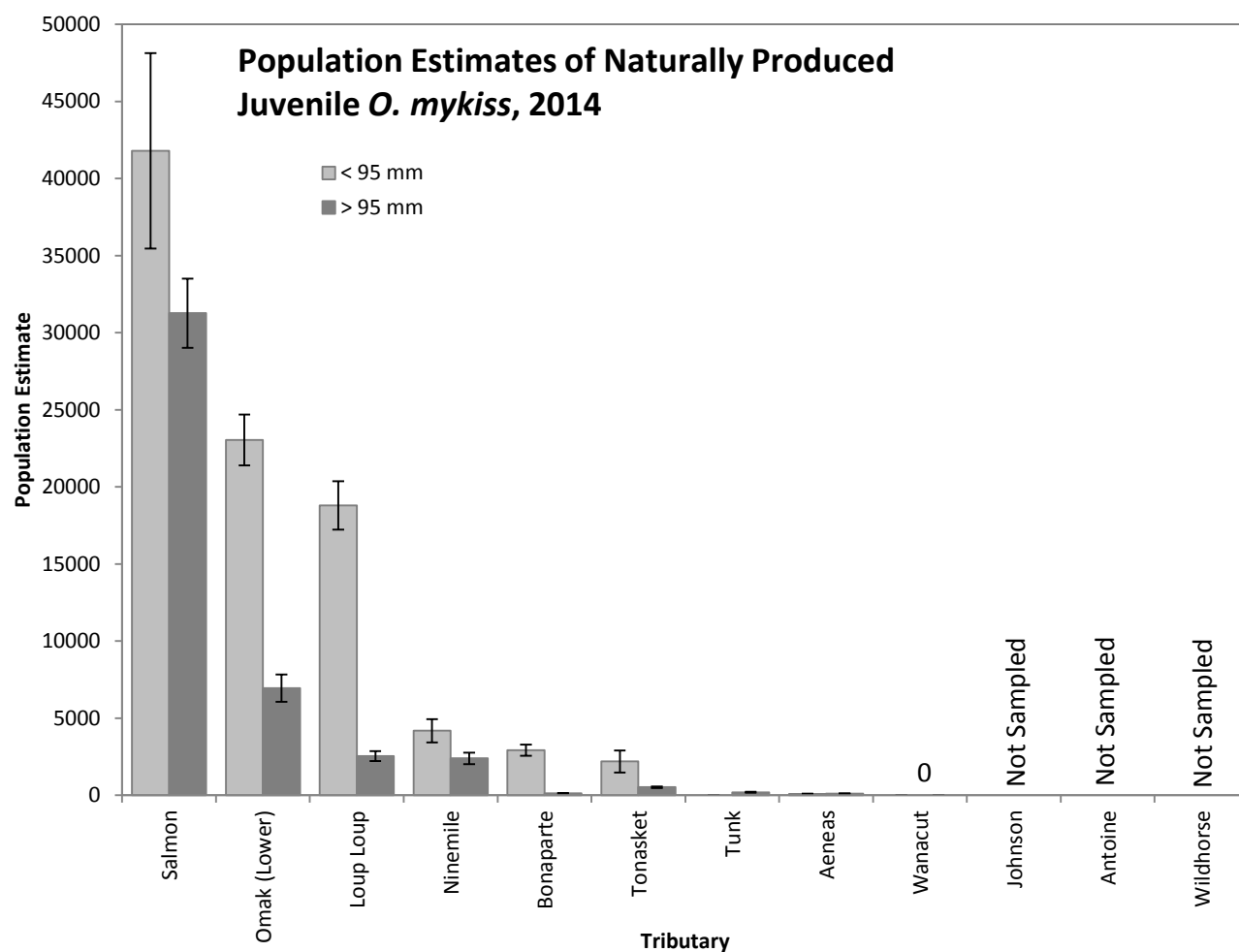


Figure F11. Estimated population of natural produced juvenile *O. mykiss* (95% CI) in tributaries to the Okanogan River. Data are presented by *O. mykiss* fry and juvenile+.

Fork length of *O. mykiss* parr varied by creek, likely due to the presence of multiple age classes and varying growth rates used in the coarse delienation (Figure F12). Although *O. mykiss* parr in Bonaparte Creek had the highest median length, this may have been influenced by a relatively small sample size (n=11). A summary of total length frequency distribution for each sampled stream is presented in Figure F13.

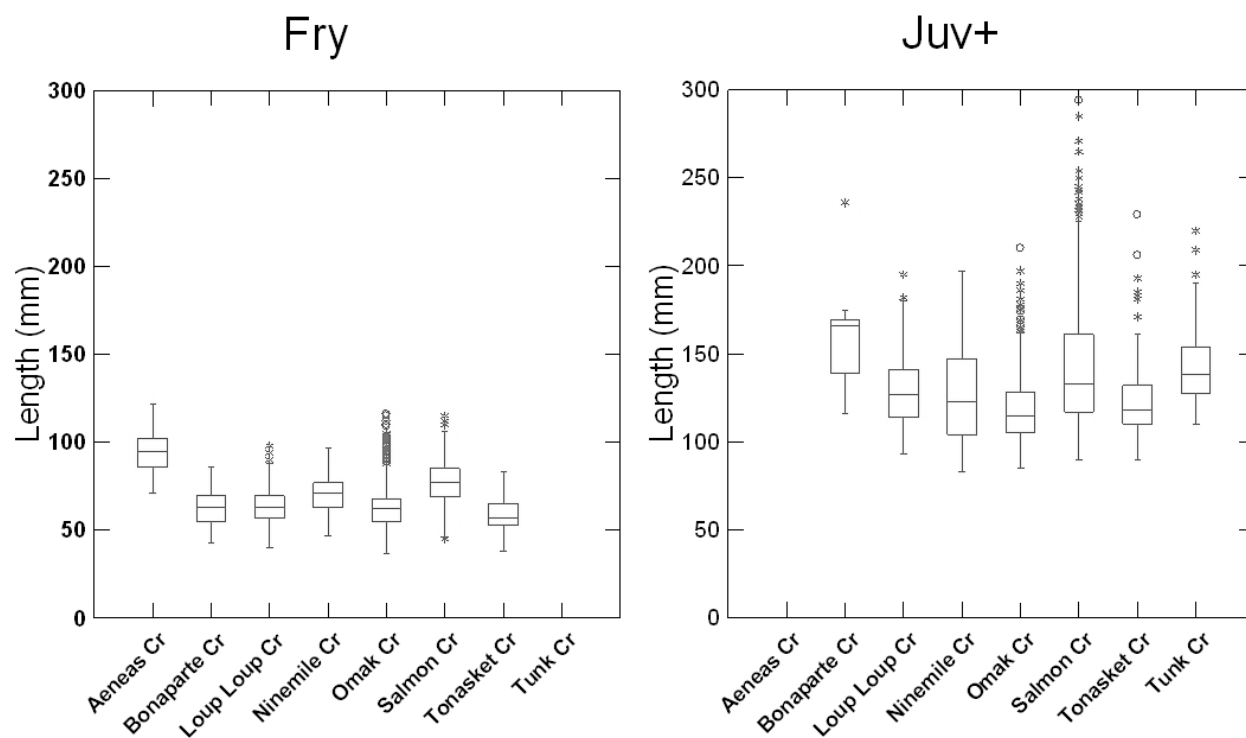


Figure F12. Fork length (mm) of *O. mykiss* fry (left panel) and parr (right panel) in tributaries to the Okanogan River during the fall of 2014.

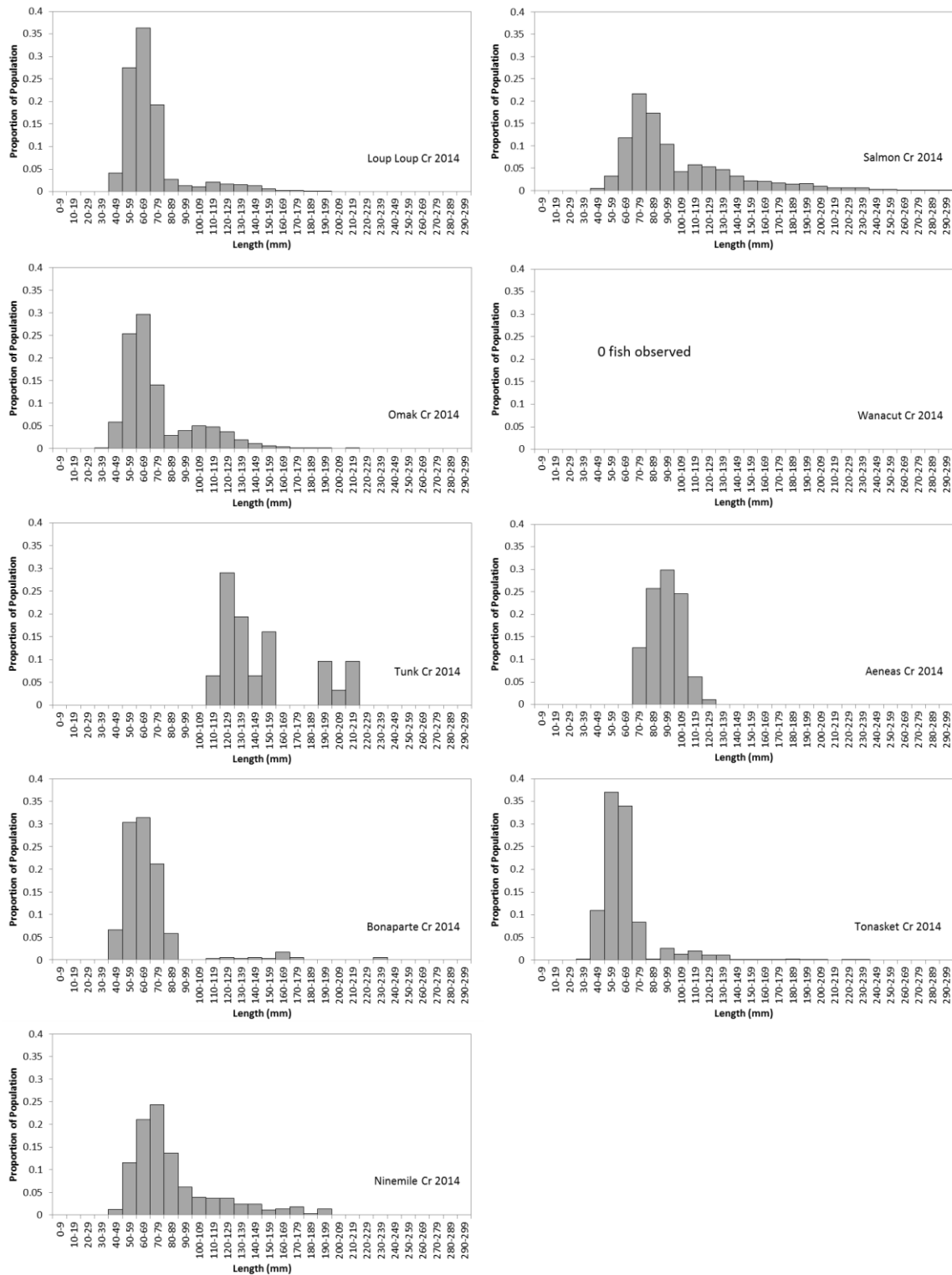


Figure F13. Length frequency data for juvenile *O. mykiss* in tributaries to the Okanogan River in Washington State.

Spatial distribution of juvenile *O. mykiss* varied within and between sub-watersheds, both by density and length distribution. For individual streams, Ninemile Creek had the largest distinction in fork length between strata, where the lowest reach was comprised primarily of age-0 fry, the middle reach was dry (except for a few small puddles in one small segment), and the uppermost reach had a much larger proportion of age-1+ *O. mykiss* (Figure F14). The average fork length of fry in the lowest reach was significantly different than fry in the upper reach ($p < 0.001$), with an average length of 75 mm ($n = 100$) and 58 mm ($n = 37$), respectively. 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.

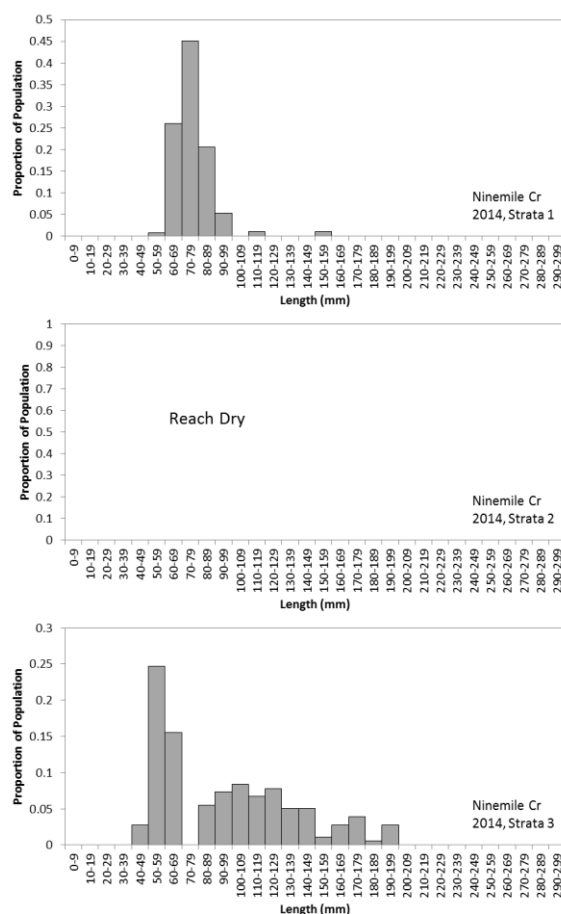


Figure F14. Length frequency distribution for Ninemile Creek by strata, below the anadromous barrier (falls); strata 1 (top panel) is the lowest reach in the watershed and strata 3 (bottom panel) is the uppermost.

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.

Many of the stated assumptions used in this study appeared to be adequate, but remained untested. Block nets were meticulously placed in attempts to create a closed population, 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 initial study period, it will be possible to explore hypotheses in the future, due to the fact that these abundance data were collected at existing habitat monitoring sites. Determining the 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.

Representatively marking a known proportion of the population upstream of the PIT tag array may enable us 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 distinct biologic reaches allowed for subsampling to occur at a finer scale and site-based abundance of juvenile steelhead were only expanded within similar habitat types. Annual outmigration estimates will 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 a small watershed with a high degree of precision.

Appendix G: Snorkel Surveys in the Okanogan Subbasin, 2004-2014

Total numbers and densities of juvenile *O. mykiss* for all streams and rivers in 2014 are shown in Table G1 for Washington and Table G2 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. Specific long term results are shown in further detail in the figures following, organized by individual site.

Table G1. Total observed numbers and densities of juvenile *O. mykiss* in the United States portion of the Okanogan subbasin, 2014.

Stream Name	Total Observed <i>O. mykiss</i> (N)	Density (fish/ha)
Aeneas Creek	not sampled	n/a
Antoine Creek	10	345
Bonaparte Creek	237	12,123
Chiliwist Creek	not sampled	n/a
Johnson Creek	not sampled	n/a
Loup Loup Creek	587	17,050
Ninemile Creek	not sampled	n/a
Okanogan River	5 ^a	0.1 ^b
Omak Creek	1226 ^a	2,644 ^b
Salmon Creek	359 ^a	1,562 ^b
Similkameen River	7 ^a	1.2 ^b
Siwash Creek	not sampled	n/a
Stapaloop Creek	not sampled	n/a
Tonasket Creek	311	14,252
Trail Creek	31	763
Tunk Creek	21	950
Wanacut Creek	not sampled	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 G2. Total observed numbers and densities of juvenile *O. mykiss* in the Canadian portion of the Okanogan subbasin, 2014.

Stream Name	Total Observed <i>O. mykiss</i>	Density (fish/ha)
snpin'ya?tk ^w (Ellis Creek)	0	0
aksk ^w ak ^w ant (Inkaneep Creek)	532 ^a	2223 ^b
McLean Creek	89	2561
qawsitk ^w (Okanagan River)	32 ^a	6 ^b
aklx ^w mina? (Shingle Creek)	21 ^a	177 ^b
Shuttleworth Creek	9	112
snʕaʕəlqax ^w iya? (Vaseux Creek)	530 ^a	774 ^b
Testalinden Creek	0	0
Wolfcub Creek	0	0

^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.

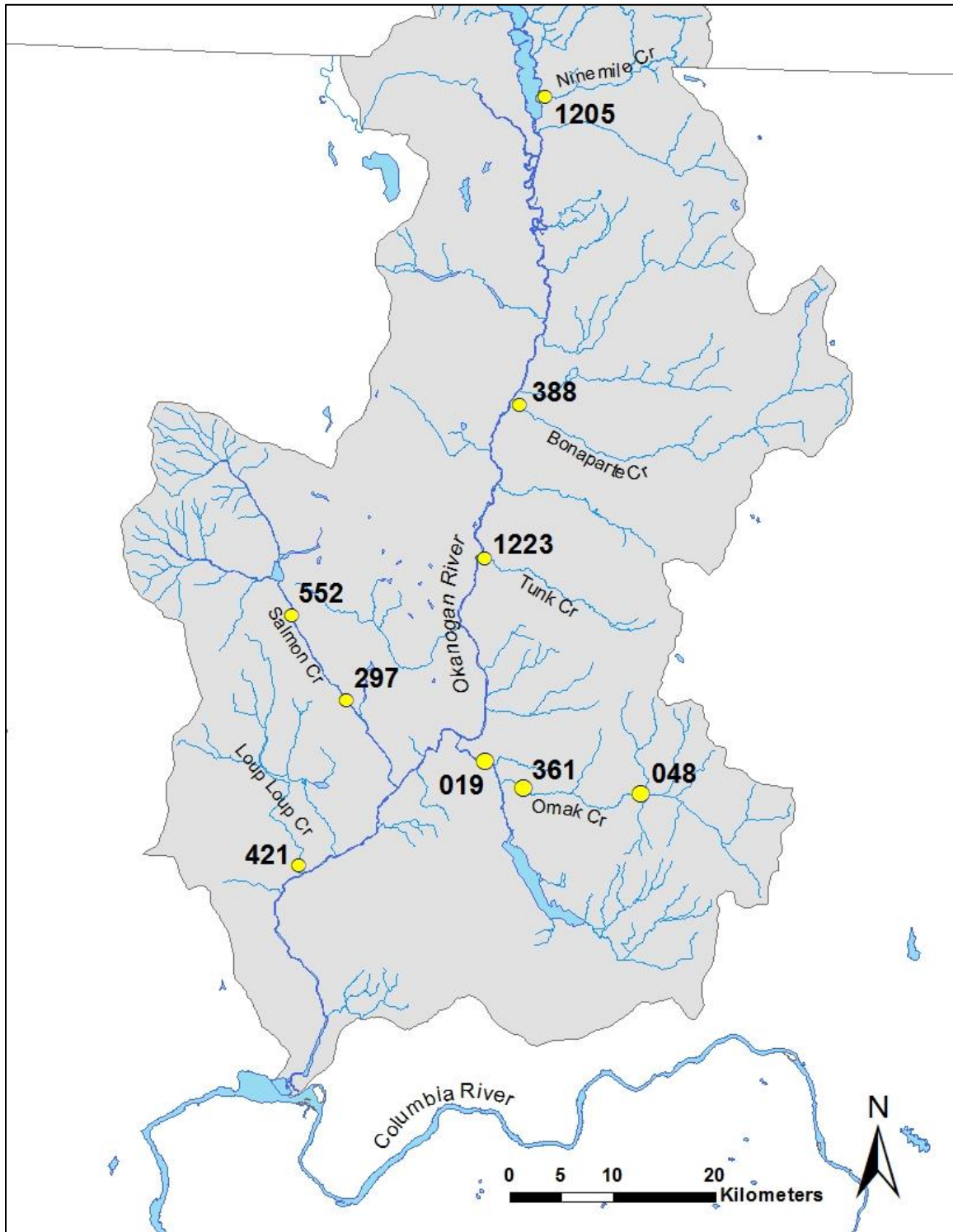


Figure G1. Location of annual snorkel survey sites on small tributaries to the Okanogan River. Rotating panel sites are not shown due to fewer years of data for each site.

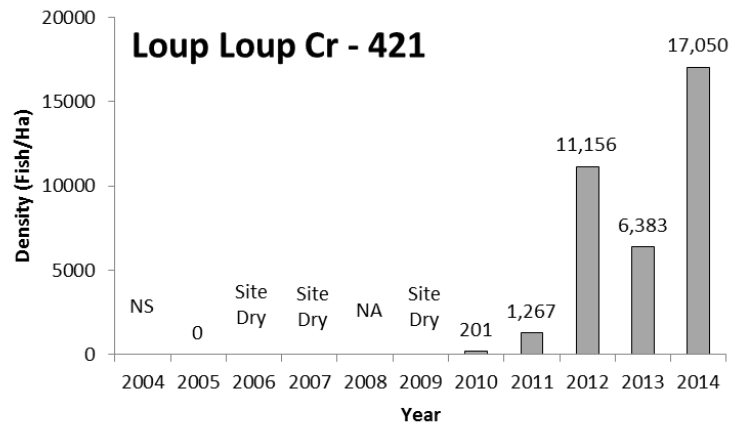


Figure G2. Observed densities of juvenile (< 300mm) *O. mykiss* in Loup Loup Creek, in the town of Malott, WA.

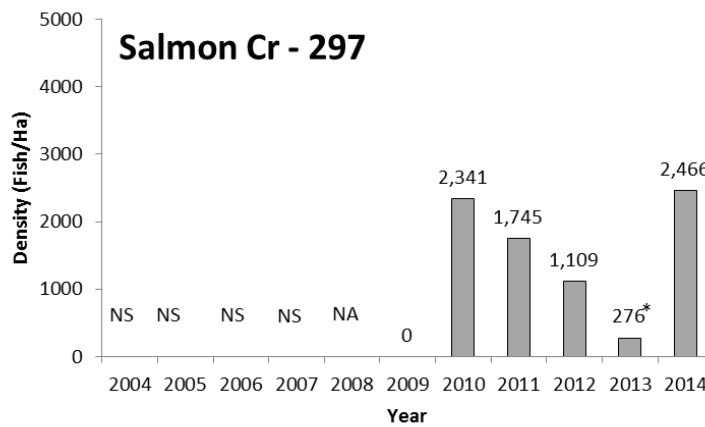


Figure G3. Observed densities of juvenile (< 300mm) *O. mykiss* in Salmon Creek. This site replaced a nearby site (site 360) that was moved in 2009 due to access related issues. Therefore, fewer years of data exist for site 297. In 2013, this site was electrofished prior to snorkeling, which may have caused fish to temporarily move out of the site.

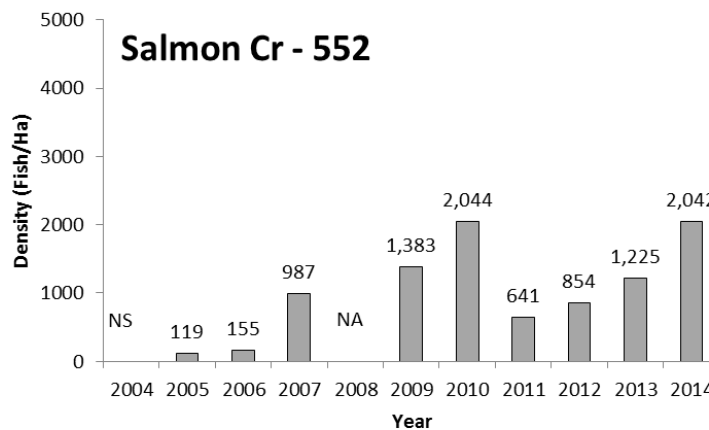


Figure G4. Observed densities of juvenile (< 300mm) *O. mykiss* in Salmon Creek, the upper most annual site on the creek, near the historical townsite of Ruby.

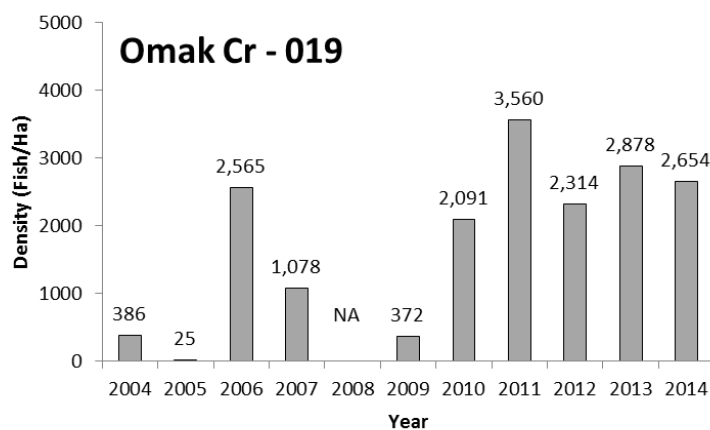


Figure G5. Observed densities of juvenile (< 300mm) *O. mykiss* in Omak Creek, the lower most site on the creek, and the only annual site below Mission Falls.

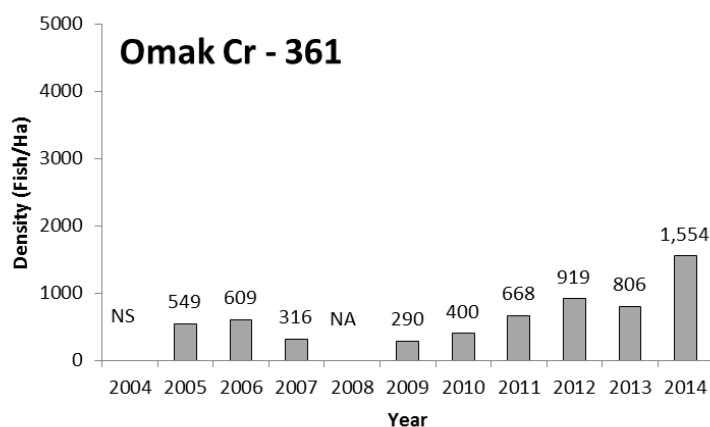


Figure G6. Observed densities of juvenile (< 300mm) *O. mykiss* in Omak Creek, located in the middle portion of the watershed, but above Mission Falls (anadromous barrier).

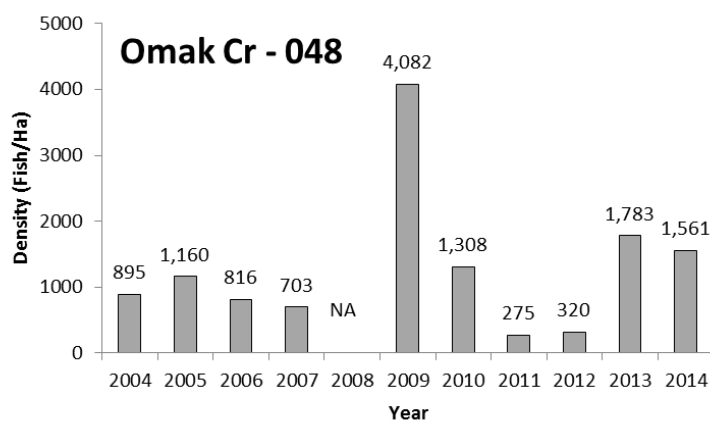


Figure G7. Observed densities of juvenile (< 300mm) *O. mykiss* in Omak Creek, the upper most site in the Omak Creek watershed.

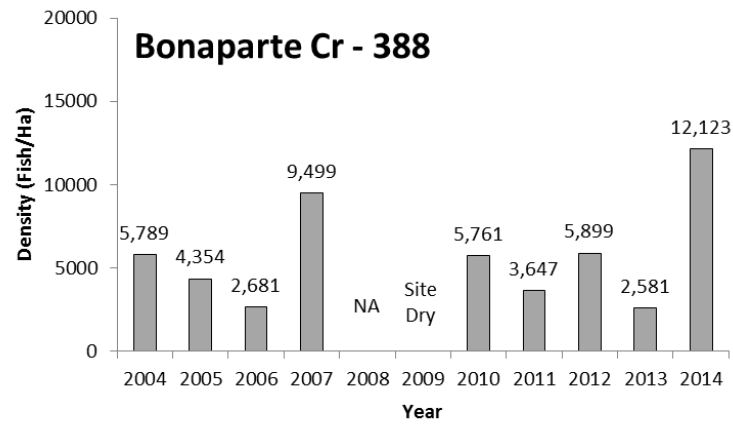


Figure G8. Observed densities of juvenile (< 300mm) *O. mykiss* in Bonaparte Creek in the city of Tonasket, WA.

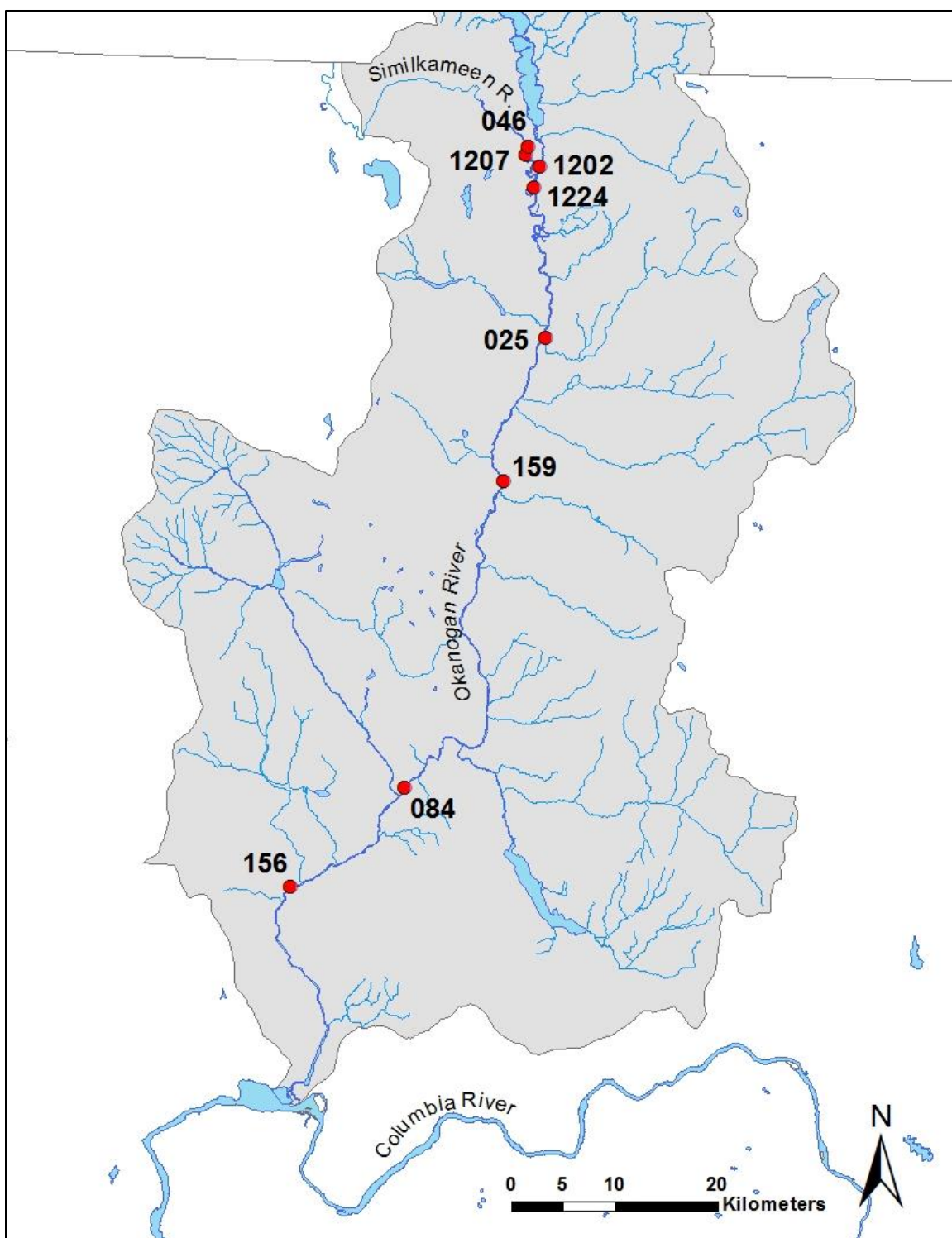


Figure G9. Location of annual snorkel survey sites on the mainstem Okanogan and Similkameen Rivers. Rotating panel sites are not shown due to fewer years of data.

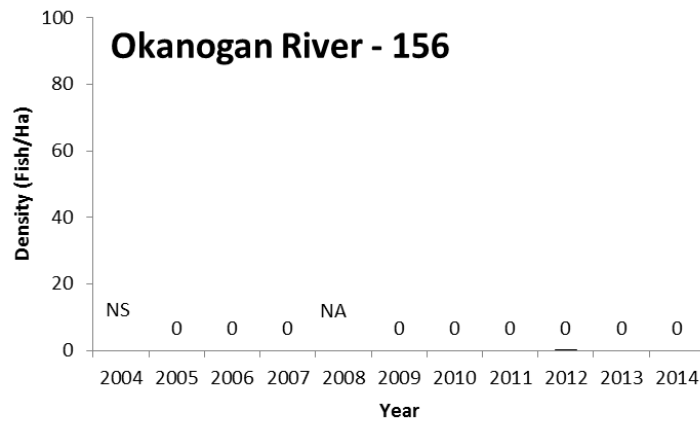


Figure G10. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, downstream of the confluence with Loup Loup Creek.

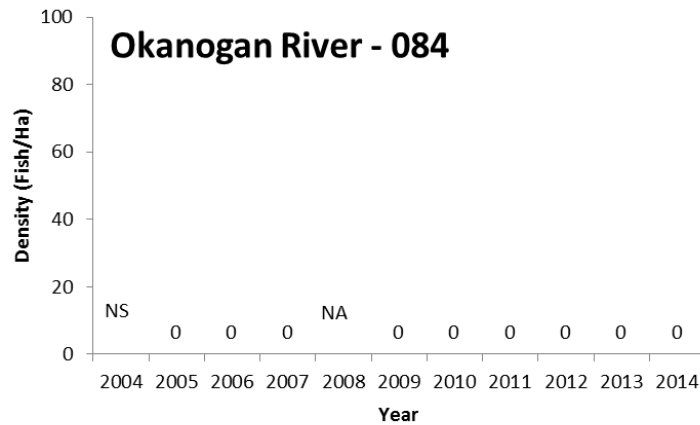


Figure G11. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, upstream of the confluence with Salmon Creek.

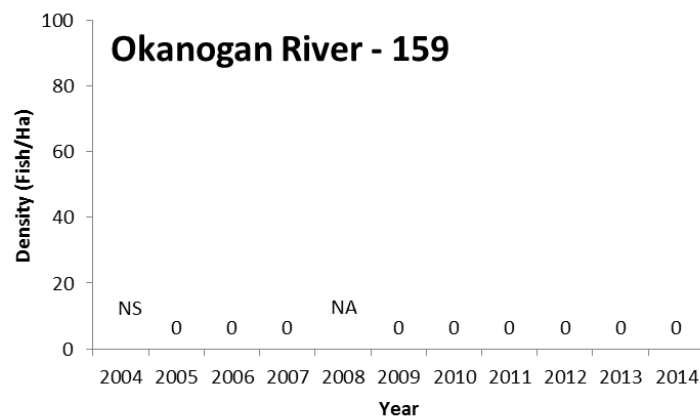


Figure G12. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, south of Tonasket, WA, below Janis Bridge.

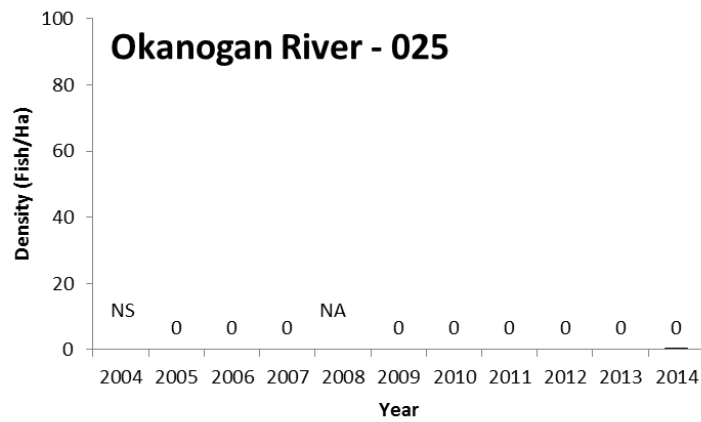


Figure G13. Observed densities of juvenile (< 300mm) *O. mykiss* in the Okanogan River, upstream of the confluence with Antoine Creek.

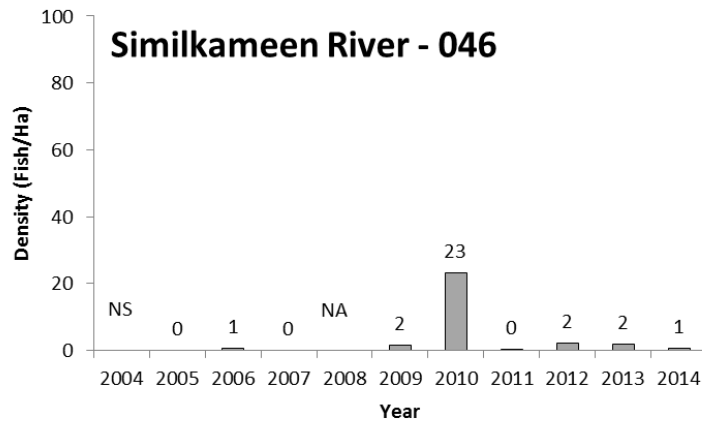


Figure G14. Observed densities of juvenile (< 300mm) *O. mykiss* in the Similkameen River, near the city of Oroville, WA.

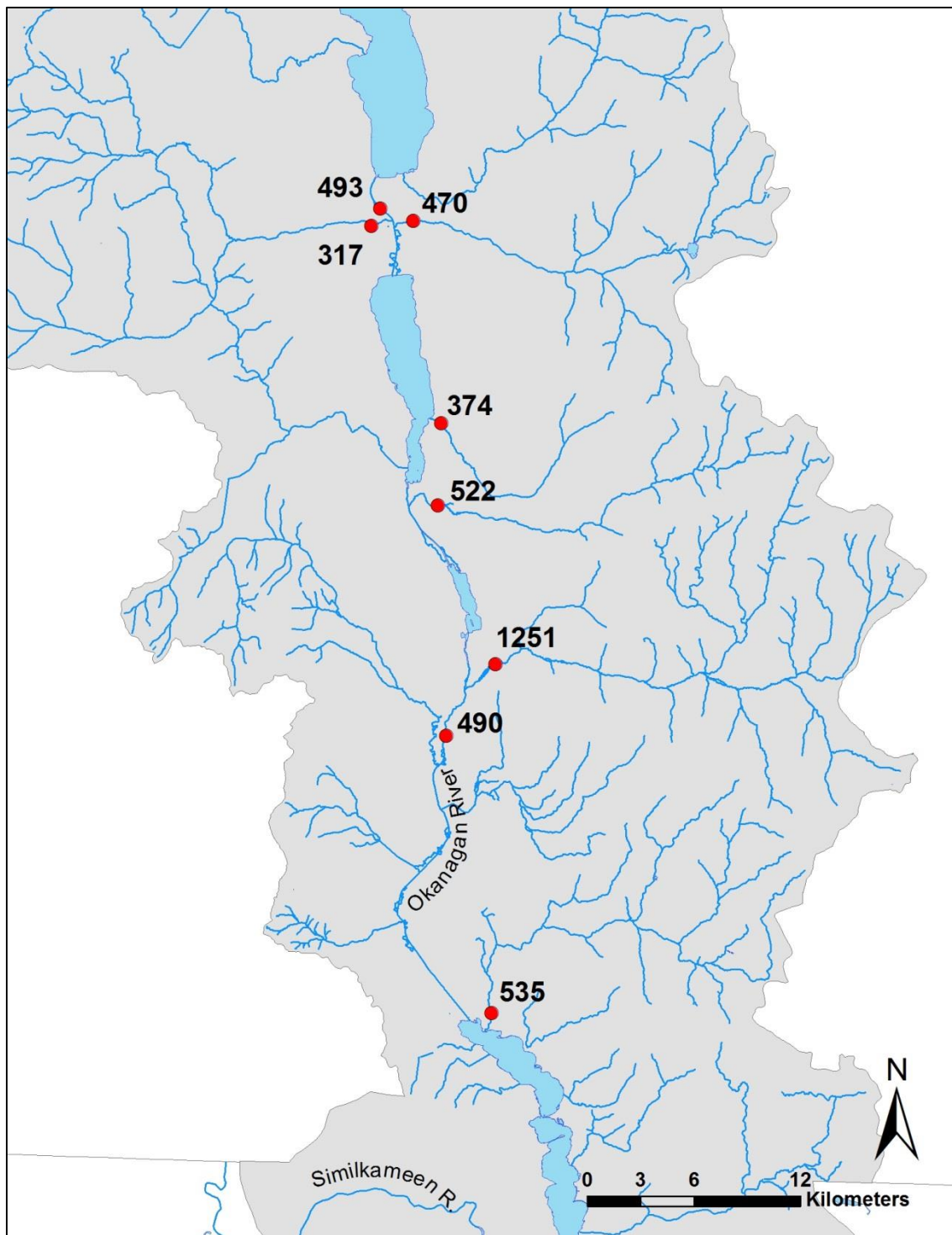


Figure G15. Location of annual snorkel survey sites on the British Columbia portion of the Okanagan subbasin. Rotating panel sites are not shown due to fewer years of data.

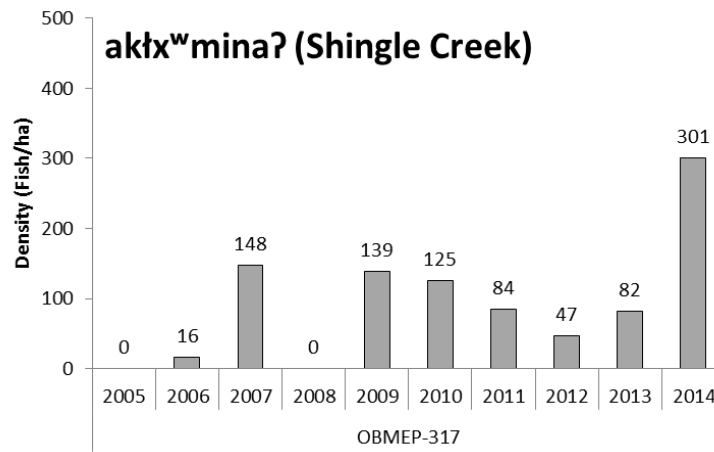


Figure G16. Observed densities of juvenile (< 300mm) *O. mykiss* in lower akłxʷmina? (Shingle Creek) at site OBMEP-317.

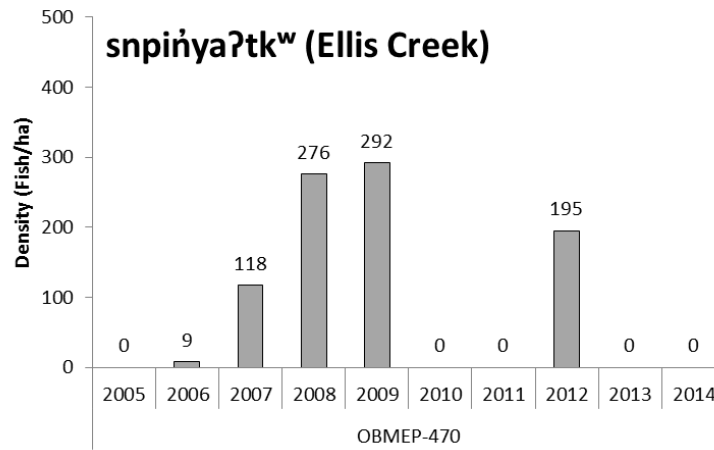


Figure G17. Observed densities of juvenile (< 300mm) *O. mykiss* in lower snpin'ya?tkʷ (Ellis Creek) at site OBMEP-470.

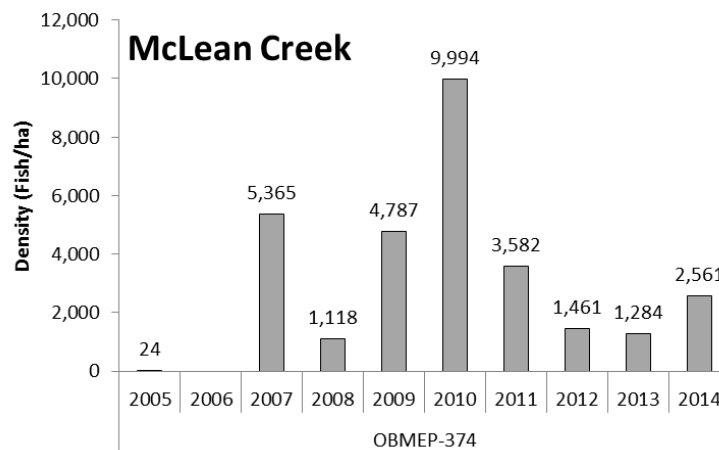


Figure G18. Observed densities of juvenile (< 300mm) *O. mykiss* in McLean Creek at site OBMEP-374.

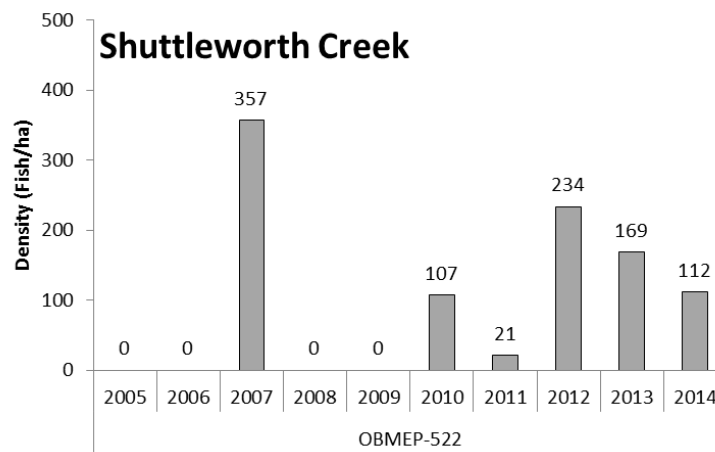


Figure G19. Observed densities of juvenile (< 300mm) *O. mykiss* Shuttleworth Creek at site OBMEP-522.

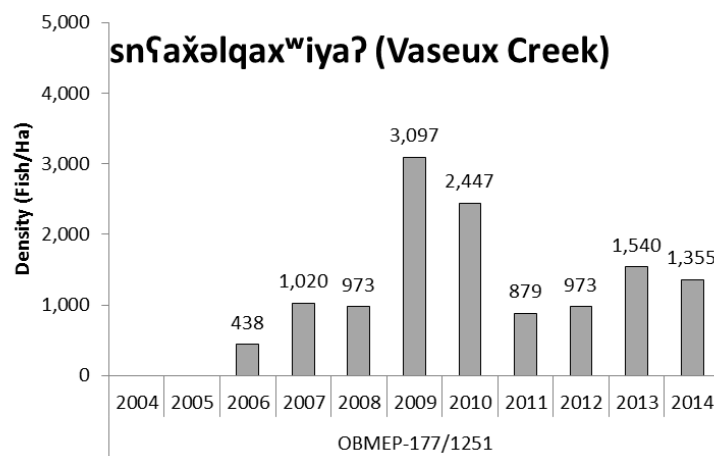


Figure G20. Observed densities of juvenile (< 300mm) *O. mykiss* sn̓aḥ̓əlqax̓w̓iya? (Vaseux Creek) at site OBMEP-177/1251.

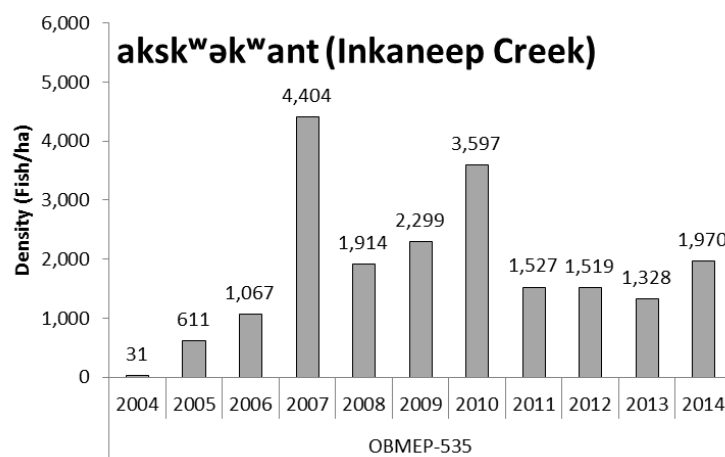


Figure G21. Observed densities of juvenile (< 300mm) *O. mykiss* aksk̓w̓ək̓want (Inkaneep Creek) at site OBMEP-535.

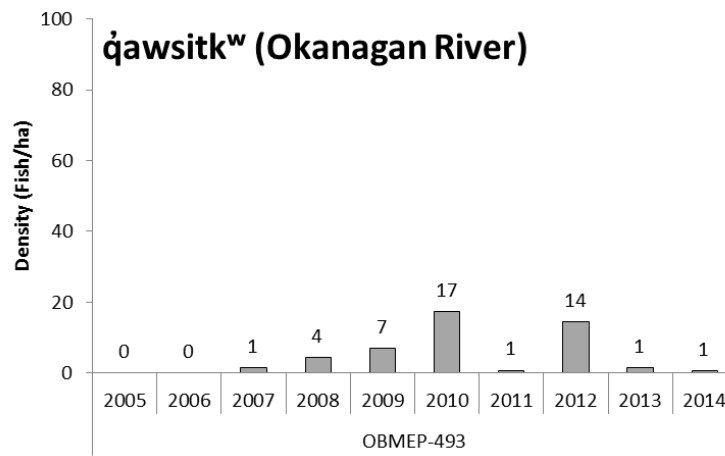


Figure G22. Observed densities of juvenile (< 300mm) *O. mykiss* qawsitkʷ (Okanagan River) at site OBMEP-493 (Penticton channel).

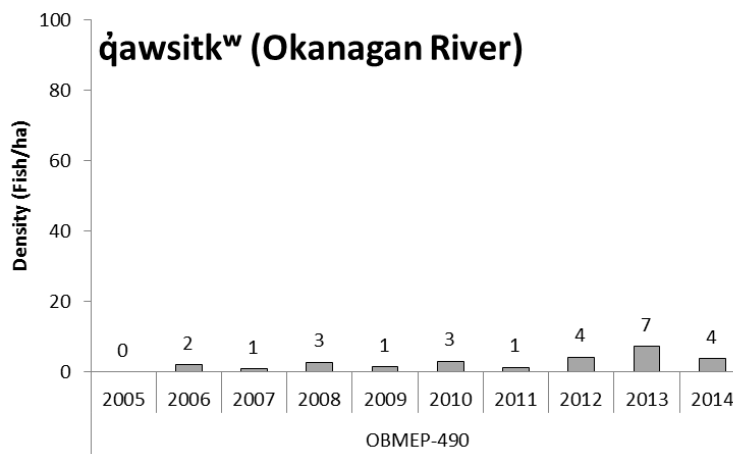


Figure G23. Observed densities of juvenile (< 300mm) *O. mykiss* qawsitkʷ (Okanagan River) at site OBMEP-490 (near Oliver).

Appendix H: Snorkel Survey Verification

In 2014, snorkel surveys in small streams were coupled with mark-recapture electrofishing, in attempt to determine potential relationships between snorkel observation and total abundance of juvenile *O. mykiss* in 150 m survey sites. The number of observed fish during snorkel surveys was compared with mark-recapture abundance estimates in order to define detection rates of fish during snorkeling and the accuracy of total snorkel counts. Although the number of data points used in the comparisons is relatively small at this time (n=19), a few initial inferences were drawn from this preliminary dataset.

Initial results suggest that snorkel surveys are fairly precise and can detect relative change in density of juvenile salmonids. However, observed snorkel survey estimates are not accurate, in that density of fish were under-reported in every instance. There was a strong correlation between estimated site abundance and the total snorkel count ($p < 0.001$) and number of < 100 mm FL *O. mykiss* ($p < 0.001$) observed during snorkel surveys (Figure H1). However, there was a noticeable decrease in observation rate of > 100 mm FL *O. mykiss*, although correlation between the two methods was still notable ($p = 0.057$).

Employing mark-recapture electrofishing led to improved results when analyzing juvenile fish data in respect to VSP parameters in small streams in the Okanogan subbasin. These methods allowed the program to determine total abundance estimates for each site and define 95% confidence intervals surrounding point estimates. In Figure H2, snorkel observation rate was 51%, 62%, and 53% for 2012, 2013, and 2014, respectively. This slight increase in observation efficiency in 2013 may explain the increased snorkel count in 2013, when the total abundance determined by mark-recapture decreased slightly that year. Nonetheless, snorkel counts for those three years remained relatively constant when compared with prior years' data and the level three year trend was also reflected in the mark-recapture abundance estimate.

Habitat characteristics of unique survey sites, both within and between streams, affected efficiency of each method. However, there was no correlation between snorkel surveys observation rate and electrofishing capture efficiency, in that, the factors that tend to reduce snorkel observation (very shallow water depth in riffles, water clarity, habitat complexity) were not necessarily the same factors that negatively influenced electrofishing capture rates (most notably deeper water, increased wetted width). Percent of *O. mykiss* observed during snorkel surveys varied between sites, which ranged from 17 - 85% (avg 51%) for < 100 mm FL and 16 - 97% (avg 44%) for > 100 mm FL. Capture efficiency for electrofishing also differed by site and ranged from 15 - 51% (avg 31%) for < 100 mm FL *O. mykiss* and 16 - 83% (avg 52%) for > 100 mm FL. Due to (often times significant) habitat variation between survey sites, inter-crew observer bias if more than one observer is employed, and subsequent changes in observation rate of fish, we would not recommend using a blanket approach in expanding observed density to total estimated density of fish, when looking at site specific data.

Mark-recapture electrofishing could not be conducted in non-wadeable streams (e.g. Okanogan and Similkameen River mainstem), leaving a large portion of habitat in the subbasin un-surveyed by that method. However, snorkel surveys have been conducted throughout the mainstem reaches, in both Washington State and British Columbia, since 2004. Results from snorkel surveys show very low summer abundance of juvenile *O. mykiss* in those habitats (refer to Appendix G), although accuracy and precision of mainstem snorkel surveys remain untested.

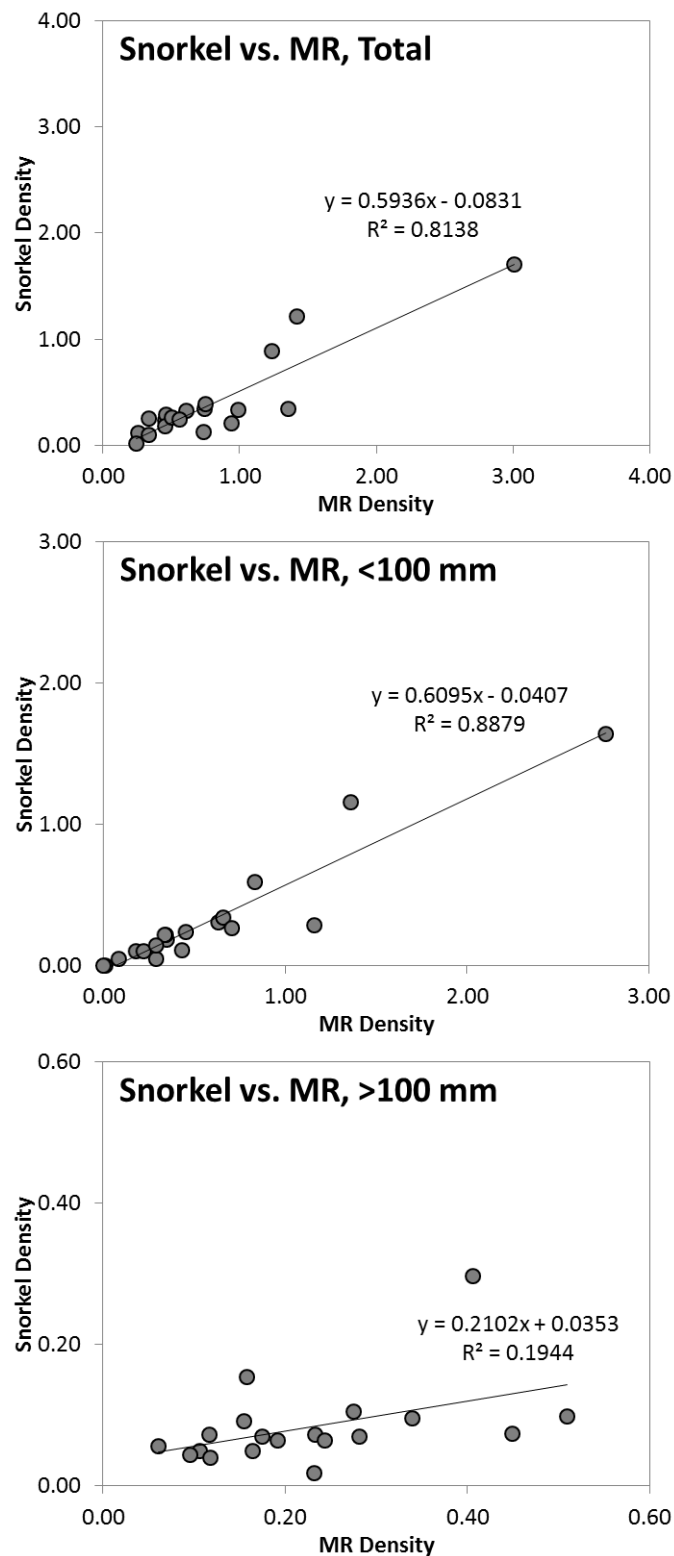


Figure H1. Comparison of snorkel survey observations and mark-recapture densities (fish/m²) within 150 m monitoring sites (n=19). Data are presented by (a.) total *O. mykiss* observed in each site and further divided by (b.) < 100 mm FL and (c.) > 100 mm FL length classes.

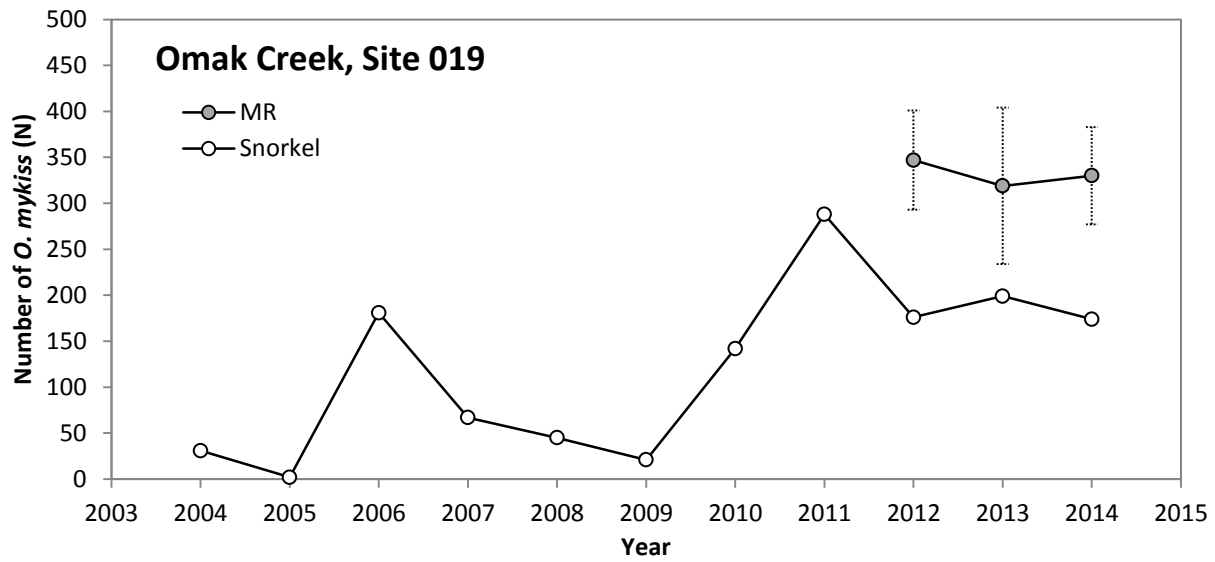


Figure H2. Juvenile *O. mykiss* site abundance data for a 150 m annual monitoring site on Omak Creek, comparing observed snorkel counts with mark-recapture abundance estimates ($\pm 95\%$ CI).

Appendix I: Habitat and Water Quality Metrics and Indicators

Habitat and Water Quality Monitoring Metrics

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Classification of Ecological or Geological Attribute	Form/Morphology	Habitat Type: Rivers & Streams		Form/Morphology
Classification of Ecological or Geological Attribute	Form/Morphology	Habitat Type: Shorelines & Banks		Confinement
Classification of Ecological or Geological Attribute	Habitat Quality	Habitat Type: Altered Habitat		Riparian Function
Classification of Ecological or Geological Attribute	Habitat Quality	Habitat Type: Rivers & Streams		Habitat Quality
Classification of Ecological or Geological Attribute	Habitat Type	Habitat Type		Habitat Type
Classification of Ecological or Geological Attribute	Habitat Type	Habitat Type		Thalweg Profile
Classification of Ecological or Geological Attribute	Habitat Type	Habitat Type		Presence of Side Channel and Backwater
Classification of Ecological or Geological Attribute	Land Ownership			Land Ownership
Classification of Ecological or Geological Attribute	Land Use			Human Influence
Disturbance/Restoration	Disturbance Presence	Habitat Type: Altered Habitat		Human Influence
Hydrology/Water Quantity	Diversion Type			Diversion Structures
Hydrology/Water Quantity	Diversion Type			Water Withdrawals

Hydrology/Water Quantity	Gauge			Stage
Landscape Form & Geomorphology	Abundance of Instream Wood Structures			Measuring LWD
Landscape Form & Geomorphology	Abundance of Species Migration Barriers			Obstructions to Fish Migration
Landscape Form & Geomorphology	Density of Habitat Type	Habitat Type: Channel: Pools		Distribution of Pools
Landscape Form & Geomorphology	Density of Instream Wood			Wood
Landscape Form & Geomorphology	Depth/Height: Bankfull			Bankfull Height
Landscape Form & Geomorphology	Depth: Bathymetry			Thalweg Profile
Landscape Form & Geomorphology	Depth: Bathymetry			Transect Stream Depth
Landscape Form & Geomorphology	Depth: Pool			Thalweg Profile
Landscape Form & Geomorphology	Edge/Density/Sinuosity	Habitat Type: Rivers & Streams		Bearing
Landscape Form & Geomorphology	Gradient			Gradient
Landscape Form & Geomorphology	Length/Width/Area	Habitat Type: Channels		Channel Length
Landscape Form & Geomorphology	Species Cover	Habitat Type: Riparian Zone		Riparian Structure
Landscape Form & Geomorphology	Width to Depth Ratio			Transect Data
Landscape Form & Geomorphology	Width: Bankfull			Bankfull Width
Landscape Form & Geomorphology	Width: Bankfull			Channel Width-month maximum
Landscape Form & Geomorphology	Width: Wetted			Wetted Width

Landscape Form & Geomorphology	Width: Wetted			Channel Width-month minimum
Light	Light Concentration			Canopy Cover
Macroinvertebrates	Abundance of Macroinvertebrates			Abundance of Macroinvertebrates
Macroinvertebrates	Composition: Macroinvertebrate Species Assemblage	Species Life Stage: RANGE: Juvenile to Adult Species		Macroinvertebrate Species Assemblage
Macroinvertebrates	Index of Biotic Integrity: Macroinvertebrate Species			IBI
Macroinvertebrates	Species Type: Macroinvertebrates			Species Type
Other	Access			Access
Other	Access			Landowner Information/Contact
Other	Location			GPS Location
Other	Photo Documentation			Photos
Sediment/Substrate/Soils	Bed Scour/Erosion Rate			Icing & Bed Scour
Sediment/Substrate/Soils	Composition: Substrate/Soil-Dominant Size			Substrate Size Class
Sediment/Substrate/Soils	Distribution of Sediment			Percent Fines
Sediment/Substrate/Soils	Embeddedness			Embeddedness
Sediment/Substrate/Soils	Type of Substrate			Fine Sediment
Time	Date			Date
Time	Time: Actual			Time
Vegetation/Plants	Dominant Vegetation			Dominant Canopy Type
Vegetation/Plants	Dominant Vegetation			Dominant Understory Type

Vegetation/Plants	Maturation Level of Vegetation			Cover
Vegetation/Plants	Presence/Absence: Plants			Ground Cover Layer
Water Quality	Alkalinity	Habitat Type: Rivers & Streams		Alkalinity
Water Quality	Conductivity			Conductivity
Water Quality	Dissolved Gas Concentration (By Gas)			Dissolved Oxygen
Water Quality	Dissolved Gas Concentration (By Gas)			Total Dissolved Gas
Water Quality	Nitrogen			Ammonia
Water Quality	Nitrogen			Nitrates
Water Quality	pH			pH
Water Quality	Turbidity			Turbidity
Water Quality	Water Temperature			Water Temperature

Habitat and Water Quality Monitoring Indicators

Category	Subcategory	Subcategory Focus 1	Subcategory Focus 2	Specific Metric Title
Hydrology/Water Quantity	Flow			Discharge
Landscape Form & Geomorphology	Aquatic or Floodplain Geomorphology: Area	Habitat Type: Channels		Habitat Type Map
Landscape Form & Geomorphology	Density of Habitat Type	Habitat Type: Channels		Thalweg Profile
Landscape Form & Geomorphology	Density of Habitat Type	Habitat Type: Channel: Riffles		Habitat Type Map
Landscape Form & Geomorphology	Density of Instream Wood			Measuring LWD

Landscape Form & Geomorphology	Distance Between Habitat Types	Habitat Type: Channel: Pools		Habitat Type Map
Landscape Form & Geomorphology	Distribution of Instream Wood			Measuring LWD
Landscape Form & Geomorphology	Surface Water Cover			Pool Surface Area
Vegetation/Plants	Composition: Vegetative Species Assemblage			Riparian Structure
Vegetation/Plants	Density of Vegetation			Riparian Structure and Canopy Cover

Appendix J: Rapid Assessment Habitat Surveys

Included in the following pages are two examples of maps created from rapid assessment habitat surveys, one for a mainstem reach (Figure J1) and the second from a tributary to the Okanogan River (Figure J2).

Table J1. List of stream corridor structure attributes comparing Ecosystem Diagnosis and Treatment (EDT) parameter inputs for Rapid Habitat Assessments with empirical data sources obtained through OBMEP.

Stream Corridor Structure EDT Attribute	Habitat Monitoring Sites	Rapid Assessment
Channel (reach) length	Not measured	Measured for entire reach
Channel width	Measured at Habitat Monitoring sites	Measured for entire reach
Gradient	Measured at Habitat Monitoring sites	Measured for entire reach
Confinement (natural and hydromodifications)	Measured as “Human Influence” only	Measured for entire reach
Habitat type	Measured at Habitat Monitoring sites	Measured for entire reach
Obstructions	Not measured	Documented for entire reach
Bedscour	Not measured	Measured*
Icing	Not measured	Measured*
Riparian function	Measured at Habitat Monitoring sites	Measured for entire reach
Wood	Measured at Habitat Monitoring sites	Counted for entire reach
Embeddedness	Measured at Habitat Monitoring sites	Measured
Fine sediment	Measured at Habitat Monitoring sites	Measured
Turbidity (suspended sediment)	Measured at Habitat Monitoring sites	Not measured

* Only measured in the U.S. portion of the Okanogan subbasin

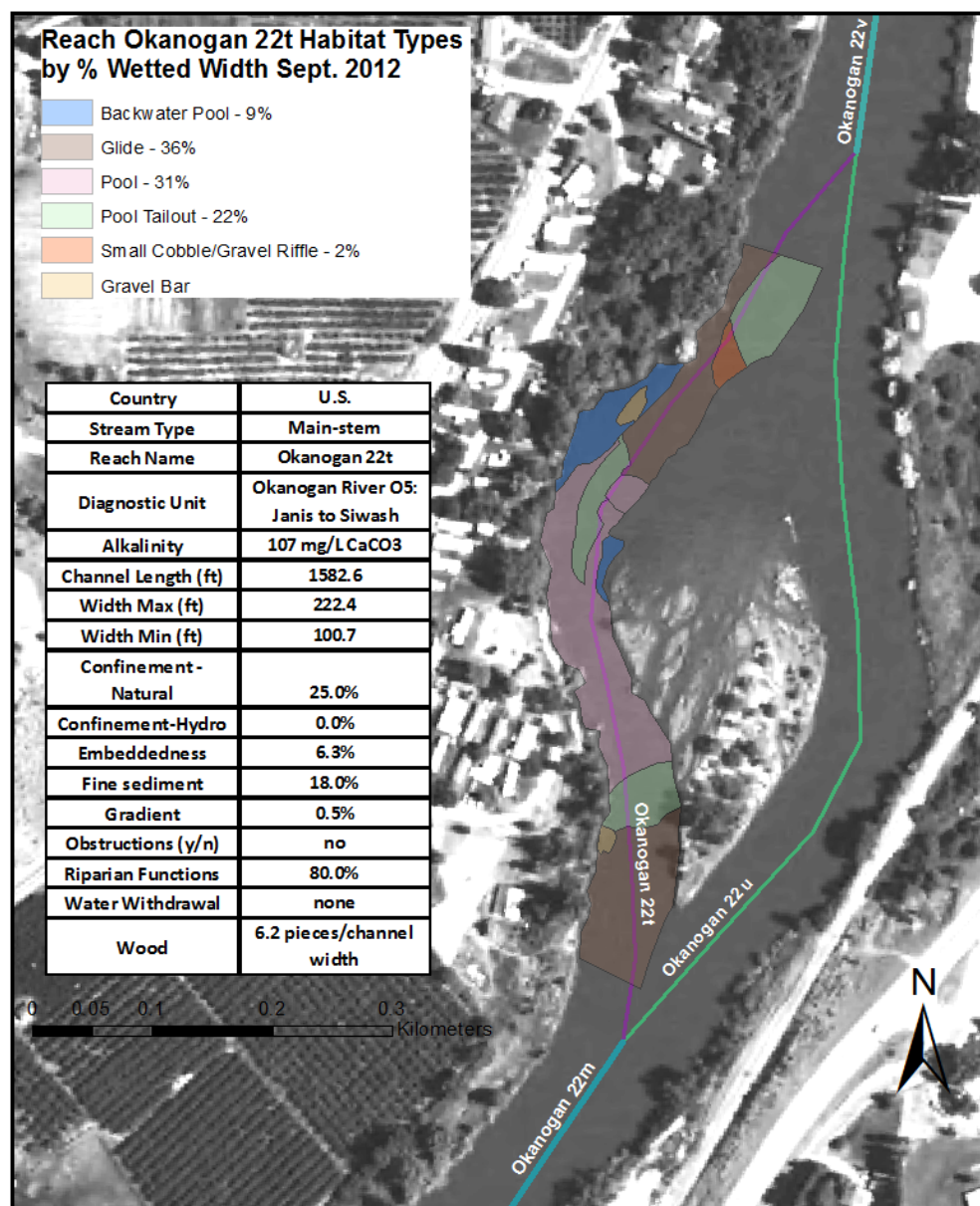


Figure J1. Reach Okanogan 22t near Tonasket, WA. Habitat types are shown as different colored polygons representing the wetted width measured during the Rapid Assessment performed September 2012.

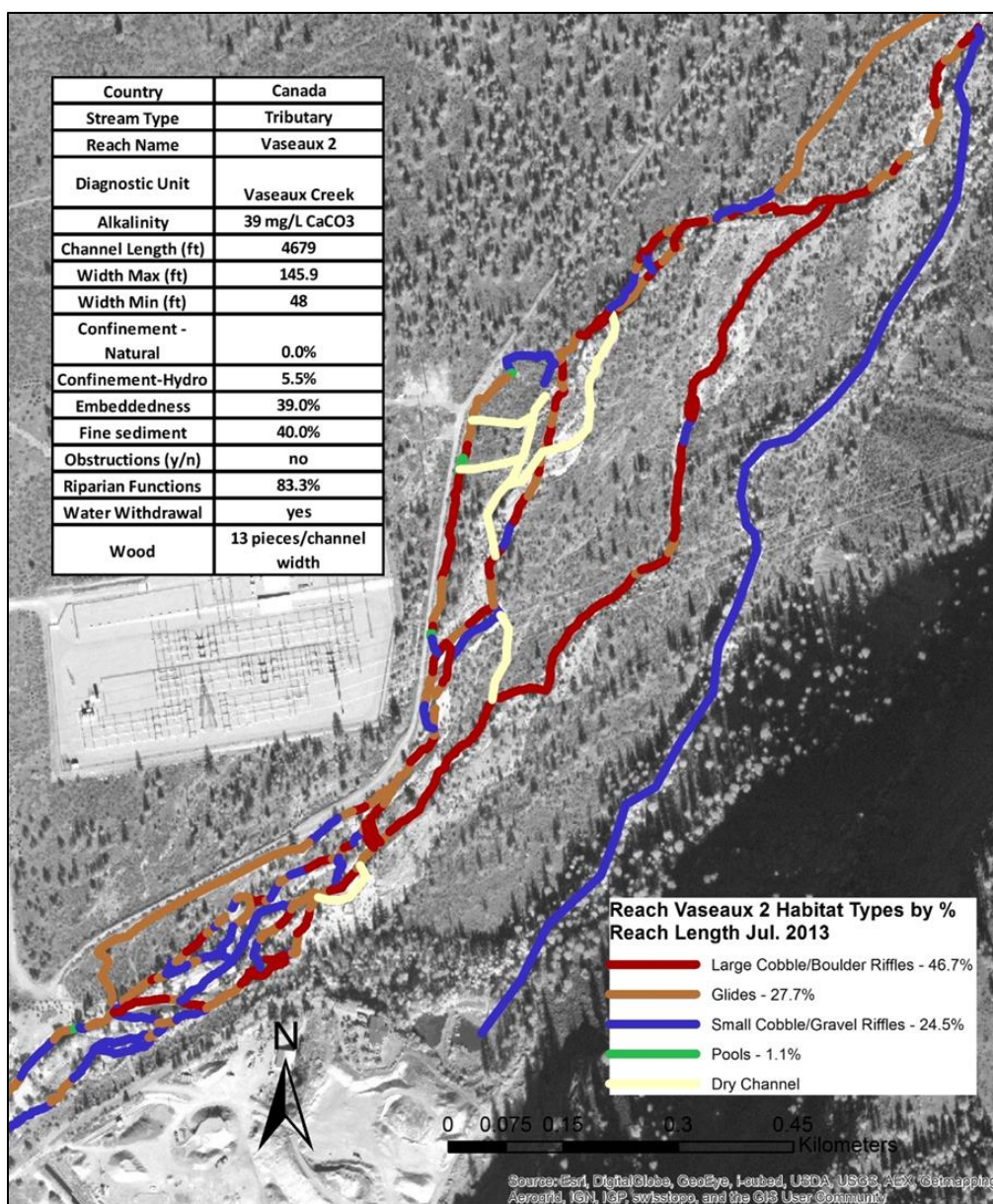


Figure J2. Reach Vaseux 2 near Oliver, B.C. Habitat types are shown as different line segments representing the reach length measured during the Rapid Assessment performed July 2013.

Appendix K: Water Quality and Discharge

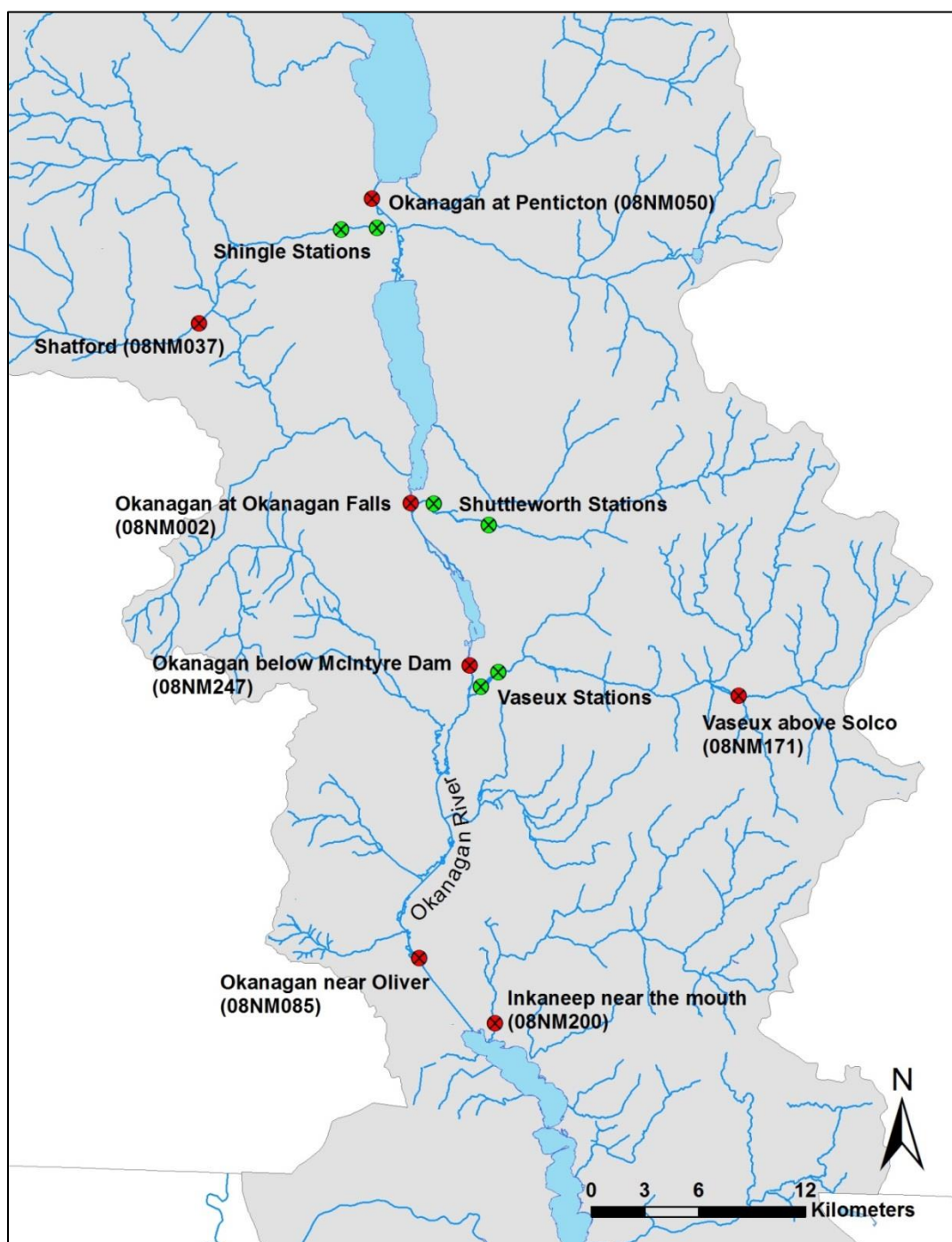


Figure K1. Map of the Canadian portion of the Okanagan subbasin showing geographic locations of discharge stations operated by OBMEP (green) and Water Survey of Canada (red) (Environment Canada 2013).

Turbidity Sampling in Canadian Portion

Turbidity was collected using two methods (TSS versus NTU's) for 12 sites on six tributaries in the Canadian portion of the Okanagan Basin. Although 2014 had a relatively low freshet discharge rate on most streams – and consequently low turbidity levels – results show that each stream had a relatively different relationship between TSS and NTU's (Figure K2, K3, and K4). It is recommended that this relationship be assessed for each stream individually in order to convert NTU measurements to TSS in the future.

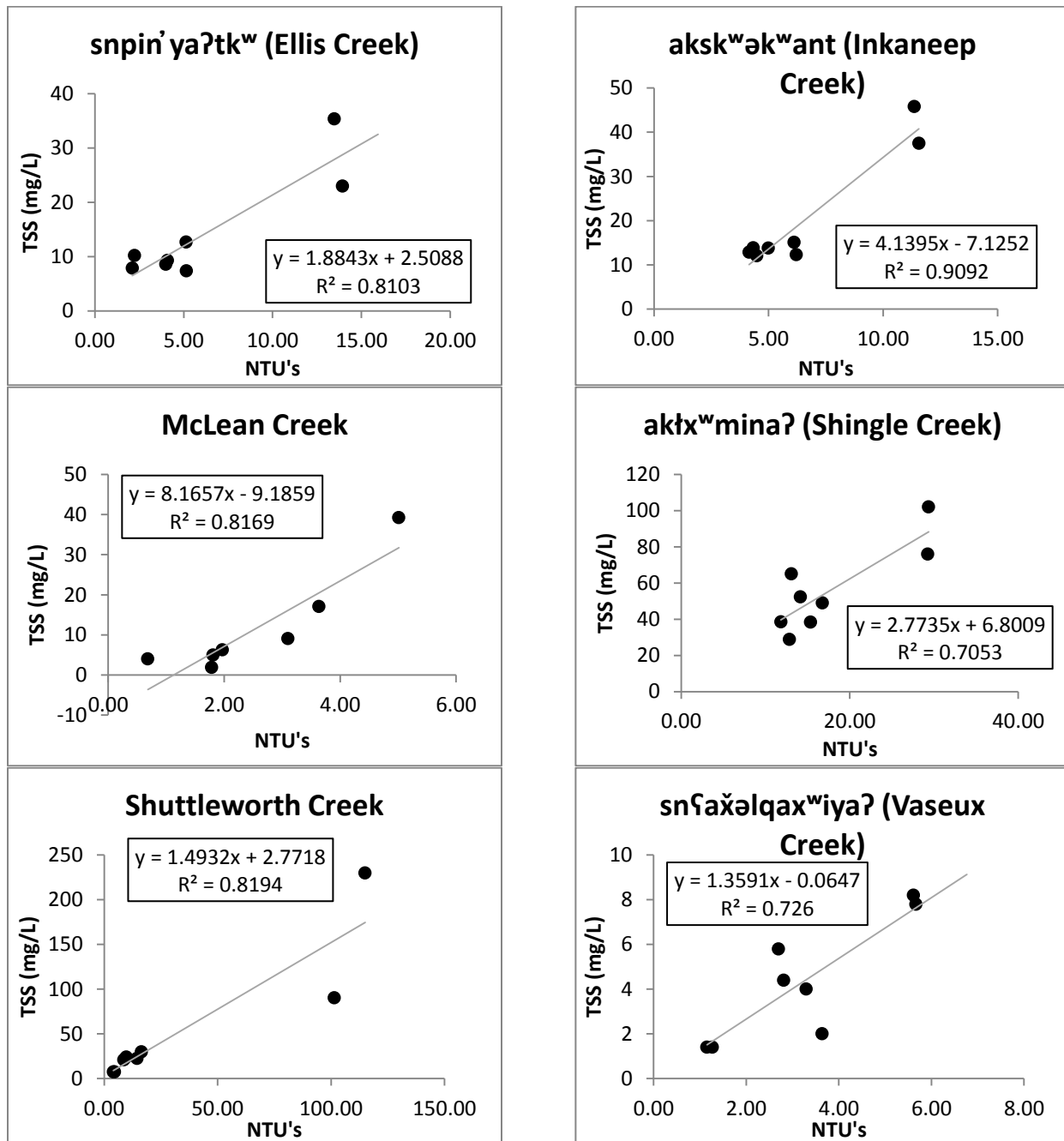


Figure K2. Relationships between total suspended solids (TSS) and NTU's for six streams in the Canadian portion of the Okanagan Basin.

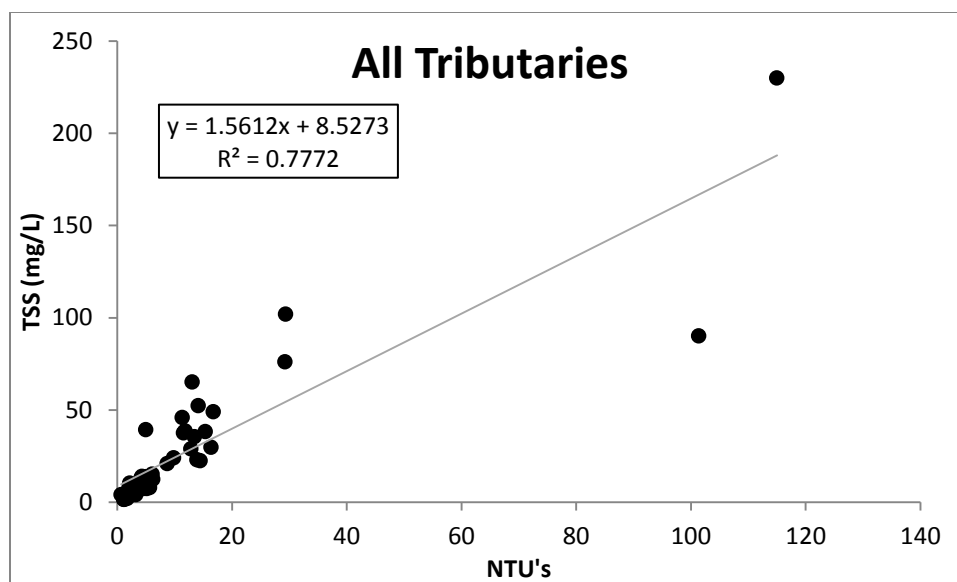


Figure K3. Overall relationship between total suspended solids (TSS) and NTUs for all six streams sampled in the Canadian portion of the Okanagan in 2014.

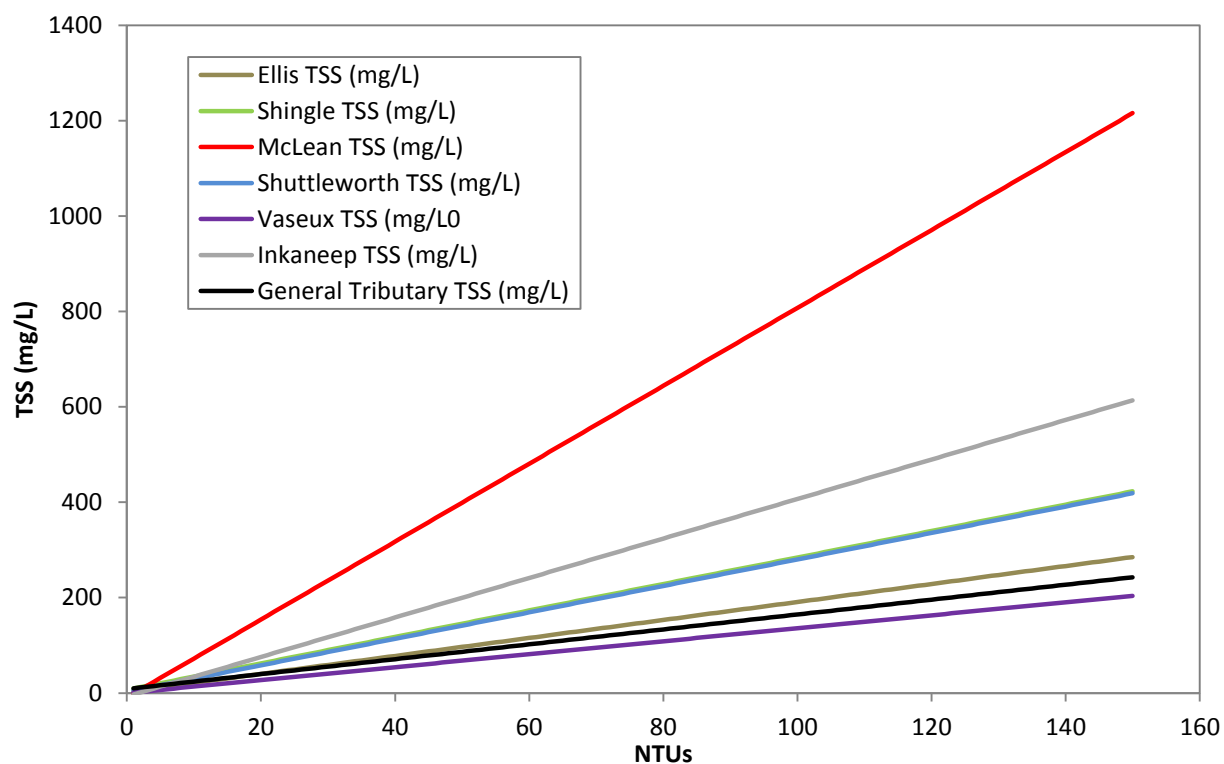


Figure K4. Relationship between total suspended solids (TSS) and NTUs developed during the spring of 2014.

Dissolved Oxygen

Onset HOBO® Dissolved Oxygen loggers recorded data that calculated July as the month with the lowest daily averages of DO for both 522 (Figure K5) and 1251 sites.

- Annual site 522 at Shuttleworth Creek recorded a lowest daily average for DO at 6.995 mg/L (with a lowest monthly average also in July at 8.503 mg/L, however, 6 days were not available for the July sample set).
- Annual site 1251 at snᑭǎłqax^{wiya}? (Vaseux Creek) recorded a lowest daily average for DO at 9.423 mg/L (with August as the site's lowest monthly average at 9.904 mg/L)

Most of the HANNA HI 9828 Multiparameter observations were primarily lower than data logged onsite. Between the two sites, equipped with data logger stations, measurements observed from the hand held meter were closer to data recorded at the Shuttleworth Creek station than at sn᠑ǎłqax“iya? (Vasux Creek). Onset HOBO® Dissolved Oxygen loggers recorded data that calculated the lowest hourly averages (Figure K6) of DO between 18:00 and 22:00 (with 522 between 18:00-20:00 and 1251 between 20:00-22:00). General observations with the HANNA HI 9828 Multiparameter occurred between 14:00 and 16:00 for 522 and 1251 station sites.

Onset HOB0® Dissolved Oxygen loggers recorded 6.22 mg/L as the lowest concentration of DO collected by the Shuttleworth Creek 522 station at 19:00 on July 12, 2014 and 9.02 mg/L as the lowest DO collected by the sn̓aḵəlgaxʷiḡa? (Vaseux Creek) station at 21:00 on July 16, 2014.

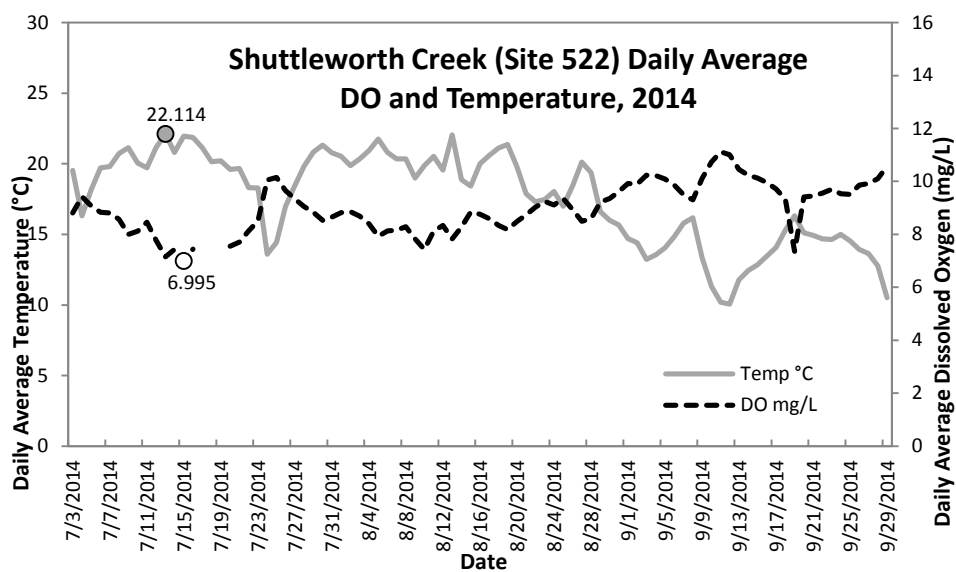


Figure K5. Relationship between daily average water temperature and daily average dissolved oxygen in Shuttleworth Creek in summer of 2014.

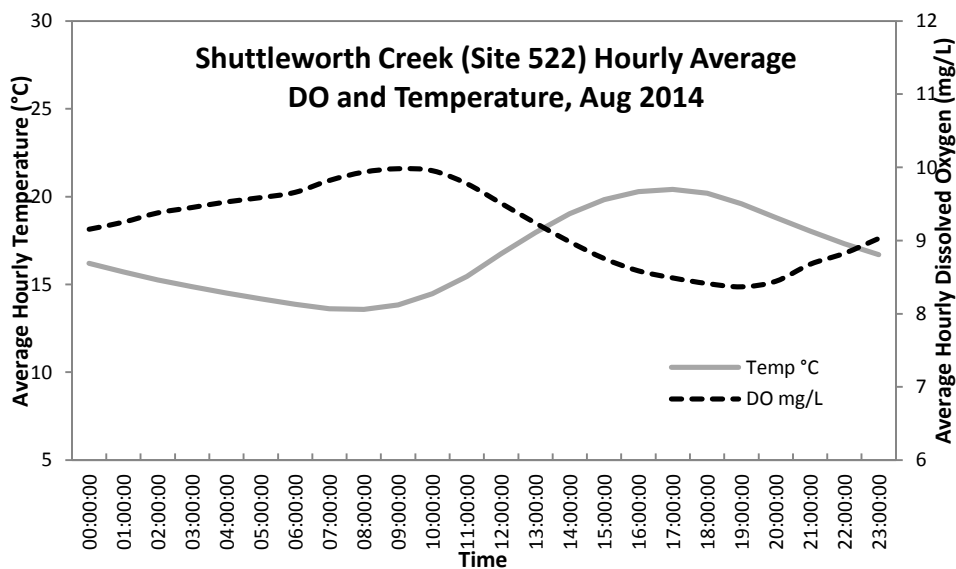


Figure K6. Diurnal relationship between average hourly water temperature and average hourly dissolved oxygen in Shuttleworth Creek in August 2014.