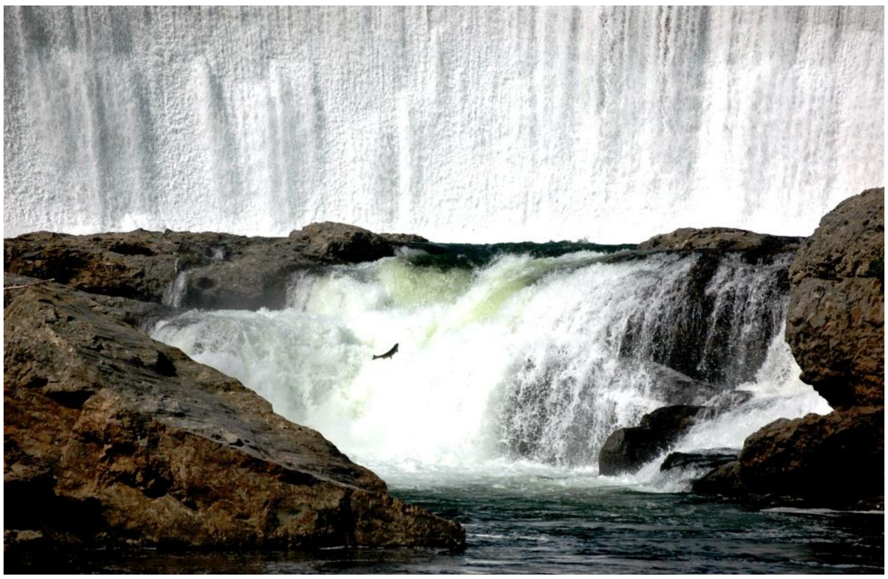
2013
Annual Report



Colville Confederated Tribes
Fish & Wildlife Department

Okanogan Basin Monitoring and Evaluation Program
BPA Project # 2003-022-00

Okanogan Basin Monitoring and Evaluation Program, 2013 Annual Report

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Executive Project Summary

Within the Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous salmonid habitat is found in the Okanogan River. The subbasin supports a stable population of summer-fall Chinook Salmon (*Oncorhynchus tshawytscha*), a greatly expanding number of Sockeye Salmon (*Oncorhynchus nerka*), a population of summer Steelhead which are considered 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 (reviews in Currie et al. 1998 and Beitinger et al. 2000), which may cause adjustments in juvenile rearing location and adult migration during that timeframe. A number of small, cold water tributaries to the Okanogan River offer additional habitat, but access is often restricted by insufficient discharge and the total extent is often limited by geographic and man-made barriers.

The Okanogan Basin Monitoring and Evaluation Program (OBMEP) is conducted by the Colville Confederated Tribes (CCT) and monitors key components of the ecosystem related to anadromous salmonids, including adult escapement, juvenile populations, physical habitat, and water quality parameters. The program addresses questions specifically related to Upper Columbia River summer Steelhead (*Oncorhynchus mykiss*), which are listed as threatened (NMFS 2009) under the Endangered Species Act (ESA). Many of the program methods were based on existing strategies (Independent Scientific Advisory Board [ISAB], Action Agencies/NOAA Fisheries, and Washington Salmon Recovery Funding Board [WSRFB]) and by the Monitoring Strategy for the Upper Columbia Basin (Hillman 2006). In addition, the monitoring program was called for in the Upper Columbia Salmon Recovery Plan and in the Okanogan Subbasin Plan (NPPC 2004). Data collected under OBMEP are not only vital to monitoring the recovery of threatened species, but are used in planning efforts, restoration projects, management decisions, and population level action effectiveness. OBMEP attempts to balance the Northwest Power and Conservation Council's (NPCC) Fish and Wildlife Program requests with the needs of NOAA Fisheries, to evaluate trends toward recovery in the Upper Columbia ESU, as they inform the NOAA Fisheries Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp).

Fish Population Status Monitoring

Adult Steelhead Monitoring

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

Results from Steelhead adult enumeration efforts in the Okanogan subbasin indicate that the number of spawning Steelhead in the Okanogan River, both hatchery and naturally produced, continued to increase since OBMEP began collecting data in 2005. The number of total Steelhead spawning in the mainstem

Okanogan and Similkameen Rivers increased at an average rate of 135 fish per year and the number of naturally produced spawners increased at an average rate of 16 fish per year. Spawning occurs throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contained suitable spawning substrates and water velocities. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. The total number and the number of naturally produced Steelhead spawning in tributaries to the Okanogan River increased at an average rate of 113 and 30 fish per year, respectively. It is likely that distribution of spawning is largely influenced by stocking location because juvenile hatchery Steelhead were scatter-planted in Omak Creek, Salmon Creek, and the Similkameen River acclimation site.

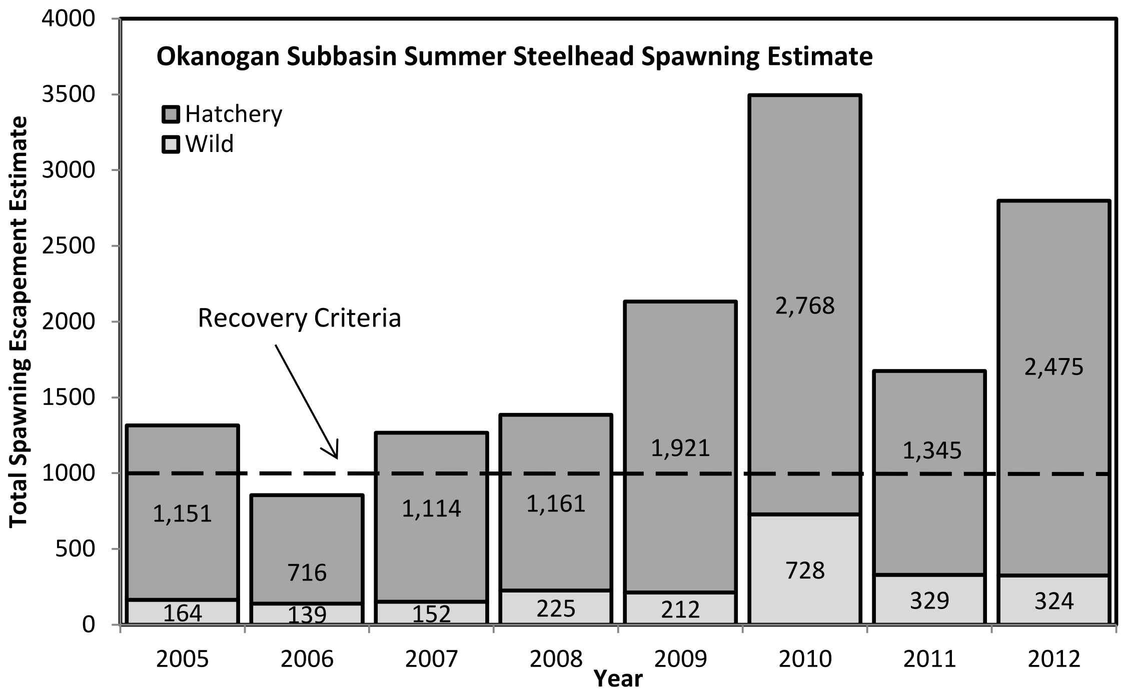

Figure ES1. Spawning estimates for the Okanogan subbasin determined by OBMEP compared with naturally produced summer Steelhead recovery goals, as outlined in the Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007).

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

Juvenile Salmonid Monitoring

A rotary screw trap (RST) was operated by OBMEP from 2004 through 2011 on the mainstem Okanogan River, but very few captures of naturally produced Steelhead produced highly variable and unreliable estimates of population size. Snorkel surveys have also been conducted at habitat monitoring sites and observations 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 remains unknown how these values relate to absolute abundance. Data from snorkel surveys conducted from 2004 through 2013 show very low numbers of juvenile Steelhead in the mainstem and considerably higher densities in tributaries. In response to recommendations from BPA and guidance from NOAA (Crawford and Rumsey 2011), OBMEP began implementing rigorous juvenile monitoring studies in 2012 and 2013 designed to estimate abundance and outmigration of naturally produced juvenile Steelhead. These studies were implemented to assess utilization of tributaries to the Okanogan River by juvenile Steelhead, while conforming to existing monitoring frameworks within the subbasin. This task was accomplished with the use of electrofishing, remote PIT tagging, mark-recapture events, and in-stream PIT tag interrogations. 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 diversity through time. Results suggest great improvements by the means in which OBMEP monitored juvenile VSP parameters.

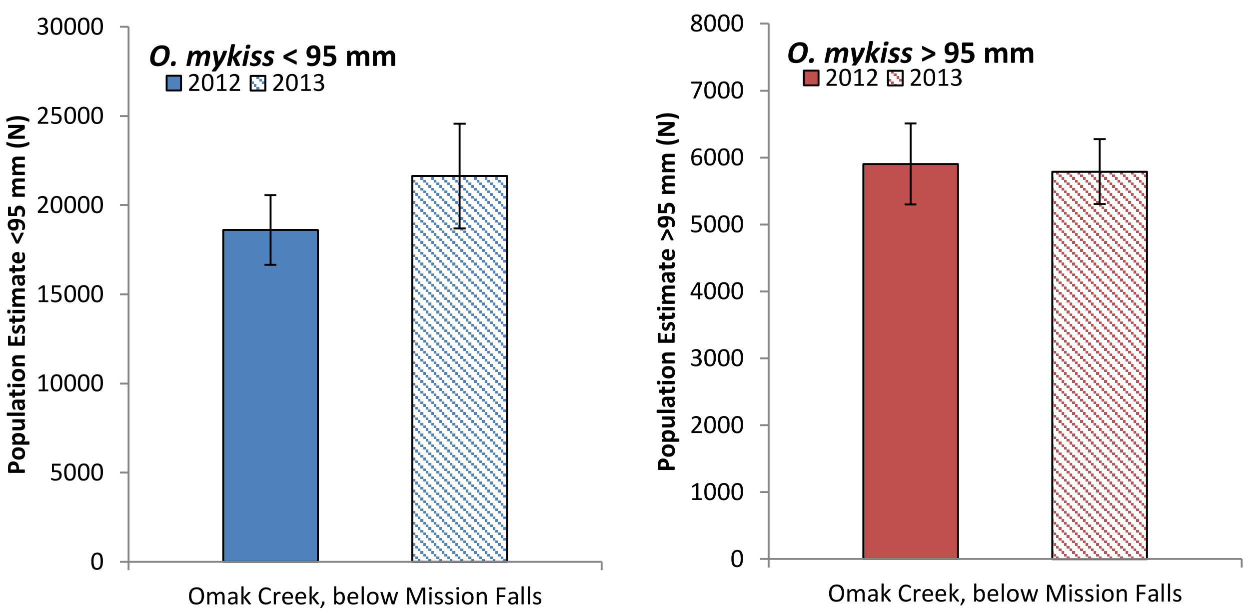

Figure ES2. Estimated abundance of juvenile *O. mykiss* in Omak Creek below Mission Falls. Data is presented by *O. mykiss* < 95 mm (left graph) and > 95 mm (right graph).

Figure ES2 contains a summary of abundance data from the past two years of monitoring on Omak Creek, a major tributary to the Okanogan River. Additional years of data for Omak Creek, as well as other tributaries to the Okanogan River with the capacity to support Steelhead, can serve as an indicator for trends in juvenile abundance and emigration throughout 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 estimates as outlined by NOAA (Crawford and Rumsey 2011). It is recommended that OBMEP should continue to expand mark-recapture population assessments on tributaries to the Okanogan River, while redefining where and when snorkel surveys are conducted and determine the usefulness of observed abundance. Research is also needed to assess egg-to-fry survival in mainstem habitats. Although a relatively large proportion of adult Steelhead spawn in the mainstem reaches of the Okanogan subbasin (55-80% on given years), abundance of juvenile Steelhead remain very low in those habitats. It is currently unknown if juveniles are succumbing to high river temperatures, or if relatively few alevin are emerging from the gravels. Additionally, 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.

Habitat Status and Trend Monitoring

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 through 2009. Results indicated that habitat conditions in the Washington State portion of the subbasin had capacity to support 2,258 summer Steelhead, with an equilibrium abundance (modeled theoretical population size) of 662. This value was far reduced from the modeled historical template capacity of 3,757 Steelhead at an equilibrium abundance of 2,574. Although the EDT model predicted that much of this capacity exists in mainstem Okanogan River, persistent high water temperatures exceeding 24 °C in the summer months likely preclude many of those habitats from contributing to summer Steelhead populations. 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 temperature may be limiting. Fine sediments also represented a limiting factor in most mainstem reaches. Fine sediment data were collected across 121 points within OBMEP habitat monitoring sites, but an average value was used to expand site data to a reach level, which likely resulted in fine sediment ratings great than what was likely present in distinct spawning areas. A different approach to collecting fine sediment data directly related to spawning substrates, pool tail-outs, and small cobble riffles would greatly improve the EDT model related to fine sediment data inputs. Habitat diversity and predation were also indicated as important limiting factors in mainstem Okanogan River.

Given systemic issues with fine sediments and high summer water temperatures in the Okanogan River, many biologists agree that tributaries contain critical habitat for recovery of listed summer Steelhead within the subbasin. Likewise, EDT modeling results indicated that Upper Salmon Creek has the most capacity of any accessible habitat in 2009. The 2009 EDT modeled habitat capacity of Upper Salmon Creek was 165 summer Steelhead with an equilibrium abundance of 113 natural origin steelhead. The historic template capacity and equilibrium abundance was 213 and 165 Steelhead, respectively. Stream flows in Salmon Creek were impaired by 69%, which represented the most heavily weighted limiting factor for that diagnostic unit. Within the Upper Salmon Creek diagnostic unit, Reach 9 represented a priority reach for protection. Salmon Creek Reach 8 was identified as the largest potential gain for improvements, where habitat was currently limited by flood flows late in the spawning and early incubation life stage. Reduced spring spill at Conconully Dam could dramatically improve steelhead production within this reach and improved water management during winter months could reduce impacts on age-0 and age-1 juveniles.

Upper Antoine Creek may contain a large potential for summer Steelhead, however, the majority of the creek remained inaccessible to summer steelhead through 2013 due to low flow and physical barriers. Upper Antoine Creek is the only diagnostic unit rated to be in good condition in the Okanogan River subbasin with an EDT capacity of 75 Steelhead and an equilibrium abundance of 42. Efforts are currently underway to protect habitat, address access issues, and supplement in stream flows within the watershed. Johnson Creek would benefit from similar projects, where summer Steelhead currently have access to only the lowest 0.5 km of stream. Under current habitat conditions, there was a modeled a capacity of three Steelhead, and over 30 times the current stream length could be made accessible by removing barriers and improving in-stream flows, which could result in a future EDT capacity of 90 Steelhead. From 2009 and 2013, considerable habitat improvement work occurred in Loup Loup Creek. Passage barriers and irrigation withdrawals were removed to restore perennial flows and access. The 2009 modeled capacity was only four summer Steelhead and the equilibrium abundance was zero. Within the next EDT status and trend report period (2015), Loup Loup Creek may serve as an example where capacity improvements are expected to be apparent.

Coordination and Data Management for RM&E

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) 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 Monitoring Methods to document and standardize protocols, developing electronic methods for data collection, review, transfer, and storage, and hiring a data steward to integrate common data elements developed in the Coordinated Assessments with OBMEP's internal database. OBMEP has also been submitting 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 some data types (GIS layers, EDT reaches, Steelhead redd GPS coordinates, and water temperature at PIT tag arrays) is occurring through the program website: www.cctobmep.com/obmep_project_data.php

Acknowledgements

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The Okanagan Nation Alliance Fisheries Department would like to acknowledge the Penticton Indian Band (PIB), the Osoyoos Indian Band (OIB), the townships of Oliver, Okanagan Falls and Penticton, the Lezard family, the Baptiste family (of OIB), Tony Thompson, Bill Barrisoff and the South Okanagan Rehabilitation Center for Owls for access granted to sites of this ongoing study. Acknowledgements also go to Lindsay George, Jamie Squakin, Zoe Masters, Skyeler Folks, Colette Louie, Kari Alex, Camille Rivard-Sirois, Amanda Warman, Floyd Baptiste, Marlo Lezard, Hannah Sungaila and Saul Squakin for providing valuable technical assistance throughout the 2013 study.

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

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List of Acronyms

BiOp	Biological Opinion
BOBTWG	Bi-lateral Okanagan Basin Technical Working Group
BPA	Bonneville Power Administration
CCT	Colville Confederated Tribes
CJHP	Chief Joseph Hatchery Program
CSMEP	Collaborative System-Wide Monitoring and Evaluation Project
CTMax	Critical thermal maximum temperature
DART	Data Access in Real Time
DMS	Data Management System
EDT	Ecosystem Diagnosis and Treatment
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
GIS	Geographic Information System
GRTS	Generalized Random Tessellation Stratified
HBI	Hilsenhoff Biotic Index
HPA	Hydraulic Project Approval
ICBTRT	Interior Columbia Basin Technical Recovery Team
ISAB	Independent Scientific Advisory Board
ISEMP	Integrated Status and Effectiveness Monitoring Project
ISRP	Independent Scientific Review Panel
IULT	Incipient Upper Lethal Temperature
MPG	Major Population Group
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council

OBMEP	Okanogan Basin Monitoring and Evaluation Program
OID	Okanogan Irrigation District
OKC	Okanagan Channel (PIT array at VDS 3)
ONA	Okanagan Nation Alliance
PIT	Passive Integrated Transponder
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
PRD	Priest Rapids Dam
PTAGIS	Passive Integrated Transponder Tag Information System
PUD	Public Utility District
QA/QC	Quality Assurance / Quality Control
RA	Rapid Assessment
RPA	Reasonable and Prudent Alternative
RKM	River Kilometer
RM&E	Research, Monitoring and Evaluation
RST	Rotary Screw Trap
RTT	Regional Technical Team
UCSRB	Upper Columbia Salmon Recovery Board
USGS	United States Geological Survey
VDS	Vertical Drop Structure
VSP	Viable Salmonid Population
WDFW	Washington Department of Fish and Wildlife
WSC	Water Survey Canada
WSRFB	Washington Salmon Recovery Funding Board

List of Okanagan Place Names

Columbia River	nx̌ʷəntkʷitkʷ
Ellis Creek	snpiṅyaʔtkʷ
Inkaneep Creek	akskʷəkʷant
Okanagan Falls	sx̌ʷəx̌ʷnitkʷ
Okanagan Lake	kłusxnitkʷ or kłusxənitkʷ
Okanagan River	q̓awsitkʷ
Osoyoos Lake	suwiẇs
Penticton	snpintktn
Shingle Creek	akłxʷminaʔ
Skaha Lake	q̓awstiḱʷt
Vaseux Creek	snʕax̌əlqaxʷiyaʔ
Vaseux Lake	np̓əxłpiẇ
Similkameen River	nməlqitkʷ

1.0 Introduction

In 2002, the Upper Columbia Regional Technical Team (RTT) attempted to standardize and improve monitoring in the Upper Columbia River Basin by developing the Monitoring Strategy for the Upper Columbia Basin (Hillman 2006). A proposal for funding the Okanogan River portion of this strategy was submitted to the Northwest Power and Conservation Council (NPCC) and received a high priority rating from the Columbia Basin Fish and Wildlife managers and the Independent Scientific Review Panel (ISRP). Funding for this project was approved in 2003. The Okanogan Basin Monitoring and Evaluation Program (OBMEP) was drawn from the existing strategies (Independent Scientific Advisory Board (ISAB), Action Agencies/National Oceanic and Atmospheric Administration (NOAA) Fisheries, Integrated Status and Effectiveness Monitoring Project (ISEMP), Pacific Northwest Aquatic Monitoring Partnership (PNAMP), and Collaborative System-wide Monitoring and Evaluation Project (CSMEP)) to address questions related to anadromous fish management and recovery in the Upper Columbia River, and more specifically, the Okanogan subbasin. The Colville Tribes' Anadromous Fisheries Division began implementing the monitoring project in the spring of 2004.

Colville Tribes began collaborating with the Okanagan Nation Alliance (ONA) Fisheries Department on this project in the Canadian portion of the subbasin in 2005, due to the trans-boundary nature of the Okanagan subbasin. Effort is put into maintaining consistent sampling programs on both sides of the border and frequent meetings and cross-training occurs regularly to align methodologies for collecting biological and physical field data.

1.1 Study Area

The Okanogan[1] subbasin extends south from its headwaters in southern British Columbia through north central Washington State (Figure 1), where it meets its confluence with the nx̌ʷəntkʷitkʷ (Columbia River). Shaped by receding glaciers during the Pleistocene Era, 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.

Within the Columbia River Basin, the furthest upstream and northern-most extent of currently accessible anadromous habitat is found in the Okanogan River. The subbasin supports a stable population of summer-fall Chinook Salmon (*Oncorhynchus tshawytscha*), a greatly expanding number of Sockeye Salmon (*Oncorhynchus nerka*), a population of Steelhead (*Oncorhynchus mykiss*) which are considered 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 (reviews in Currie et al. 1998 and Beitinger et al. 2000), which may cause adjustments in juvenile rearing location and adult migration during that timeframe.

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

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 geographic and man-made barriers.

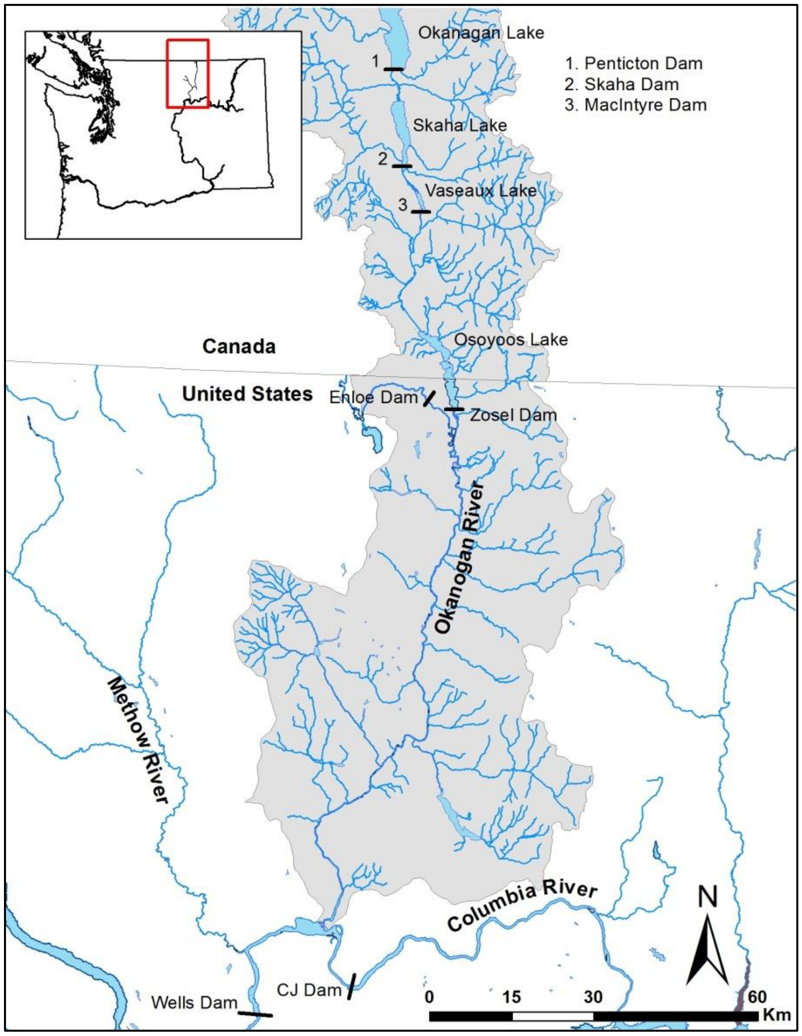

Figure 1. Study area, the Okanogan subbasin in north-central Washington State and southern British Columbia.

Within the Washington State portion of the Okanogan subbasin, the vast majority of land along the river is under private landownership, and landowner cooperation is required for fisheries research activities to occur. Economic activity in the subbasin is centered on fruit crops, ranching, agriculture, tourism, mining, and timber harvest. In this relatively arid environment, a complex system of fisheries and water management requires coordination between many local stakeholders, state agencies, federal agencies, and Tribes, spanning two countries.

In the Canadian portion of the Okanagan subbasin, man-made barriers are major constraints to present salmonid migrations (Figure 1). Dams exist at the outlets of Canadian Okanagan mainstem lakes including, suwiẇs (Osoyoos Lake), np'əxłpiw' (Vaseux Lake), q̇awstik̓ʷt (Skaha Lake), and kłusxnitkʷ (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 kłusxnitkʷ (Okanagan Lake) outlet dam at snpintktn (Penticton) is the upstream barrier for all anadromous salmon species and the q̓awstik̓ʷt (Skaha Lake) outlet is still undergoing improvements for fish passage. It is known that anadromous salmonids have previously occupied the entire q̓awsitkʷ (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-strategies[2]:

- Assess the status and trend of natural and hatchery origin abundance of fish populations for various life stages.
- Assess the status and trend of juvenile abundance and productivity of natural origin fish populations.
- Assess the status and trend of spatial distribution of fish populations.
- 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-strategy[3]:

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

OBMEP was designed to monitor key components of the ecosystem including biological, physical habitat, and water quality parameters and was designed specifically to be a status and trends monitoring program. 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.

In consideration of the overall Steelhead BPA Fish and Wildlife management goals, the objectives of the Okanogan Basin Monitoring and Evaluation Program are to monitor the current status and possible trends in:

1. Steelhead population abundance, distribution and productivity;
2. Steelhead habitat capacity and limiting factors;
3. Environmental factors including water quality, temperature and discharge; and
4. Biological community factors.

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[2] Fish Population RM&E - http://www.cbfish.org/ProgramStrategy.mvc/ViewProgramStrategySummary/1

[3] Tributary Habitat RM&E - http://www.cbfish.org/ProgramStrategy.mvc/ViewProgramStrategySummary/3

On top of these objectives, an over-arching objective is that the program be coordinated across geo-political boundaries within the Upper Columbia Evolutionary Significant Unit (ESU), Columbia Basin, and the Pacific Northwest region.

2.0 Fish Population Status Monitoring

To assess presence or absence of meaningful change in biological factors at the population scale for summer Steelhead, the Okanagan 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

Summer Steelhead are listed as threatened in the Upper Columbia River Evolutionarily Significant Unit (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 2013.

In the Canadian portion of the Okanagan subbasin, previous studies have shown that, historically, Steelhead were found throughout the Okanagan subbasin (Ernst and Vedan 2000). Prior to 2009, McIntyre Dam – at the outlet of np̓əxƛ̓piẁ (Vaseux Lake) – was the upstream barrier for returning anadromous salmonids. During this time, akskʷəkʷant (Inkaneep Creek) and snʕax̌əlqaxʷiyaʔ (Vaseux Creek) were the only major tributaries accessible to anadromous Steelhead for spawning and rearing. ONA Fisheries Department conducted redd surveys on both streams and operated a counting weir on akskʷəkʷant (Inkaneep Creek) through OBMEP from 2006 until 2011. While anadromous Steelhead were documented during these monitoring actions (Audy et al. 2011), surveys were discontinued due to difficulties in data collection during spring freshet and low-confidence estimates. McIntyre Dam was refitted in 2009 to allow upstream migration of salmonids and, currently, migrating Steelhead have access to habitat as far upstream as the kłusxnitkʷ (Okanagan Lake) outlet dam at snpintktn (Penticton). This allows Steelhead access to at least four more major tributaries for spawning and rearing including Shuttleworth Creek, McLean Creek, snpiṅyaʔtkʷ (Ellis Creek) and akłxʷminaʔ (Shingle Creek). In 2012 and 2013, the only enumeration method used was a Passive Integrated Transponder (PIT) antenna array in the q̇awsitkʷ (Okanagan River) mainstem just upstream of suwiẁs (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

The q̓awsitkʷ (Okanogan River) flows from the northern headwaters near Vernon, BC to the confluence with the Columbia River near Brewster, WA. 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 2012, OBMEP employed multiple methods to determine a total spawning estimate for the subbasin. Each method has been described in detail in the monitoringmethods.org links listed above. Counts of all Steelhead spawning downstream of anadromous fish migration barriers were attempted in the mainstem and all accessible tributaries of the Okanogan and Similkameen River drainages within the United States (Arterburn et al. 2007, Walsh and Long 2006). Adult weir traps, PIT tag arrays, and underwater video enumeration were used to improve escapement estimates at locations where habitat was extensive, environmental conditions were unfavorable for redd surveys to occur, and to coordinate with other ongoing data collection efforts.

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

2.1.3 Results

Summer Steelhead spawning distribution and estimates were determined throughout the Okanogan subbasin in 2012 using redd surveys, adult weir traps, underwater video enumeration, and expansion of PIT tag detections to estimated total abundance. It was estimated that 2,799 summer Steelhead spawned in the Okanogan River subbasin. The Washington Department of Fish and Wildlife (WDFW) estimated maximum spawner escapement into the Okanogan at 2,784 summer Steelhead (Charles Frady, WDFW, pers. comm.). The WDFW estimate was derived from Wells Dam passage counts, modified by harvest information, and divided into individual subbasins (Methow and Okanogan) through the use of radio telemetry data (English et al. 2001, 2003). For the 2012 spawning estimates, OBMEP methods relied on the WDFW total value to calculate the mainstem spawning component, so it was not surprising that the two estimates were comparable. The WDFW escapement estimate for wild Steelhead in the Okanogan subbasin was 261. OBMEP estimated that 324 ad-present (adults with a non-clipped adipose fin) Steelhead spawned within the Okanogan River subbasin in 2012. Inconsistent percentages of ad-present Steelhead that utilized individual tributaries may have complicated percent-wild calculations from redd counts where there were no means of determining local counts.

Due to an unusually high water year in 2012, with prolonged high flows and turbid water that limited visibility, many mainstem redd surveys missed the peak and the later portion of spawning. Therefore, previous years' data were used, including the proportion of the run spawning in each mainstem reach, to synthesize an estimated escapement for mainstem reaches. Steelhead spawning estimates for tributaries to the Okanogan River were more straightforward, primarily due to multiple data collection methods, including PIT tag detections, underwater video observation, and successful on-the-ground redd surveys.

Data presented in Figure 2 summarizes spawning estimates in the Okanogan subbasin from 2005 through 2012, for both hatchery and wild Steelhead. Estimates were compared with recovery goals outlined by the Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007). Data from 2013 are not presented in this report as data from contributing agencies has yet to be made available and are required for a detailed estimate. These data will be available in early 2014, and at such time, a technical report on total Steelhead escapement will be posted to the OBMEP website and uploaded to PISCES with estimates for 2013.

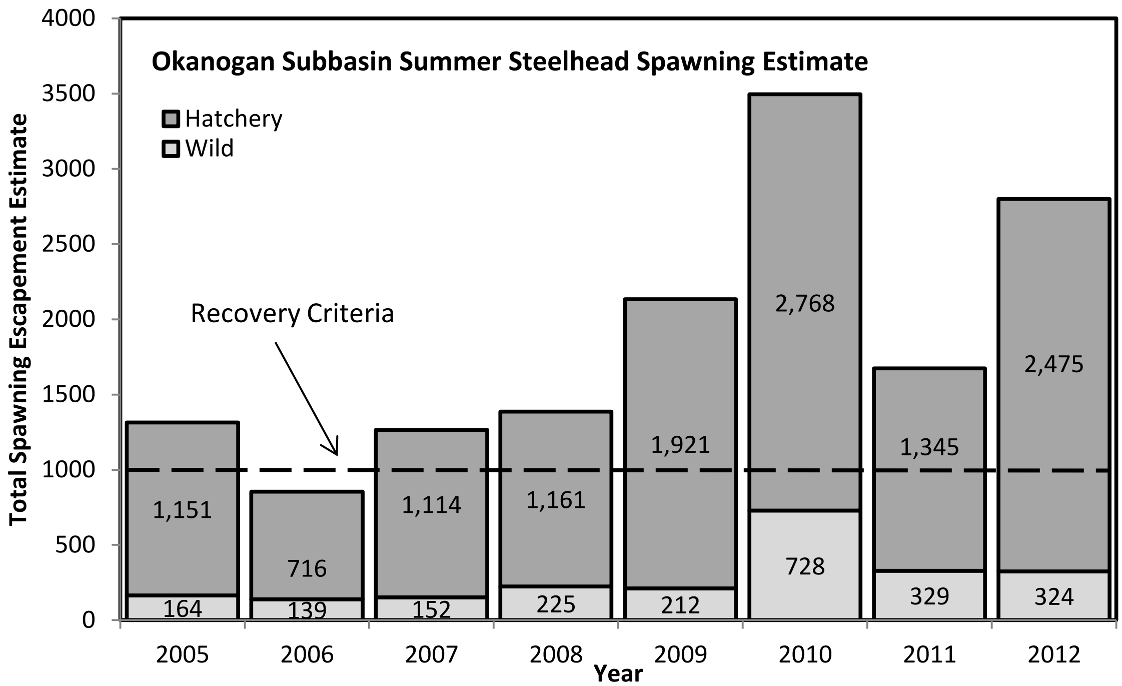

Figure 2. Spawning estimates determined by OBMEP compared with summer Steelhead recovery goals, as outlined in the Upper Columbia Spring Chinook and Steelhead Recovery Plan (UCSRB 2007).[4]

Spawning occurs throughout the mainstem Okanogan River, although narrowly focused to distinct areas that contain suitable spawning substrates and water velocities. Steelhead spawning has been documented to be most heavily concentrated below Zosel Dam on the Okanogan River and in braided island sections of the lower Similkameen River. It is likely that distribution of spawning is largely influenced by stocking location as juvenile hatchery Steelhead were acclimated and stocked in Omak Creek, Salmon Creek, and the Similkameen River. Steelhead redds have been commonly observed near these stocking locations, as well as near Chinook Salmon redd mounds and mid-channel islands.

[4] The Interior Columbia Basin Technical Recovery Team (ICBTRT) determined that 500 naturally produced Steelhead adults would meet the minimum abundance recovery criteria within the U.S. portion of the Okanogan subbasin. If the Canadian portion of the subbasin was included, minimum abundance recovery criteria would be 1,000 naturally produced adults (UCSRB 2007).

For the Canadian portion of the Okanagan subbasin, PIT tag detections on the q̓awsitkʷ (Okanagan River) at VDS 3 (Okanagan Channel - OKC) upriver of suwiw̓s (Osoyoos Lake) are listed in Appendix C from 2010 to 2013. In all years listed, a higher proportion of wild Steelhead detected at Zosel Dam continued up the q̓awsitkʷ (Okanagan River) upriver of suwiw̓s (Osoyoos Lake) than hatchery Steelhead. However, these proportions are based on extremely small sample sizes. There are no data for 2011 to 2013 for the number of Steelhead spawners entering Canadian tributaries.

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

Table 1. Abundance estimates of Steelhead passage at OKC antenna array on the q̓awsitkʷ (Okanagan River) upstream of suwiw̓s (Osoyoos Lake).

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

* *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) no loss of tags, (4) closed population, and (5) fish falling back downstream had an equal chance of being detected as fish migrating upstream.

Annual collection of adult summer Steelhead data provided a comprehensive depiction of spawning distribution and minimum escapement within the Okanogan River subbasin. More detail concerning escapement estimates can be found in the 2012 Okanogan Basin Steelhead Escapement and Spawning Distribution report (Miller et al. 2013). Within this document is contained a synthesis of the past eight years of summer Steelhead spawning data in the Okanogan subbasin, including initial trend analysis.

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). Detailed percent-wild information has been provided annually and every attempt has been made to ensure that these estimates are as accurate as stated methods currently allow. However, these data should be used with caution, as it is difficult to define natal origin through visual observation alone (i.e. intact adipose fin). Values presented in this document represent our best scientific estimate from available information, but the variability surrounding point estimates are currently undefined.

Many assumptions have been made when developing local escapement estimates. However, these on-the-ground surveys have only been conducted over short periods in the Okanogan subbasin, from 2005-2013. 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 8-year 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. Numerous methods have been described in the literature for analyzing complex fisheries data. When more years of data become available, additional detailed data analysis methods may be employed. We have made every effort to ensure that the reported values are as accurate as possible, including using multiple data collection methods for validation, comprehensive on-the-ground surveys, and best scientific judgment based on extensive local experience with the subbasin.

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

Annual variations of environmental factors can profoundly impact redd distributions in small tributaries to the Okanogan River. Changes in summer Steelhead spawning distribution within tributaries appear to be driven by the following four factors:

1) Discharge and elevation of the Okanogan River
2) Discharge of the tributary streams
3) Timing of runoff in relation to run timing of Steelhead
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, no certain conclusions can be drawn for those survey years. Summer Steelhead that spawn in tributary habitats of the Okanogan subbasin are more likely to find suitable environmental conditions and rearing habitats than those spawning in mainstem habitats. Therefore, the Program should consider continuing restoration projects that address adequate flow in tributaries to the Okanogan River.

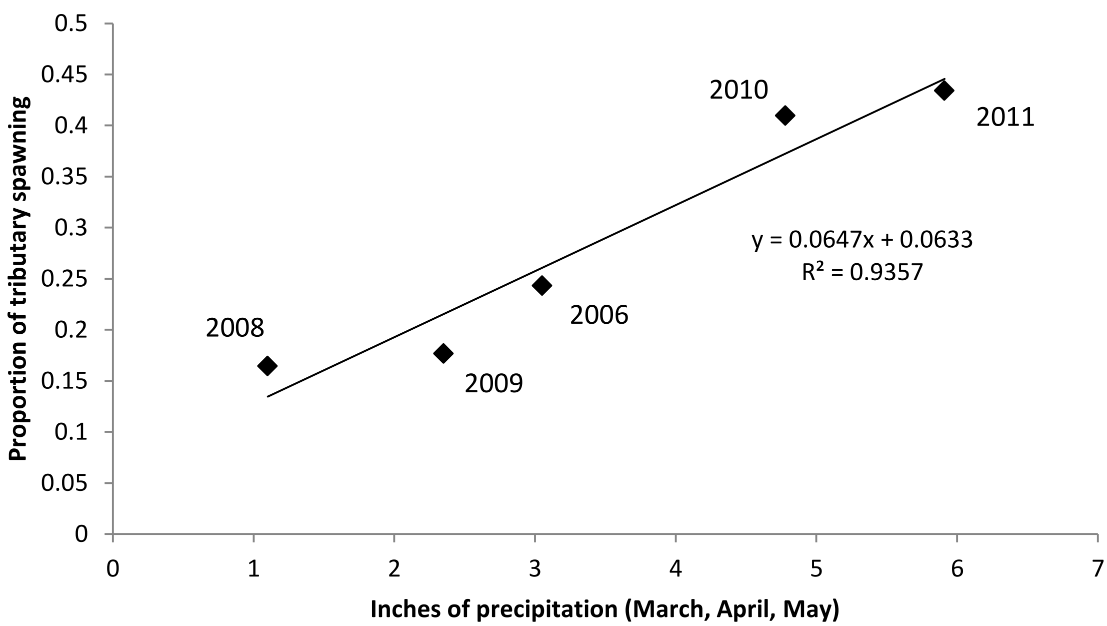

Figure 3. Correlation between precipitation occurring during March, April, and May and the proportion of Steelhead spawning in tributaries to the Okanogan River in Washington State.

Summer Steelhead redd surveys can provide a reasonable depiction of spawning distribution and 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, to validate redd survey efficiency, and describe 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 extent of tributaries.
    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, undercounted, and define confidence intervals surrounding point estimates.
3. Examine feasibility of determining adult escapement estimates from mark-recapture PIT tag expansion estimates.
    a. Spring redd surveys may produce practical 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 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 yielded highly variable and unreliable estimates of population size.

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 snorkel surveys conducted by OBMEP from 2004 (2005 in British Columbia) through 2013 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 wild juvenile Steelhead in the subbasin, population monitoring efforts are being refocused to the cool water tributaries.

In 2013, new rigorous 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 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) 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 2013, juvenile monitoring data collection occurred through the implementation of snorkel surveys (in the U.S. and Canada), as well as, an Okanogan 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 representitive of the total population of juvenile *O. mykiss*, the estimated proportion of tags from the study that pass the array will be applied to the population estimate to determine a total yearly emigration estimate.

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

In attempts to minimize inter-crew observer bias, tributaries were snorkeled by the same observers from 2009 through 2013, 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 *O. mykiss*/ha, which was derived by dividing the observed number of fish 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 D.

2.2.3 Results

Mark-Recapture Abundance Estimates

During the 2013 field season, a total of 1,080 m of stream were sampled across the seven sites in Omak Creek. This represented 11.9% of the total stream length between the confluence of Omak Creek with the Okanogan River and the upstream anadromous barrier (Mission Falls). The population of juvenile *O. mykiss* in Omak Creek was divided into two size classes for analysis, based on the approximate size difference of fish between age 0 (< 95 mm) and age 1+ (> 95 mm) during the time of sampling. The population of juvenile *O. mykiss* larger than 95 mm in Omak Creek was estimated at 5,790 ± 487 (Figure 4). The coefficient of variation was 4.3%. The average capture rate of this size class during mark-recapture sampling across all sites was 47%. The population of juvenile *O. mykiss* less than 95 mm was estimated at 21,637 ± 2,939 (Figure 4) with a coefficient of variation of 6.9%. The average capture efficiency of this size class during mark-recapture sampling across all sites was 28%. A total of 581 PIT tags were placed in fish greater than 95 mm, which represented 10.0% of the population > 95 mm ($\widehat{N}$ = 5,790). These fish will be used as a representative mark-recapture group to estimate the total emigrating population through the following year. A final yearly emigration estimate will be reported at a later date.

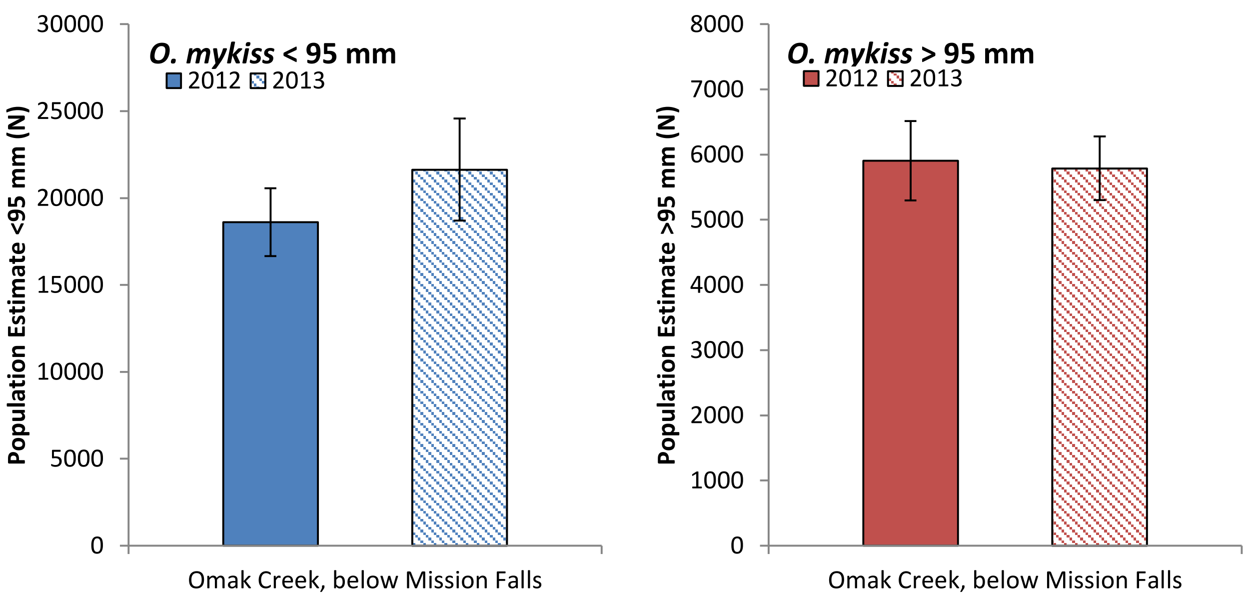

Figure 4. Estimated abundance of juvenile *O. mykiss* in Omak Creek below Mission Falls. Data is presented by *O. mykiss* < 95 mm (left graph) and > 95 mm (right graph).

In Salmon Creek, a total of 1,043 m of stream were sampled across nine sites. Two of the nine sites were dry during the summer of 2013 and the fish population assumed to be zero in those respective reaches. The combined length of habitat sampled represented 3.8% of the total stream length between the confluence of Salmon Creek with the Okanogan River and the upstream anadromous barrier (Conconully Dam). The population of juvenile *O. mykiss* larger than 95 mm in Salmon Creek was estimated at 29,386 ± 1,953. The coefficient of variation was 3.0% and the average capture rate of this size class during mark-recapture sampling across all sites was 41%. The population of juvenile *O. mykiss* less than 95 mm was estimated at 22,746 ± 4,080 with a coefficient of variation of 9.2%. The average capture efficiency of this size class during mark-recapture sampling across all sites was 24%. A total of 911 PIT tags were placed in fish greater than 95 mm, which represented 3.1% of the population > 95 mm ($\widehat{N}$ = 29,386). These fish will be used as a representative mark-recapture group to estimate the total emigrating population through the following year.

In Bonaparte Creek, a total of 150 m of stream were sampled in one site. The combined length of habitat sampled represented 9.1% of the total stream length between the confluence of Bonaparte Creek with the Okanogan River and the upstream anadromous barrier (natural falls). The population of juvenile *O. mykiss* larger than 95 mm in Bonaparte Creek was estimated at 385 ± 25. The coefficient of variation was 3.4% and the capture rate of this size class during mark-recapture sampling was 83%. The population of juvenile *O. mykiss* less than 95 mm was estimated at 432 ± 189 with a coefficient of variation of 22.3%. The capture efficiency of this size class during mark-recapture sampling was 24%. A total of 34 PIT tags were placed in fish greater than 95 mm, which represented 8.8% of the population > 95 mm ($\widehat{N}$ = 385). These fish will be used as a representative mark-recapture group to estimate the total emigrating population through the following year.

Refer to Appendix E for a detailed report on juvenile mark-recapture abundance estimates.

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 Tunk Creek (10,111 fish/ha), followed by Loup Loup Creek (6,819 fish/ha), and Wanacut Creek (3,518 fish/ha). Four sites were sampled on Salmon Creek, and densities among these sites ranged from 276 to 1,768 fish/ha. Two sites below the anadromous barrier (Mission Falls) on Omak Creek had densities of 2,878 and 3,301 fish/ha. In contrast, the density of juvenile *O. mykiss* at three sites above the anadromous barrier on Omak Creek ranged from 806 to 1,793 fish/ha. No juvenile *O. mykiss* were observed in 11 out of 14 sites total sites on the mainstem Okanogan River.

In the British Columbia portion of the Okanagan subbasin, 11 out of the 12 tributary sites were snorkeled. One site on upper McLean Creek (OBMEP-1259) was dry at base flow. Juvenile *O. mykiss* were observed at 10 of the 11 sites. No juvenile *O. mykiss* were observed in lower snpin'yaʔtkʷ (Ellis Creek, OBMEP-470). The highest average density of juvenile *O. mykiss* (fish/ha) was observed in akskʷəkʷant (Inkaneep Creek) (1,706 fish/ha). The highest total of juvenile *O. mykiss* was observed was in snʕax̌əlqaxʷiyaʔ (Vaseux Creek), which also had the largest wetted area.

All four q̓awsitkʷ (Okanagan River) mainstem sites were sampled in Canada; however, *O. mykiss* were only observed at three sites. No *O. mykiss* were observed at the mainstem site (OBMEP-346) upriver of np̓əxłpiw̓ (Vaseux Lake). The average density of juvenile *O. mykiss* was lower in the mainstem (9 fish/ha) compared to tributaries (82 fish/ha at the lowest).

Refer to Appendix F for further detail on observed abundance estimates from snorkel surveys.

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 (Appendix F, Figures 19-25, 27-31). 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 3.2 Water Quality, Temperature, and Discharge Monitoring). The apparent absence of juvenile salmonids during the summer months may be attributed to mortality or avoidance behavior of harsh conditions.

Quantity of water (i.e. dry creeks, as noted in the figures contained in Appendix I) appeared to limit distribution of juvenile *O. mykiss* in some small streams. Tributaries that support adult Steelhead spawning, but are most notably affected by low summer discharges, include Tonasket, Wild Horse Spring, Tunk, lower Salmon, and Loup Loup Creeks in Washington.

Results from juvenile salmonid 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 Viable Salmonid Population (VSP) parameters (McElhany et al. 2000). Additional years of data for Omak Creek, as well as 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 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 means it may be possible to monitor numbers of out-migrating juveniles at reduced costs when compared to traditional methods. 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 wild 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. Conduct research 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

In order to monitor the current status and possible trends in Steelhead habitat capacity and limiting factors, the Okanagan Basin Monitoring and Evaluation Program developed the following measurement objectives:

1. Assess the quantity and quality of habitat available to Steelhead by monitoring stream corridor structure parameters;
2. Assess the quality of environmental factors impacting Steelhead productivity including water quality, temperature and discharge parameters; and
3. Assess the quality of biological community factors impacting Steelhead 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 – operated 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 Stream Corridor Structure Monitoring

3.1.1 Introduction

Since 2004 (2005 in British Columbia), OBMEP has collected salmonid habitat data throughout the Okanogan subbasin at predetermined, randomly-generated sites developed using the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (EMAP) with a Generalized Random Tessellation Stratified (GRTS) sample design. While the empirical data collected at these EMAP/GRTS habitat monitoring sites[5] provided information on specific sections of selected reaches, it was recognized that a more complete suite of data would be required to populate the inputs of the EDT model to generate the outputs needed to report on salmonid habitat capacity and limiting factors. For this purpose, OBMEP started developing the Rapid Assessment program in 2012[6] to start collecting some habitat data previously not recorded and in reaches that were previously not sampled. The Rapid Assessment program was developed to efficiently collect habitat data during a stream walk process where data are collected at a resolution usable by the EDT model and functionally mapped in the Geographic Information System (GIS).

With the combined inputs from the habitat monitoring sites and the Rapid Assessment 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 more 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

[5] For the remainder of this report, EMAP/GRTS-generated sites referred to as "habitat monitoring sites."

[6] Began collaborating with ONA to develop methods and collect data in Canada in 2013.

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. Data are collected annually (four-year rotating panels) using the habitat monitoring sites that were established in 2004, and all other remaining reaches that are accessible to anadromous salmon are sampled once every four years using the Rapid Assessment methodologies. 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 G.

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 (Appendix H, Table 8). In 2013, thirty-four sites were located in the Washington State portion of the Okanogan subbasin and 16 sites were located in Canada.

For the remaining reaches accessible to anadromous salmon, populating the EDT model relies on data collected through the Rapid Assessment program. However, since the Rapid Assessment program was designed around populating the EDT model, and the habitat monitoring site data collection was developed prior to EDT integration, not all attributes are collected at all reaches (Table 2). Likewise, not all attributes are collected at the same geographic scale. 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).

Table 2. 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*

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 bestprofessional judgment, were used to develop some remaining attributes. These include channel gradient, hatchery outplanting, hydrologic regime, water withdrawals, and water quality conditions.

Habitat monitoring site data are managed in a Microsoft SQL Server database, which data are uploaded to digitally and managed by CCT and Summit Environmental. 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 still being developed.

3.1.3. Results

In 2013, all habitat monitoring sites were completed as listed in Appendix H, Table 8. In the U.S. portion of the subbasin, the Rapid Assessment reaches completed are listed for 2012 and 2013. For the Canadian portion of the subbasin, 2013 was the first year that Rapid Assessment data were collected. The number of reaches and total length completed are also listed in Appendix H, Table 8. Data collected by the Rapid Assessment program are used to populate the EDT model; however, the process involves a habitat mapping component which could be used for any number of different objectives outside of the EDT program. An example of the maps and data produced for Okanogan mainstem and tributary reaches through the Rapid Assessment program is presented in Appendix H.

The data collected under both habitat monitoring methodologies are analyzed using the EDT model; therefore, all results are listed in a separate report which can be accessed at the website provided below (very large files).

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

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

The EDT summer Steelhead report is comprised of an introduction, data sources and methods, a user guide, Steelhead habitat status and trends report cards by specific reach, and summary and conclusions. The EDT report cards present 'results' of OBMEP habitat analysis and include a selection of bar graphs, and 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. 3-1)

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 abundance 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 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 (Okanagan River) in British Columbia, as well as Washington State. Rapid Assessment data identified previously unknown fish passage barriers, validated locations of known passage barriers, 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.

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. Continuing to refine specific data collection, and in addition, examining comparability with current GRTS habitat monitoring techniques, will remain an important task in the near future.

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.
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 refugium 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.

3.2 Water Quality, Temperature, and Discharge Monitoring

3.2.1 Introduction

Since 2004 (2005 in British Columbia), OBMEP has collected water quality data in the Okanogan mainstem and tributaries including water chemistry parameters and temperature. Water chemistry attributes have been collected at varying frequencies and timing throughout the basin; however, water temperature has been collected consistently at all habitat monitoring sites using Onset® temperature data loggers. In the U.S. portion of the Okanogan subbasin, water discharge data have been collected through the United States Geological Survey (USGS). In the Canadian portion of the Okanagan subbasin, the Water Survey of Canada (WSC) has collected historic and current water discharge data on the mainstem and periodically at a number of tributary sites. In 2012 and 2013, OBMEP began collecting discharge data on Canadian tributary sites where discharge data was previously unavailable.

Water temperature 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.

3.2.2 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
OBMEP - Habitat Monitoring (ID:9)
https://www.monitoringmethods.org/Protocol/Details/9

In 2013, water chemistry parameters were collected by OBMEP through the methods and protocols listed on monitoringmethods.org above. The EDT model inputs require a number of water chemistry attributes that were previously not collected at habitat monitoring sites (Table 3) and, consequently, methods were developed to collect those attributes as part of the Rapid Assessment program (link to methods also listed above). Water temperature was collected at all Annual Panel and Panel 4 habitat sites using Onset® hobo temperature loggers. While discharge data were collected on the mainstem by U.S. and Canadian governmental organizations, tributary discharge data were collected on Canadian tributaries through OBMEP (Appendix I, Figure 43).

Table 3. List of water quality, temperature and discharge attributes used to populate the Ecosystem Diagnosis and Treatment (EDT) model and associated measurement status for 2013 obtained through OBMEP.

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

Water chemistry testing was conducted monthly from 2010 through 2012 at 18 sites in the U.S. Okanogan River, Similkameen River, and major tributaries in the subbasin. Three sites are located on the mainstem Okanogan near the USGS monitoring stations near the town of Malott (lower), Tonasket (middle), and Oroville (upper). Water chemistry was collected at the following tributaries to the Okanogan: Ninemile, Tonasket, Antoine, Siwash, Aeneas, Bonaparte, Tunk, Johnson, Wanacut, Omak, Salmon, and Loup Loup Creeks. Tonasket, Siwash, and Wanacut Creeks have very limited data sets because these creeks are typically dry for most of the sampling period. Historically, Loup Loup Creek was intermittently connected to the mainstem, until recently when the Colville Confederated Tribes secured water rights to keep the creek connected year around.

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). Due to the different tasks and the need for accuracy and quality, OBMEP relied on contracts with the USGS or the WA Department of Ecology for all stream flow data collection and publishing. In 2013, the DOE discontinued data collection at the Omak Creek stream gauge. OBMEP took the opportunity to fill that gap and expand the scope of stream flow data collection by working directly with the USGS. The USGS assisted with developing cooperative agreements to allow OBMEP personnel to perform stream flow data collection, which are subsequently hosted by the USGS. OBMEP personnel attended USGS trainings, assisted in the installation of new stream gages, and acquired USGS calibrated equipment to conduct stream flow data collection.

3.2.3 Results

Washington State

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 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. Web links for water temperature and discharge monitoring site data, within the Washington portion of the Okanogan subbasin, are provided in Appendix I. Water chemistry data collected by OBMEP are stored in the OBMEP database and historical water chemistry data collected by the Washington Department of Ecology are available at: http://www.ecy.wa.gov/apps/watersheds/riv/regions/state.asp?mode=cro

A subset of data has been presented for the Okanogan River and selected tributaries known to support summer Steelhead within the Okanogan subbasin. Figure 5 outlines the difference in water temperature between the mainstem and the significance of tributary habitat in respect to thermal refuge. Additional water temperature and discharge data are presented in Appendix I. Specific data requests can be referred to the OBMEP Data Analyst, 509-422-7733.

Based on long-term monitoring data and known limitations of cold-water salmonid species (reviews by Currie et al. 1998 and Beitinger et al. 2000), water temperature appears to be a limiting factor for summer Steelhead recovery in the Okanogan River. Temperature data in the Okanogan subbasin reveal distinctions between tributaries and the mainstem of the Okanogan. All tributaries were several degrees cooler than the mainstem Okanogan during the peak summer temperatures (i.e. Omak Creek, Figure 6a.), and creeks with known groundwater inputs (i.e. Aeneas and Wild Horse Spring Creeks) tended to be warmer over the winter months (Figure 6b.). For the 2013 water year (October 1, 2012 through September 30, 2013), the daily maximum temperature in the mainstem Okanogan exceeded 28°C on one day at the USGS gauge in Oroville, at Zosel Dam. Additionally, daily average temperature at the USGS gauge in Malott (near the confluence) exceeded 24°C 5% of the year and 18°C 23% of the year.

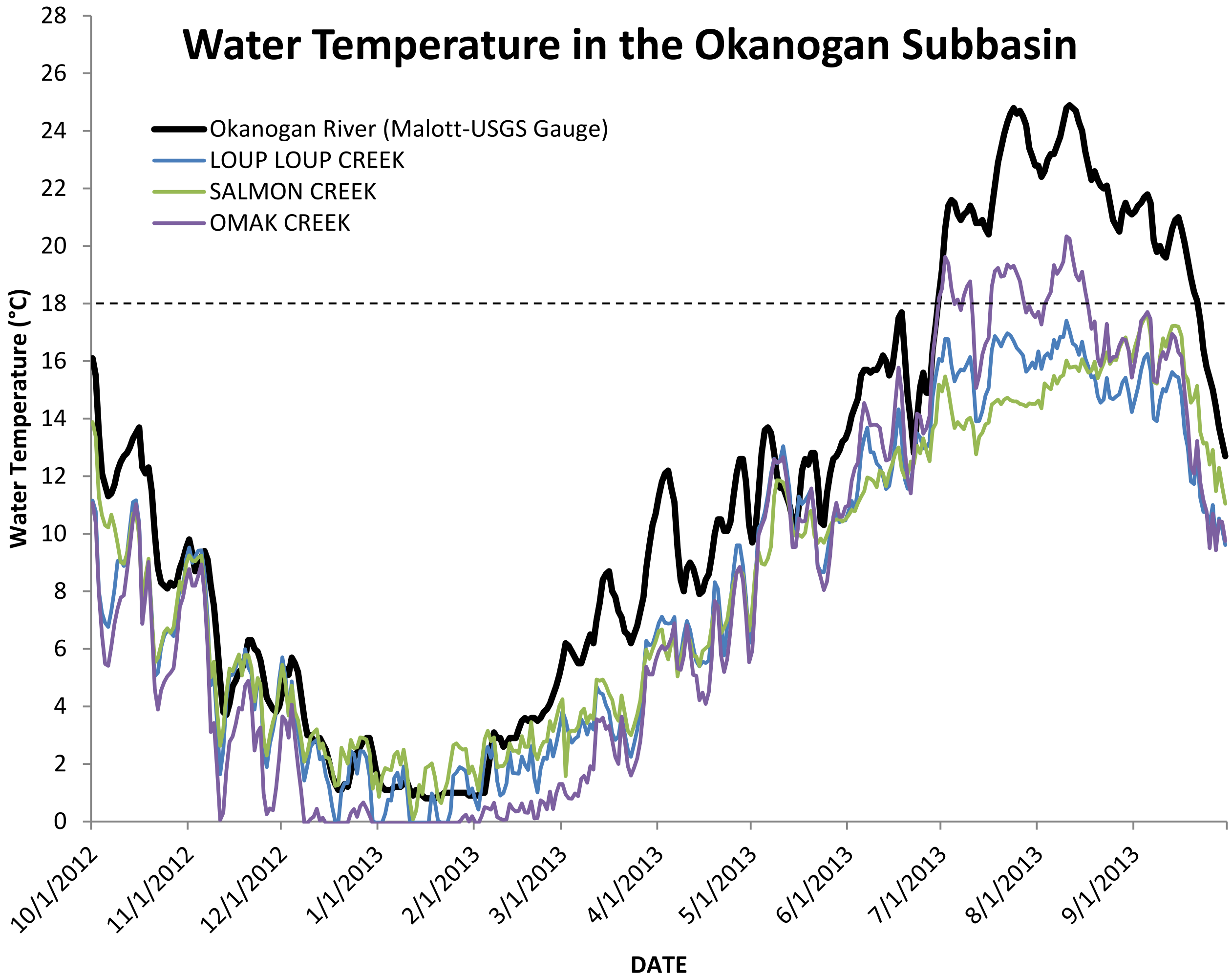

Figure 5. Daily average water temperature in the Okanogan subbasin for the 2013 water year.

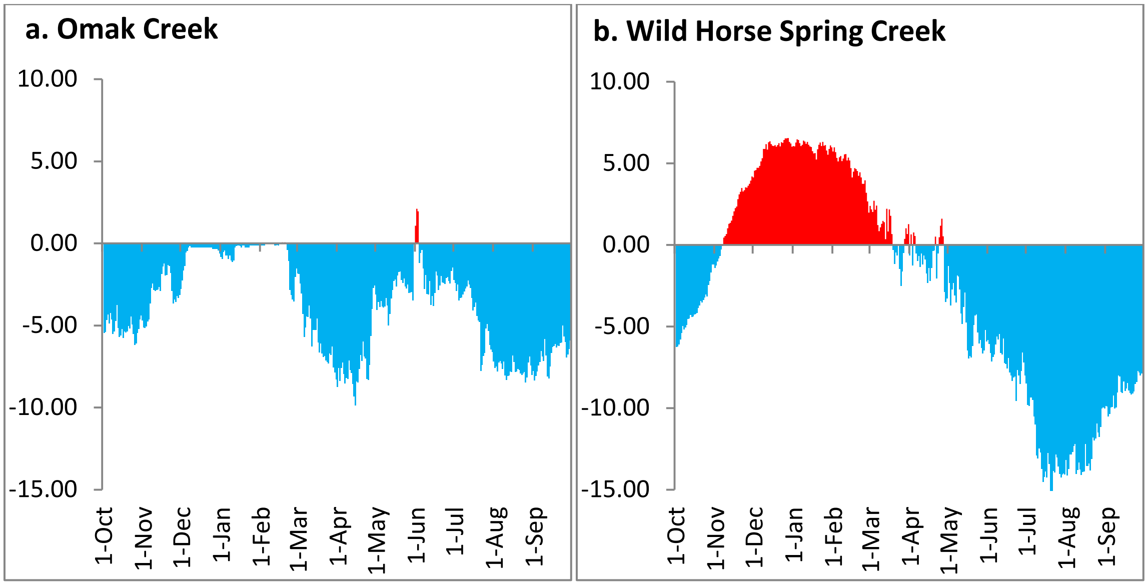

Figure 6. Difference in water temperature (°C) between (a.) Omak Creek and the Okanogan River (USGS Malott), and (b.) Wildhorse Spring Creek and the Okanogan River (USGS Oroville) for the 2012 water year.

British Columbia

A subset of water temperature data is shown in Appendix I for the northern region (Figure 44), central region (Figure 45), and the southern region (Figure 46) of the Canadian study area. Discharge was monitored at six stations (two stations per tributary for three tributaries) through OBMEP for 2013 (Appendix I, map). Hydrographs of discharge data collected are shown in Appendix I. Other discharge monitoring on tributaries and the q̓awsitkʷ (Okanagan River) mainstem was done through Water Survey of Canada (Environment Canada 2013).

Peak water temperatures were especially higher in mainstem reaches characterized by channelization and sparse riparian coverage; whereas, the unchannelized reach of the mainstem (natural section) showed lower peak summer temperatures (Appendix I). In most tributaries, summer temperatures peak around 18 to 20°C (Appendix I).

Discharge data on the mainstem collected by Water Survey of Canada show that, in 2013, the mean daily discharge peaked at 86.93 m^3/s near nʕaləm̓xnitkʷ (Oliver) at station 08NM085 (Appendix I) and that the discharge was greater downriver than in the north. However, on July 20, 2013 the mean discharge at nʕaləm̓xnitkʷ (Oliver) was less than upstream at snpintktn (Penticton) until September 23, 2013. During this period, more water was lost out of the system than contributed.

A historic analysis of mainstem discharge at Water Survey of Canada site 08NM085 near sx̌ʷəx̌ʷnitkʷ (Okanagan Falls) shows that the period from 2000 to 2012 is characterized as having relatively low average monthly discharge (Figure 7). Baseflows are lower than previous monthly averages and the overall total discharge is lower. These lower flows and high seasonal temperatures reduce habitat quality available to *O. mykiss* rearing.

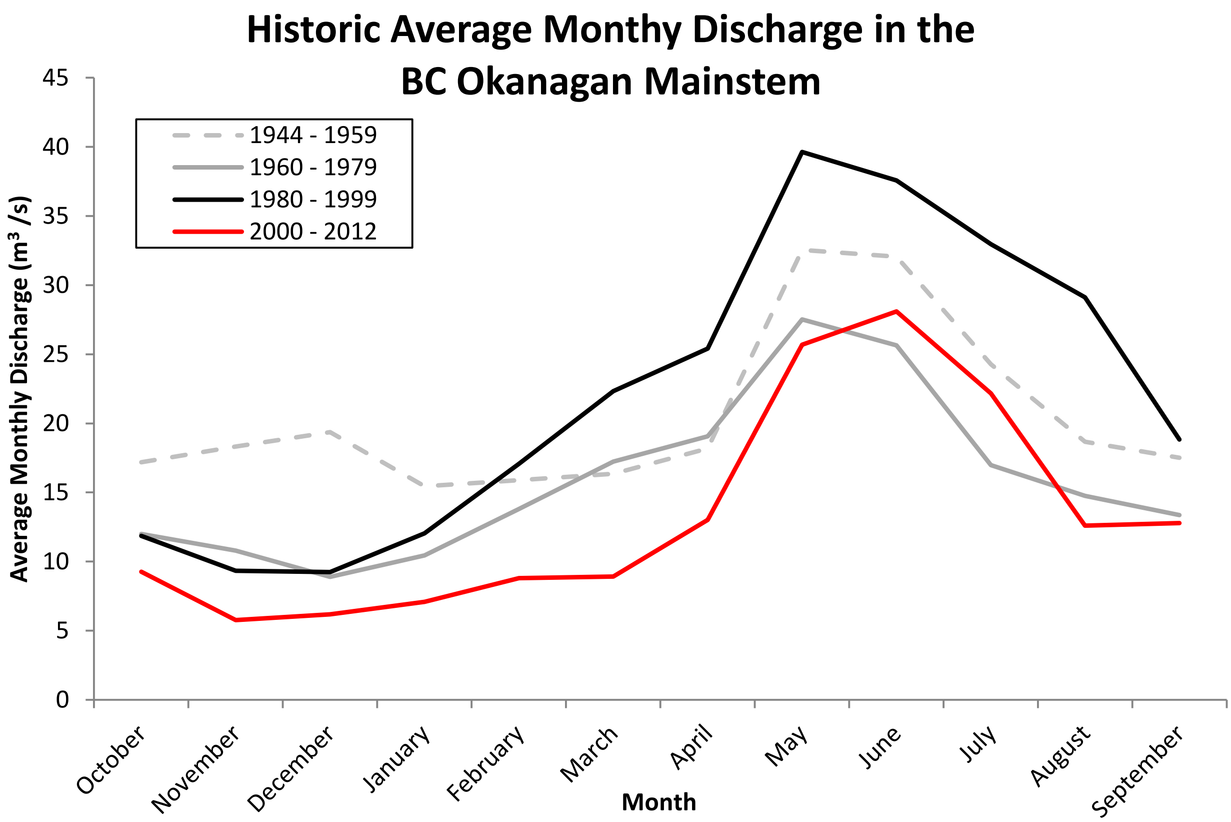

Figure 7. Historic mean monthly discharge recorded at Water Survey Canada station 08NM085 near sx̌ʷəx̌ʷnitkʷ (Okanagan Falls) from 1944 to 2012 (Environment Canada 2013).

3.2.4 Conclusions

Water temperature in the Okanogan and its tributaries remains an important variable affecting the spatial, distribution, growth rate, 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 *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.

In the Canadian portion of the Okanagan subbasin, results also show extremely high summer temperatures in the mainstem, especially in channelized areas and that, during this time, more water is removed from the river than contributed. As well, in the past decade there was less water in the system altogether compared with historic levels and lower base-flows (Figure 7). Tributaries have seasonally high temperatures and flashy hydrographs, showing large spikes during freshet followed quickly by a drop back down to baseflows.

As shown in snorkel surveys (Appendix F), juvenile salmonids are consistently observed in greater numbers in small tributaries than in the mainstem Okanogan River, where they are rarely 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[7]. It is unknown if high summer 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 the snorkel method may not be as efficient for observing juveniles in the mainstem. Monitoring temperature in the mainstem Okanogan and its tributaries will continue to play an important role in understanding life histories of Steelhead in the Okanogan subbasin.

Most observed water quality readings were 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, although 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.

3.3 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 2013, benthic macroinvertebrate assemblages were collected and assessed at all Annual Panel and Panel 4 habitat monitoring sites that were not dry. The benthic macroinvertebrate collection methods are listed on monitoringmethods.org at: https://www.monitoringmethods.org/CustomizedMethod/Details/11512. Currently, 2013 samples are still being processed in the lab; however, 2012 data have been processed. A summary of 2012 *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 Appendix J.

Introduced fish species abundance was observed through OBMEP snorkel surveys in 2013. 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.

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[7] Refer to Steelhead spawning survey reports - http://www.colvilletribes.com/obmep_publications.php

4.0 Coordination and Data Management (RM&E)

OBMEP supported the BPA Fish and Wildlife Program data management strategy 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[8]."

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?

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, and hiring a data steward to integrate common data elements

[8] Coordination and Data Management RM&E - http://www.cbfish.org/ProgramStrategy.mvc/ViewProgramStrategySummary/8

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:

www.cctobmep.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 2013, a custom habitat data collection template was refined and successfully used 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/QCed 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). The Coordinated Assessments Data Exchange Standard (DET) is a standardized format defining the types of data to be used in a high-level population assessment, and was published in November 2012 by the Pacific States Marine Fisheries Commission. In 2013, OBMEP was awarded additional funding to match the funding OBMEP had set aside for a data steward who would be responsible for integrating DET definitions into the OBMEP database and enabling us to fully participate in the Coordinated Assessment process. The data steward was hired in the beginning of December and will begin incorporating DET definitions into OBMEP database outputs, and will be fully involved in all meetings and workshops as the Coordinated Assessment project proceeds.

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 2013 included:

- Columbia Cascade Regional Fisheries Enhancement Group
- Upper Columbia Regional Technical Team
- Bilateral Okanagan Basin Technical Working Group (BOBTWG)
- Okanogan Irrigation District board meetings
- Native American Fish and Wildlife Society, Pacific Regional Conference
- Regional Fisheries Enhancement Group Advisory Board and Coalition
- PNAMP Habitat Metric meetings
- HCP Hatchery Oversight Technical Team Conference
- 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, which users can collect their data in a standardized format with. 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

With the listing of several salmonid species as threatened or endangered under the Endangered Species Act (ESA), state, federal, 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. Salmon population monitoring also includes collecting applicable data that can be used in real-time decisions about harvest, as well as project implementation. From 2004 to 2013, biological data corresponding to adult and juvenile abundance, as well as spatial and temporal distribution, were collected by OBMEP throughout the Okanogan subbasin. Additional monitoring efforts included physical habitat measurements, stream corridor, water quality, temperature, and discharge data. Over the long-term, status data can be used to examine trends, which may indicate if salmon populations and respective habitats are improving.

Steelhead Abundance, Distribution, and Productivity

In 2013, OBMEP increased sampling effort with regards to Viable Salmonid Population (VSP) parameters (McElhany et al. 2000) of Steelhead populations through the installation of PIT tag antenna arrays and the juvenile mark-recapture program in U.S. tributaries (collaboratively with WDFW Upper-Columbia project). On both sides of the border, OBMEP continued long-term juvenile relative abundance sampling through the use of snorkel surveys. Results from these sampling efforts show that juvenile rearing in summer months is largely limited to tributary habitat in the subbasin (Appendix F), likely due to high mainstem water temperatures (Figure 5). Results also suggest that tributary capacity and spatial distribution are impacted by low discharge in summer months (Appendix I). Some limitations identified through the 2013 sampling year are that 1) the juvenile mark-recapture program was conducted on three tributaries in the U.S. only, 2) only one PIT tag antenna array has been installed on Canadian portion of the q̓awsitkʷ (Okanagan River) mainstem, 3) snorkel data is limited to observed densities only and it is not currently known how these data relate to absolute abundance, 4) spawning distribution for Steelhead in Canada is largely unknown, and 5) enumeration techniques at Zosel Dam are inadequate at high flows. For future biological sampling efforts, it is recommended that the juvenile mark-recapture program be expanded to additional tributaries on both sides of the border, that PIT tag antenna arrays be installed at strategic positions in the Canadian portion of the subbasin, that secondary snorkel surveys be conducted at different times of the year in the mainstem reaches, that methods for identifying Steelhead redd distribution be assessed in Canada, and that alternative techniques be evaluated for enumeration of adults at Zosel Dam.

Steelhead Habitat Capacity and Limiting Factors

Monitoring status and trends of salmonid physical habitat, in both the mainstem and tributaries to the Okanogan, requires measuring a variety of attributes including stream corridor structure, water quality, hydrological characteristics, and the biological community. In 2013, OBMEP increased the sampling effort with regards to Steelhead habitat through the Rapid Assessment program (Appendix H, Table 8) while continuing long-term habitat sampling through the EMAP/GRTS-generated habitat monitoring sites (Table 2). Results from habitat monitoring in the Okanogan subbasin have been largely used to populate the EDT model, operated by ICF International, and summarized in reports listed in section 3.1.3. Some limitations identified through the 2013 sampling year are: 1) precision, accuracy and biases of empirical habitat data are not currently assessed, 2) habitat data populating the model are not complete for all reaches and parameters (Table 2), and 3) it is unclear how Steelhead lifestages and habitat are related within the model, specifically for Okanogan populations. For future habitat sampling, it is recommended that habitat data be analyzed for precision and that juvenile and adult abundance estimates be used to test the outputs of the EDT model and that future sampling be designed to test the model. Additionally, it is recommended that habitat data collection be expanded to appropriate reaches and parameters, that the Steelhead habitat capacity-productivity relationship in the EDT model be summarized, and that the relationships represented in the EDT model be assessed for their suitability specific to Okanogan River summer Steelhead populations.

Environmental Factors – Water Quality, Temperature and Discharge

Data collection changed in terms of water chemistry parameters, but remained consistent with regards to water temperature data collection in 2013. With the recognized need to further describe quantity and quality of water as a potential limiting factor to recovery of listed salmonids, particularly in a semi-arid subbasin, OBMEP expanded discharge monitoring efforts on both sides of the border. Water chemistry parameters were altered to be more specific to EDT model inputs (Table 3) or in some cases, discontinued. In the U.S. portion of the Okanogan subbasin, CCT began collecting discharge data at stations previously operated by the Washington Department of Ecology, in collaboration with USGS. In the Canadian portion of the subbasin, OBMEP expanded discharge monitoring to tributaries where data were previously unavailable and increased data collection effort in tributaries with current discharge stations. Results from these sampling efforts show that mainstem water temperatures are markedly higher than tributary temperatures in summer months (Figure 5), water temperature from spring-fed tributaries are markedly contrasted to mainstem water temperatures (Figure 6), in the last decade less water has been available over the entire year than in the past (Figure 7), and that in the Canadian portion of the Okanagan subbasin, more water is removed from the system than contributed in summer months (Appendix I, Figure 51). Limitations identified throughout the 2013 sampling year are: 1) water chemistry attributes were not collected consistently in all reaches (Table 3), in successive years, and on both sides of the border, 2) many of the water chemistry attributes required by the EDT model are not currently measured (Table 3), and 3) spatial variation of water temperatures and cold water refugia have not been assessed (Table 3), but likely remain an important habitat component for juvenile and adult salmonids. For future sampling, it is recommended that water chemistry data collection be synchronized and expanded to fill gaps, that a focused study be conducted to assess cold water refugia and interactions between hyporheic and surface flows, and discharge data be assessed for its use in the EDT model.

Biological Community Factors

Benthic macroinvertebrate collection occurred at all habitat monitoring sites that were not dry and non-native fish species observed densities was documented as well at all habitat monitoring sites. Results from macroinvertebrate sampling show that EPT taxa richness was lower in stream reaches with elevated summer water temperatures (Appendix J). Non-native fish species are also more prevalent in streams with lower EPT taxa richness and higher average summer water temperatures (Appendix J). Some limitations identified throughout the 2013 sampling year are: 1) benthic macroinvertebrate collection field sampling methods were not conducted consistently on both sides of the border, 2) benthic macroinvertebrate collection only occurs at habitat sampling sites, and 3) snorkel surveys that document non-native fish occurrence only record observed relative fish densities and the relationship to absolute abundance is not known. For future sampling it is recommended that benthic macroinvertebrate collection field sampling be thoroughly coordinated, that the sampling locations be assessed for suitability considering the use in the EDT model and Rapid Assessment sampling, that the benthic macroinvertebrate data results be assessed for use in answering Steelhead management and research questions, that alternative sampling methods be assessed for quantifying non-native fish species abundance, and that non-native fish species data be assessed for use in the EDT model.

Data Management and Coordination

OBMEP continued improving internal data management systems to collect data more efficiently, with fewer opportunities for human error, and improved capacity for sharing data in an automated, web-based format. In order to share and exchange data, OBMEP utilized tools, such as Monitoring Methods, to document and standardize protocols, developing electronic methods for data collection, review, transfer, and storage, and integrate common data elements developed in the Coordinated Assessments with OBMEP's internal database. Data collected under OBMEP are used in fisheries management processes and entities such as the Fish and Wildlife Program, the FCRPS BiOp, and NOAA's 5-year review of ESA-listed species to determine listing status of summer Steelhead. The overall outcome of monitoring strategies is to aid natural resource managers in guiding 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. 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 valuable status and trend monitoring data and to make those data readily available to agencies for use in more comprehensive, broad-scale analysis.

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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 are available from 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

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.

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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	N/A	Run Timing

		Returner		
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: Adult Steelhead Enumeration

Table 4. Table of Steelhead PIT tag detections on the q̓awsitkʷ (Okanagan River) at VDS 3 (OKC) as compared to detections at Zosel Dam.

	Detection Site		
	***OKC*[9]**	***Zosel Dam***	***% of tagged fish past OKC from Zosel***
2010			
Summer Steelhead (Hatchery)	*2*	*NA*	*NA*
Summer Steelhead (Unknown)	*5 (4 PRD[10])*	*NA*	*NA*
Summer Steelhead (Wild)	*0*	*NA*	*NA*
2011 Total	***7***	***NA***	***NA***
2011			
Summer Steelhead (Hatchery)	*4*	*31*	*12.90%*
Summer Steelhead (Unknown)	*0*	*2*	*0.00%*
Summer Steelhead (Wild)	*3 (2 PRD)*	*9*	*33.33%*
2011 Total	***7***	***42***	***16.67%***
2012			
Summer Steelhead (Hatchery)	*3 (2 PRD)*	*50*	*6.00%*
Summer Steelhead (Unknown)	*0*	*3*	*0.00%*
Summer Steelhead (Wild)	*2 (2 PRD)*	*7*	*28.57%*
2012 Total	***5***	***60***	***8.33%***
2013			
Summer Steelhead (Hatchery)	*2*	*48*	*4.17%*
Summer Steelhead (Unknown)	*0*	*3*	*0.00%*
Summer Steelhead (Wild)	*4 (3 PRD)*	*11*	*36.36%*
2013 Total	***6***	***62***	***9.68%***

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

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

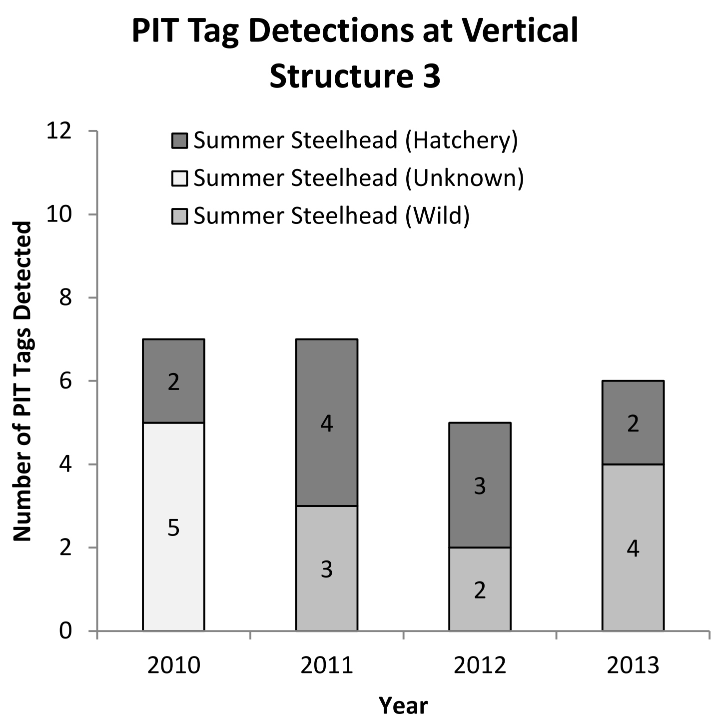


Figure 8. Graph of Steelhead PIT tag detections by year at Okanagan Channel (OKC) at VDS 3 broken down for hatchery and wild fish.

Table 5. 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).

Brood 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

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

Appendix D: 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 & Geomorphology	Length/Width/Area	Habitat Type: Channels	N/A	Channel Length
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 E: Juvenile *O. mykiss* Mark-Recapture Population Assessment

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 2013 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 wild 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 in 2012 and 2013 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

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 9). 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 random ~150 m site was 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.

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 10). 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 random ~150-200 m site was 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.

Bonaparte Creek

Bonaparte Creek is a relatively small creek that enters the Okanogan River at RKM 91.3. Discharge ranges from 1 cfs during low flow conditions and may reach 20 to 40 cfs during peak runoff. During summer base flow, wetted widths range from 1.5 m to 3 m. 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 randomly selected sample site corresponded with the annual OBMEP GRTS habitat survey site (Figure 11).

A PIT tag interrogation site (BON) is located at the mouth of the creek, approximately 80 m from the confluence with the Okanogan River, and consists of three pass-through PVC antennas in series.

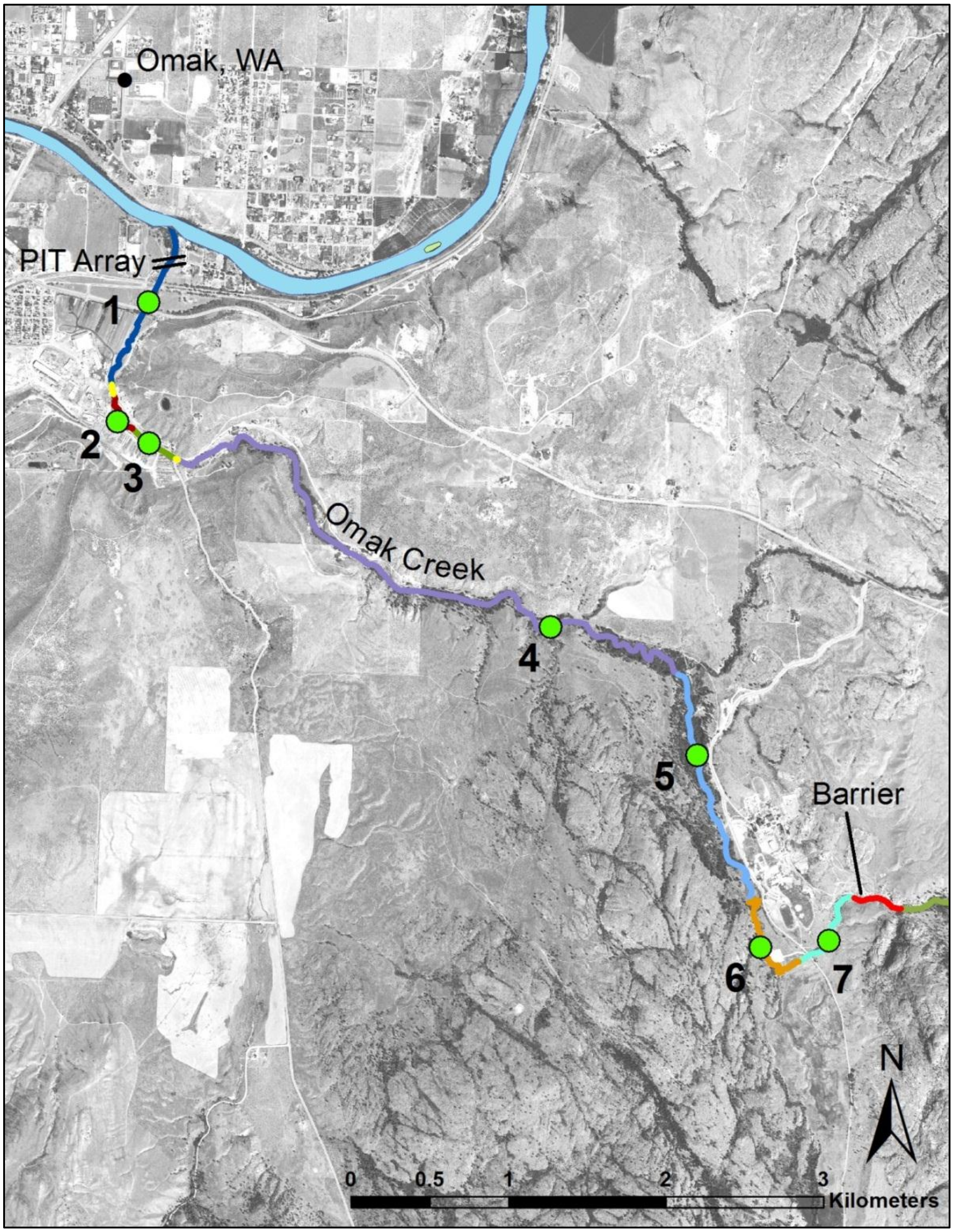


Figure 9. Omak Creek juvenile *O. mykiss* mark-recapture study sites and strata.

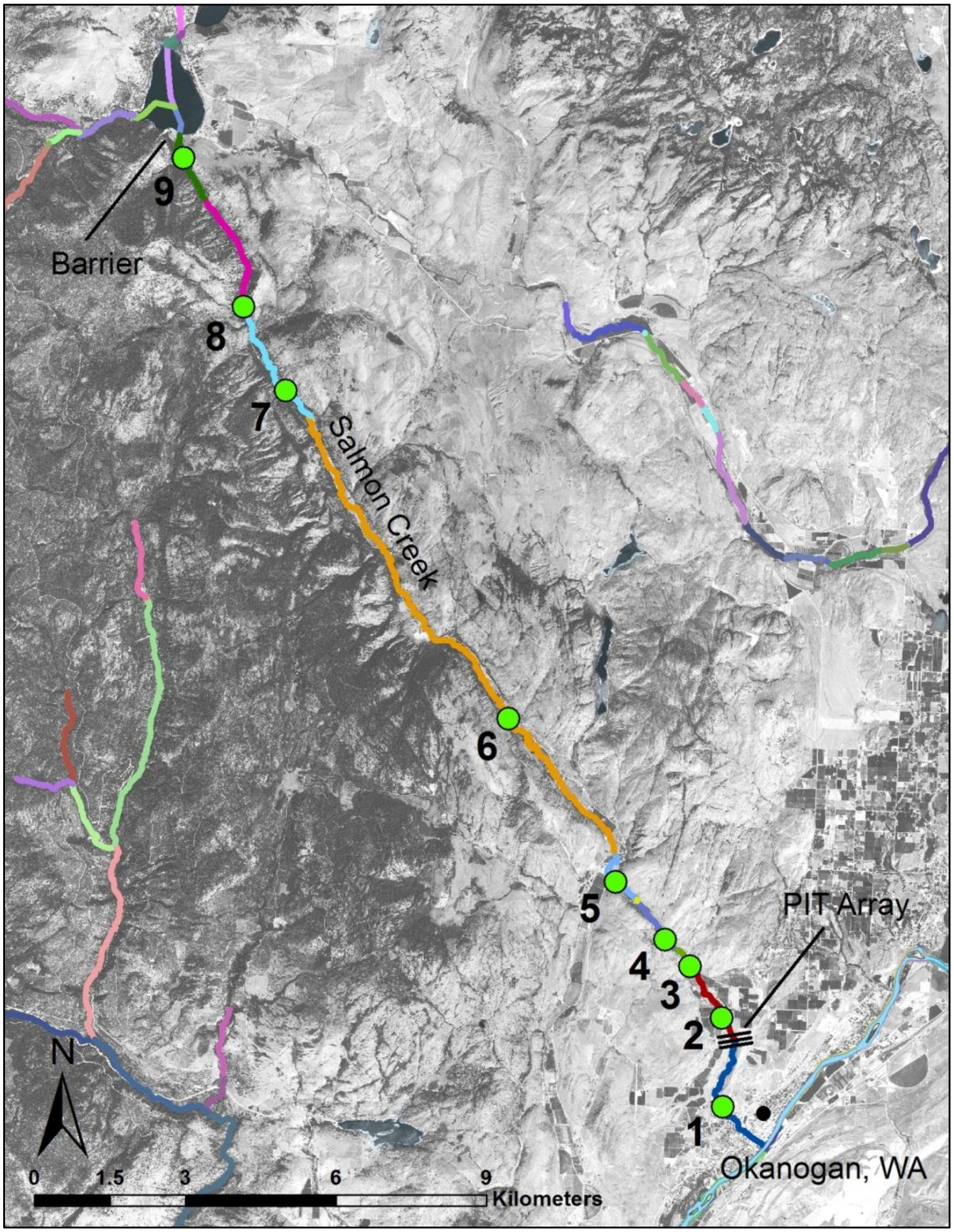


Figure 10. Salmon Creek juvenile *O. mykiss* mark-recapture study sites and strata.

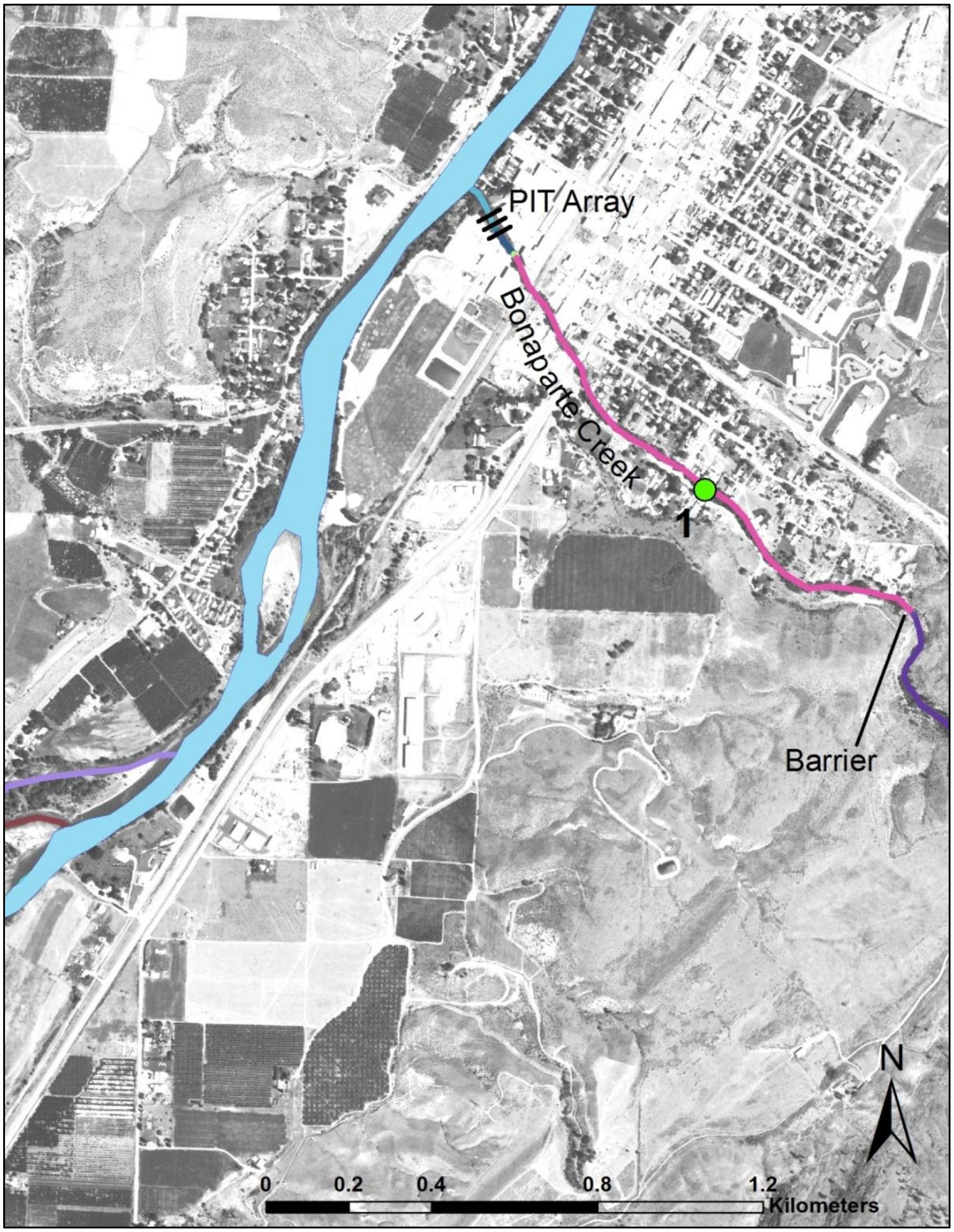


Figure 11. Bonaparte Creek juvenile *O. mykiss* mark-recapture study sites and strata.

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, 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, $\widehat{N}_i$ for $i = 1, \ldots, 7$). It was assumed that each site was representative of the reach in which it is located and that fish were evenly distributed throughout the reach. Each reach has an expansion factor for the area not sampled (i.e., R_i),

$$R_i = \frac{Reach\ Length_{\ i}}{Sample\ Site\ Length_{\ i}} .$$

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

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

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

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

with variance of

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

and a 95% confidence interval (CI) of

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

The coefficient of variation (CV) was calculated as:

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

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. The overall probability of detection $(\hat{P})$ can be calculated as:

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

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.

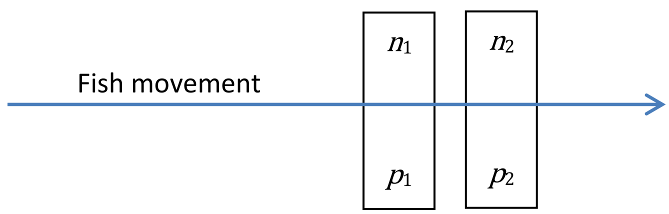


Figure 12. Diagram for probability of detection and estimated number of PIT tags past a parallel array.

Assuming that the fish tagged upstream are representitive of the total population of juvenile *O. mykiss*, the estimated proportion of tags from the study that pass the array will be applied to the population estimate to determine a total yearly emigration estimate.

Results

Steps a. through c. outlined in the methods section were conducted during the fall of 2012 for Omak Creek and for Omak, Salmon, and Bonaparte Creeks in the fall of 2013. Detection and calculation of out-migration estimate (step d.) will occur the following season, and thus, total emigration results will only be reported for Omak Creek in this summary.

Omak Creek

During the 2013 field season, a total of 1,080 m of stream were sampled across the seven sites in Omak Creek. This represented 11.9% of the total stream length between the confluence of Omak Creek with the Okanogan River and the upstream anadromous barrier (Mission Falls).

The population of juvenile Steelhead in Omak Creek was divided into two size classes for analysis, based on the approximate size difference of fish between age 0 (< 95 mm) and age 1+ (> 95 mm) during the time of sampling. The population of juvenile Steelhead larger than 95 mm in Omak Creek was estimated at 5,790 ± 487 (Figure 13). The coefficient of variation was 4.3%. The average capture rate of this size class during mark-recapture sampling across all sites was 47%. The population of juvenile Steelhead less than 95 mm was estimated at 21,637 ± 2,939 with a coefficient of variation of 6.9% (Figure 13). The average capture efficiency of this size class during mark-recapture sampling across all sites was 28%.

Length frequency of juvenile *O. mykiss* in Omak Creek showed that 78.9% were less than 95 mm. For the purpose of this study, these fish were assumed to be age 0. Although scale samples were taken on a subsample of fish handled, those results are not yet available. Therefore, the general age class separation at 95 mm was used for analysis the initial study years. In the future, the use of scale aging to link age 0 fish to a specific size class may allow us to further characterize the population by age. Length frequency distribution of juvenile Steelhead in Omak Creek in the fall of 2012 and 2013 is shown in Figure 14 and Figure 15.

A total of 581 PIT tags were placed in fish greater than 95 mm. This value represented 10.0% of the population > 95 mm ($\widehat{N}$ = 5,790). These fish will be used as a representative mark-recapture group to estimate the total emigrating population through the following year. A final yearly emigration estimate will be reported at a later date.

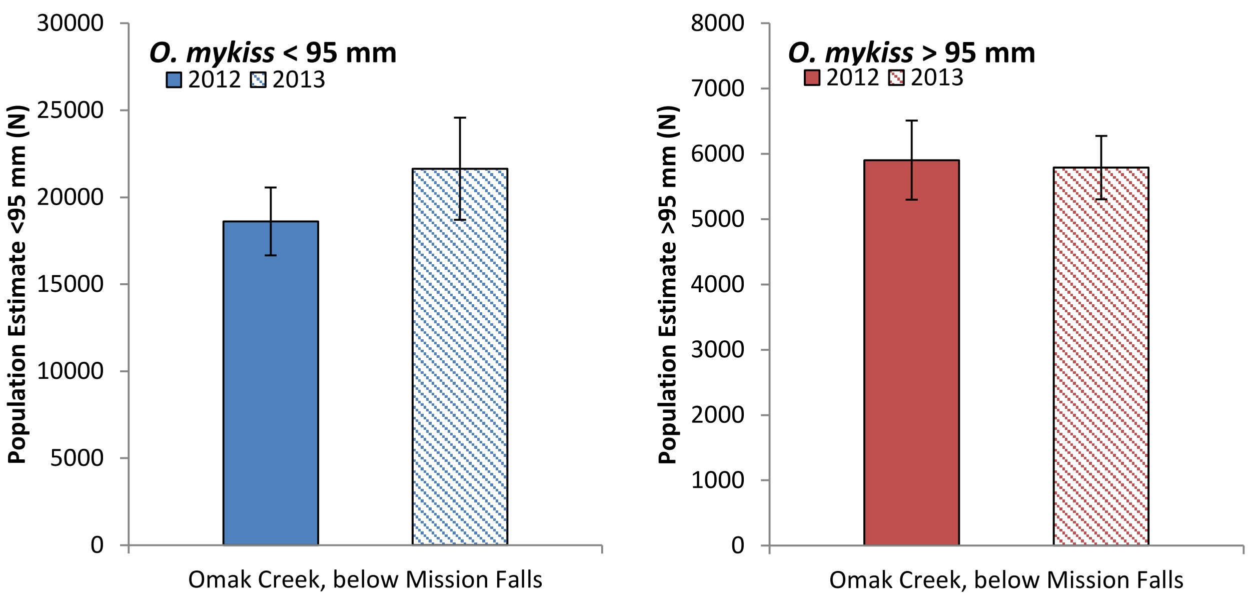


Figure 13. Estimated abundance of juvenile *O. mykiss* in Omak Creek below Mission Falls. Data is presented by *O. mykiss* < 95 mm (left graph) and > 95 mm (right graph).

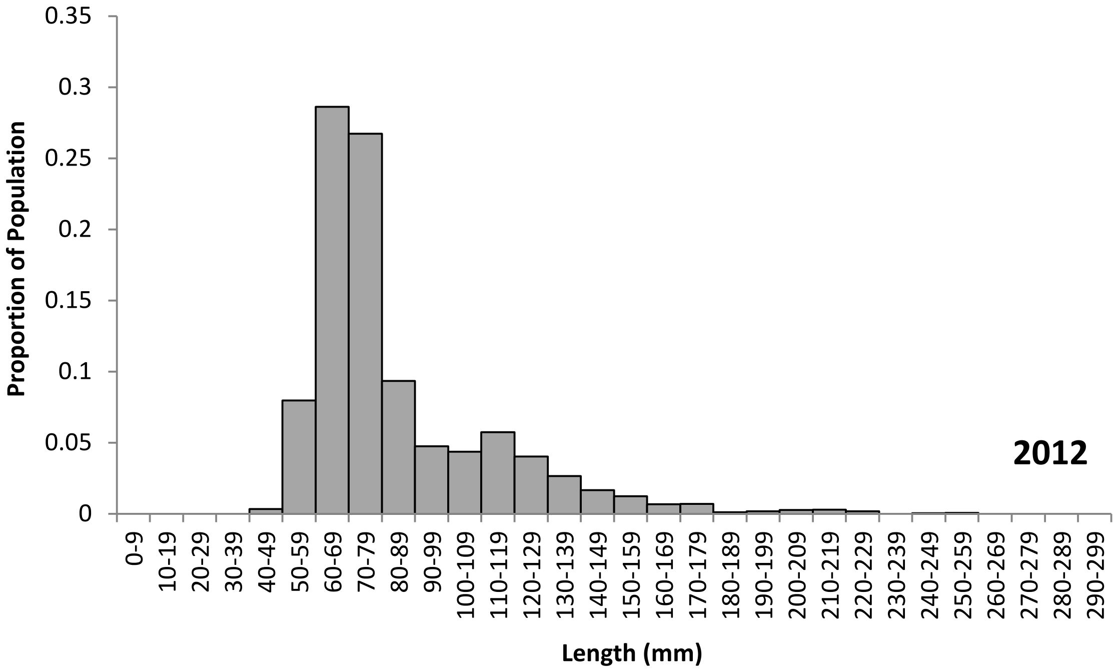


Figure 14. Length frequency of juvenile *O. mykiss* at sample sites in Omak Creek, adjusted for capture efficiency. 2012.

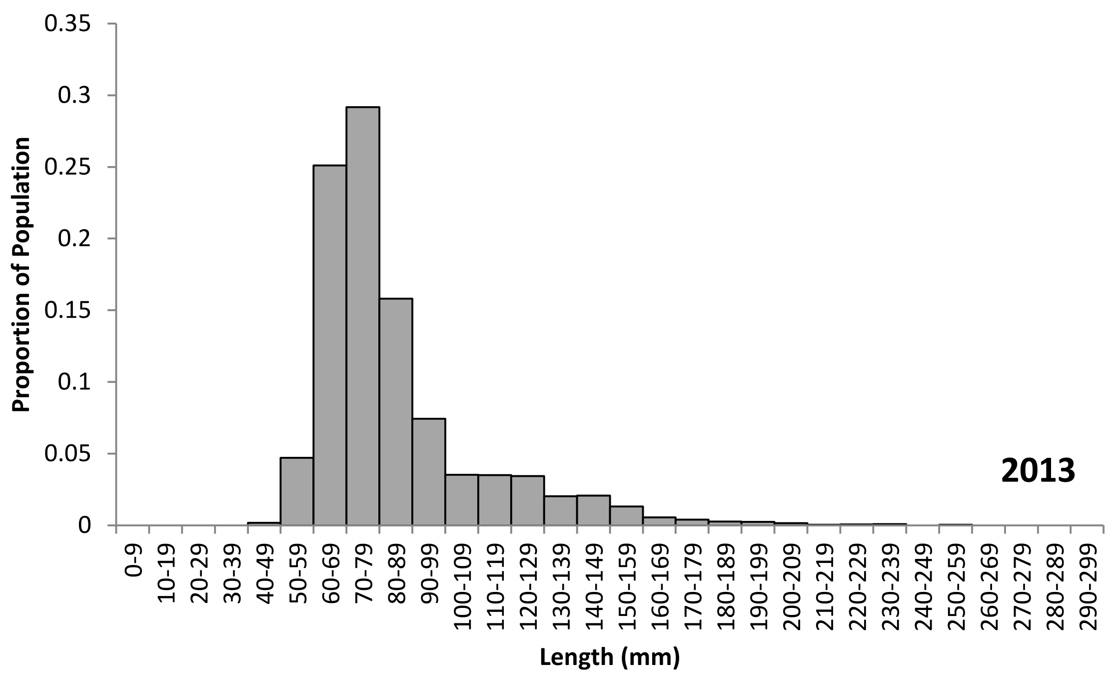


Figure 15. Length frequency of juvenile *O. mykiss* at sample sites in Omak Creek, adjusted for capture efficiency. 2013.

Salmon Creek

In Salmon Creek, a total of 1,043 m of stream were sampled across nine sites. Two of the nine sites were dry during the summer of 2013 and the fish population assumed to be zero in those respective reaches. The combined length of habitat sampled represented 3.8% of the total stream length between the confluence of Salmon Creek with the Okanogan River and the upstream anadromous barrier (Conconully Dam).

The population of juvenile Steelhead larger than 95 mm in Salmon Creek was estimated at 29,386 ± 1,953. The coefficient of variation was 3.0%. The average capture rate of this size class during mark-recapture sampling across all sites was 41%. The population of juvenile Steelhead less than 95 mm was estimated at 22,746 ± 4,080 with a coefficient of variation of 9.2%. The average capture efficiency of this size class during mark-recapture sampling across all sites was 24%. Length frequency of juvenile *O. mykiss* in Omak Creek showed that 43.6% of the population was less than 95 mm (Figure 16).

A total of 911 PIT tags were placed in fish greater than 95 mm. This value represented 3.1% of the population > 95 mm ($\widehat{N}$ = 29,386). These fish will be used as a representative mark-recapture group to estimate the total emigrating population through the following year. A final yearly emigration estimate will be reported at a later date following the spring freshet.

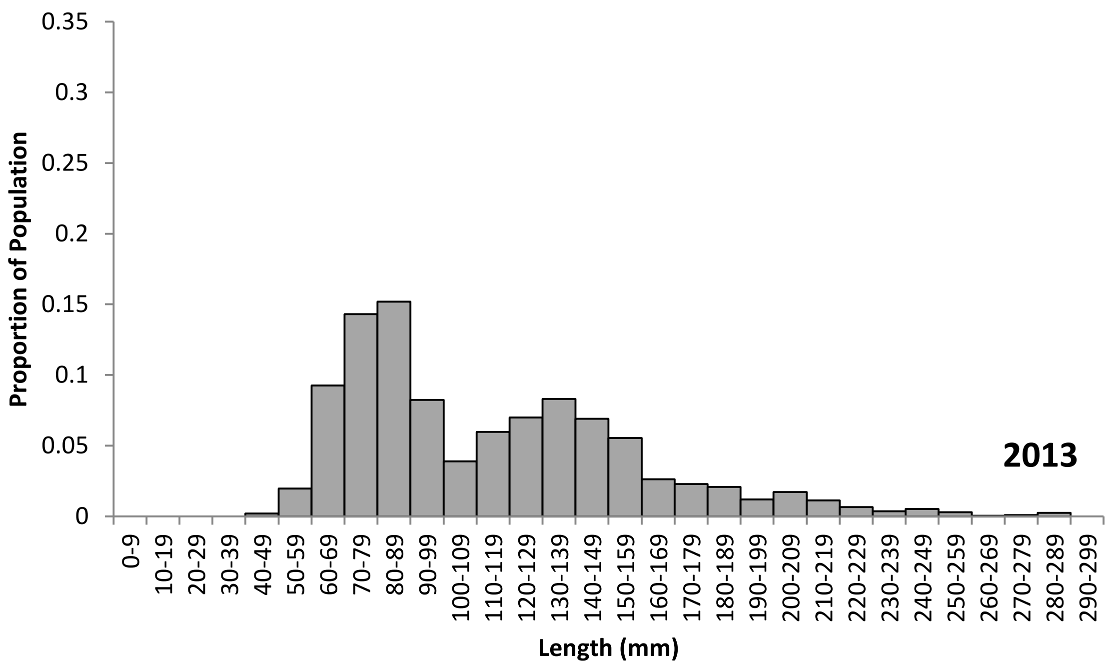


Figure 16. Length frequency of juvenile *O. mykiss* at sample sites in Salmon Creek, adjusted for capture efficiency. 2013.

Bonaparte Creek

In Bonaparte Creek, a total of 150 m of stream were sampled in one site. The combined length of habitat sampled represented 9.1% of the total stream length between the confluence of Bonaparte Creek with the Okanogan River and the upstream anadromous barrier (natural falls).

The population of juvenile Steelhead larger than 95 mm in Salmon Creek was estimated at 385 ± 25. The coefficient of variation was 3.4%. The capture rate of this size class during mark-recapture sampling was 83%. The population of juvenile Steelhead less than 95 mm was estimated at 432 ± 189 with a coefficient of variation of 22.3%. The capture efficiency of this size class during mark-recapture sampling was 24%. Length frequency of juvenile *O. mykiss* in Bonaparte Creek showed that 53% of the population was less than 95 mm (Figure 17).

A total of 34 PIT tags were placed in fish greater than 95 mm, which represented 8.8% of the population > 95 mm ($\widehat{N}$ = 385). These fish will be used as a representative mark-recapture group to estimate the total emigrating population through the following year. A final yearly emigration estimate will be reported at a later date following the spring freshet.

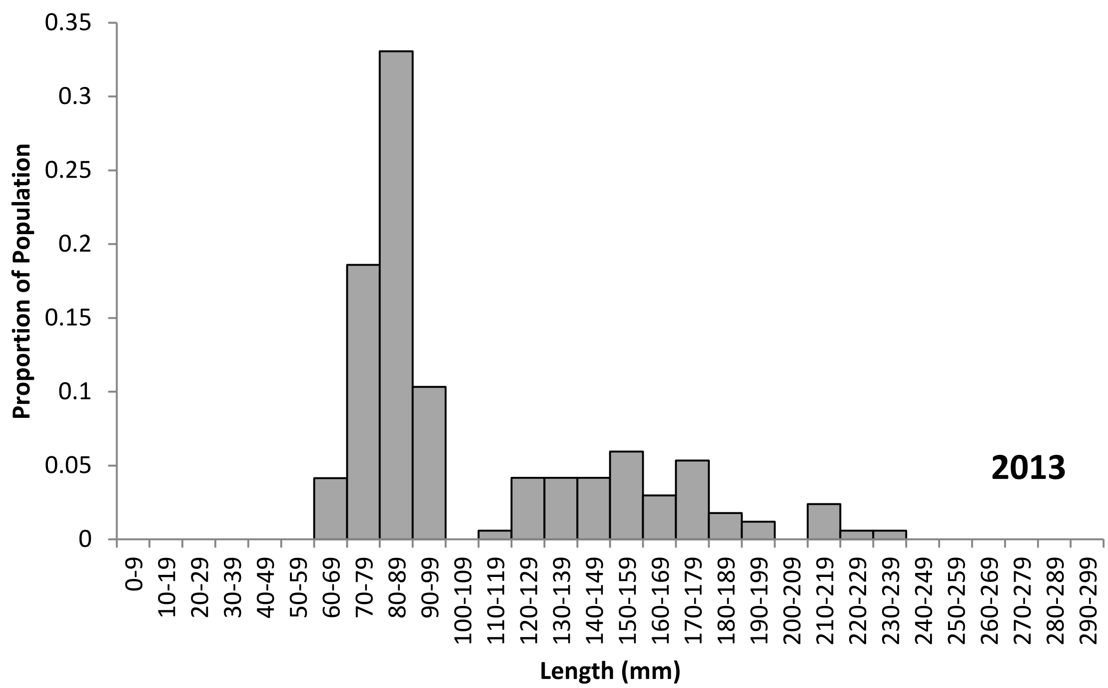


Figure 17. Length frequency of juvenile *O. mykiss* at the sample site in Bonaparte Creek, adjusted for capture efficiency. 2013.

Conclusions

This study demonstrated that it was possible to determine a population estimate of juvenile Steelhead in a small creek 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. Block nets were meticulously placed to create a closed population, detections of marks were easily distinguishable with the use of PIT tags and top caudal 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 could not be validated include that handling and marking of fish did not affect the likelihood of recapture and that no marks were lost. 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. 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 Reach 4, Omak Creek) where the site only covered 3.6% of the reach length. However, this bias was minimized by randomly sampling in all seven reaches. 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 age 0 Steelhead 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 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 us to estimate emigration, even in the absence of an RST. This means we may be able to monitor numbers of out-migrating juveniles at reduced costs when compared to traditional methods. 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 F: Detailed Results from Snorkel Surveys in the Okanogan Subbasin, 2004-2013

Snorkel Surveys

Total numbers and densities of juvenile *O. mykiss* for all streams and rivers are shown in Table 6 for Washington and Table 7 for British Columbia. Due to the GRTS rotating panel design, not all tributaries are sampled each year and are labeled as "not sampled" in the table below.

Specific results are shown in further detail in the figures below, organized by individual site. Figure 18 and Figure 26 provide a geographic reference for annual snorkel survey sites in the Okanogan subbasin. Trends of observed juvenile *O. mykiss* during snorkel surveys for tributaries to the Okanogan River are shown in Figures 19 – 25 and for mainstem locations in Figures 27 – 31. The highest densities of juvenile *O. mykiss* continue to be observed in tributaries to the Okanogan River, when compared with the mainstem Okanogan and Similkameen Rivers.

Table 6. Total observed numbers and densities of juvenile *O. mykiss* in the United States portion of the Okanogan subbasin, 2013.

Stream Name	Total Observed *O. mykiss* (N)	Density (fish/ha)
Aeneas Creek	not sampled	n/a
Antoine Creek	not sampled	n/a
Bonaparte Creek	57	2,581
Chiliwist Creek	not sampled	n/a
Johnson Creek	not sampled	n/a
Loup Loup Creek	653 [a]	6,819 [b]
Ninemile Creek	67	2,430
Okanogan River	3 [a]	0 [b]
Omak Creek	834 [a]	2,025 [b]
Salmon Creek	429 [a]	1,114 [b]
Similkameen River	22 [a]	2 [b]
Siwash Creek	not sampled	n/a
Stapaloop Creek	not sampled	n/a
Tonasket Creek	not sampled	n/a
Trail Creek	not sampled	n/a
Tunk Creek	338	10,111
Wanacut Creek	62	3,518
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.

For the British Columbia portion of the subbasin, a map is presented in Figure 32 and observed densities of *O. mykiss* in Figures 33 – 40.

Table 7. Total observed numbers and densities of juvenile *O. mykiss* in the Canadian portion of the Okanagan subbasin, 2013.

Stream Name	Total Observed *O. mykiss* (N)	Density (fish/ha)
snpin'yaʔtkʷ (Ellis Creek)	22[a]	190[b]
akskʷəkʷant (Inkaneep Creek)	454[a]	1,706[b]
McLean Creek	47	1,284
q̓awsitkʷ (Okanagan River)	48[a]	9[b]
Shatford Creek	51	652
akłxʷminaʔ (Shingle Creek)	5	82
Shuttleworth Creek	80[a]	446[b]
snʕax̌əlqaxʷiyaʔ (Vaseux Creek)	804[a]	1,449[b]

[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.

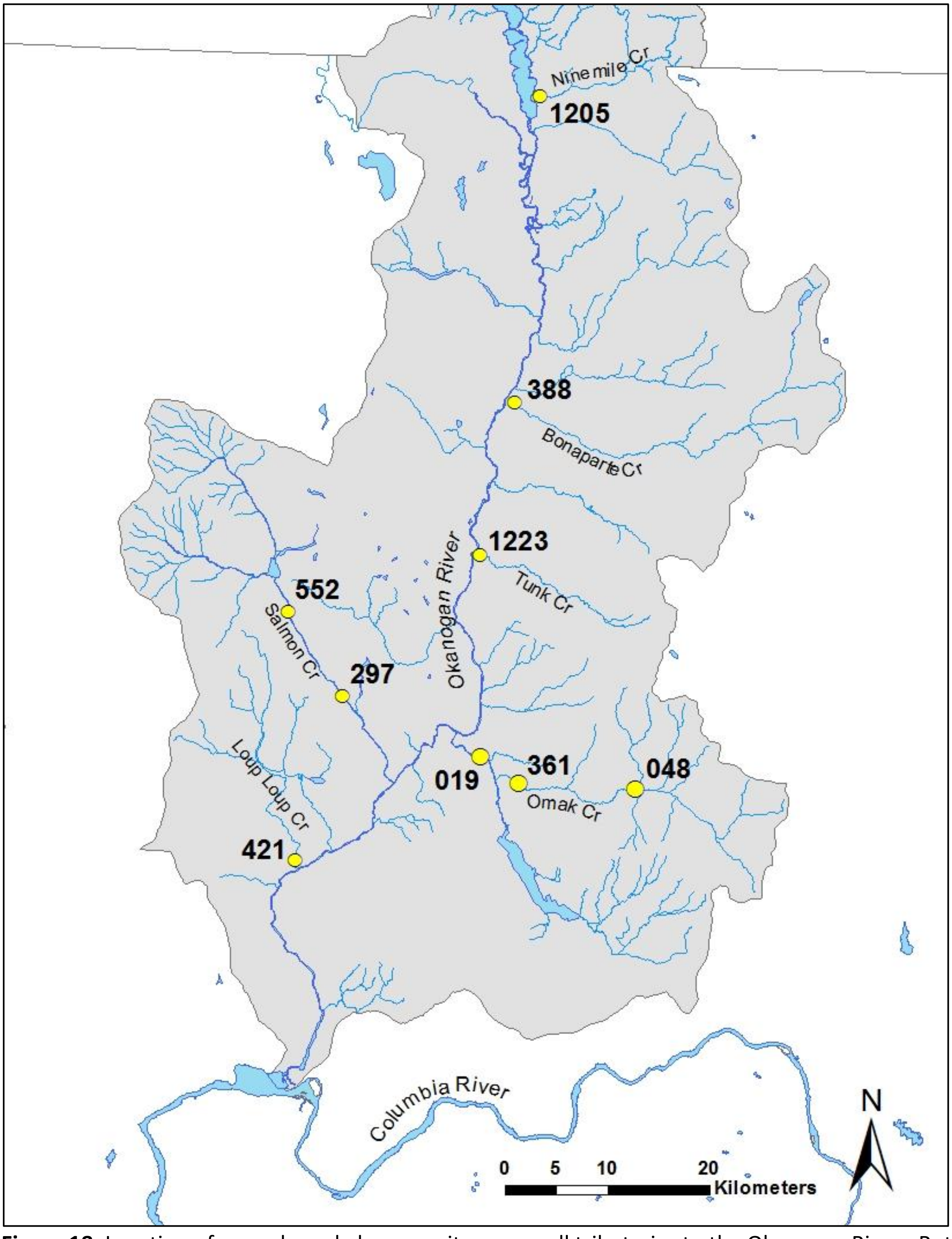


Figure 18. Location of annual snorkel survey sites on small tributaries to the Okanogan River. Rotating panel sites are not shown due to fewer years of data for each site.

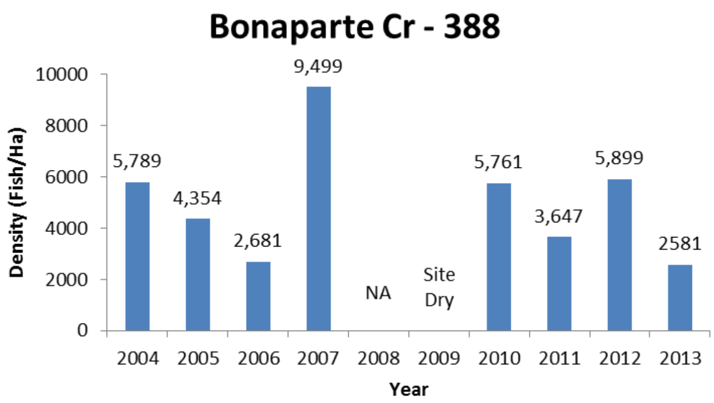


Figure 19. Observed densities of juvenile (<300mm) *O. mykiss* in Bonaparte Creek in the city of Tonasket, WA.

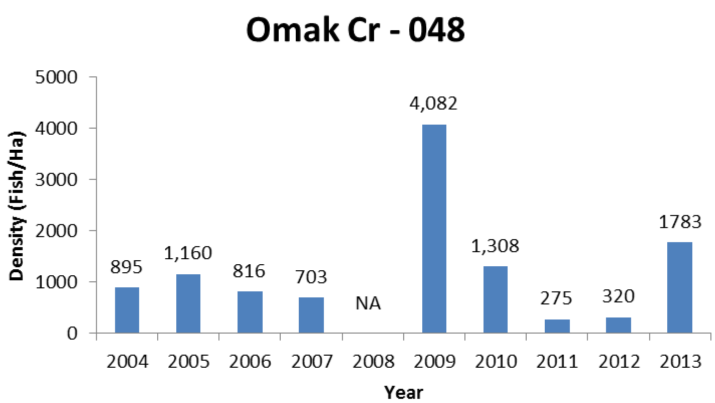


Figure 20. Observed densities of juvenile (<300mm) *O. mykiss* in Omak Creek, the upper most site in the Omak Creek watershed.

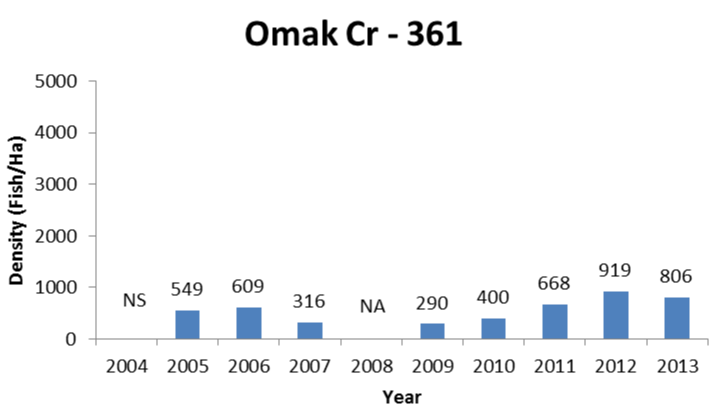


Figure 21. Observed densities of juvenile (<300mm) *O. mykiss* in Omak Creek, located in the middle portion of the watershed, but above Mission Falls (anadromous barrier).

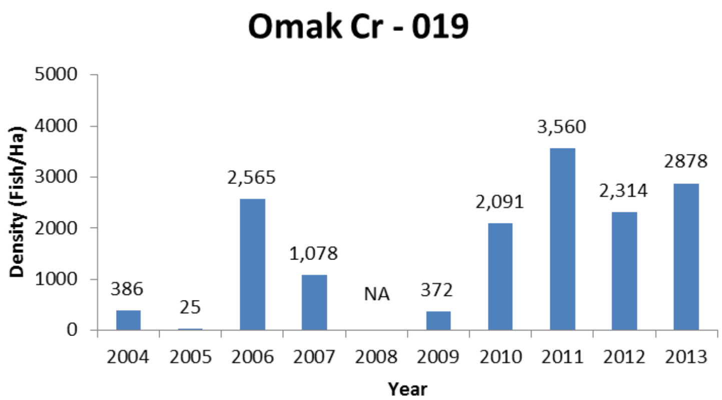


Figure 22. Observed densities of juvenile (<300mm) *O. mykiss* in Omak Creek, the lower most site on the creek, and the only annual site below Mission Falls.

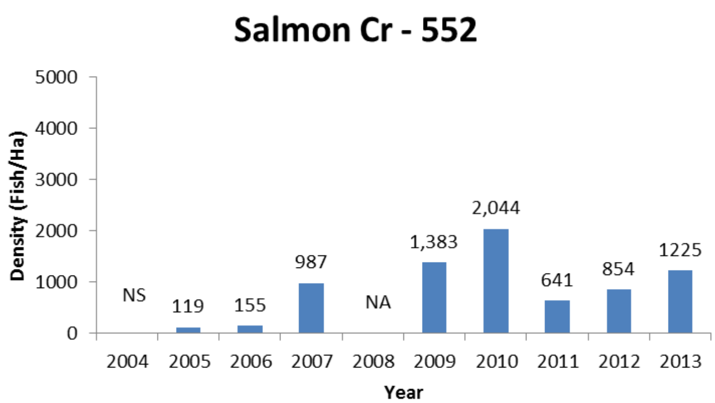


Figure 23. Observed densities of juvenile (<300mm) *O. mykiss* in Salmon Creek, the upper most annual site on the creek, near the historical townsite of Ruby.

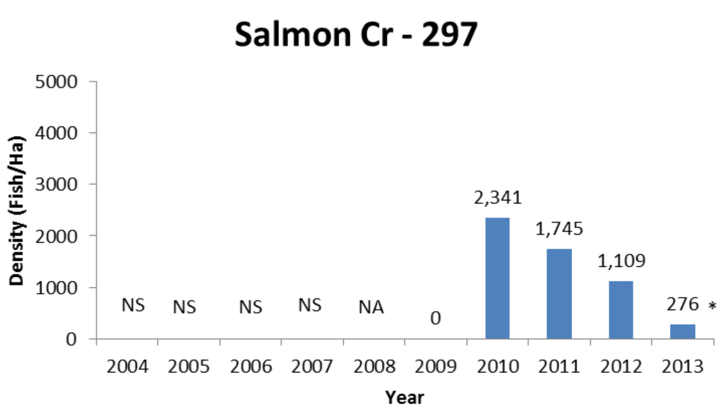


Figure 24. Observed densities of juvenile (<300mm) *O. mykiss* in Salmon Creek. This site replaced a nearby site (site 360) that was moved in 2009 due to access related issues. Therefore, fewer years of data exist for site 297. In 2013, this site was electrofished prior to snorkeling and may biased the estimate.

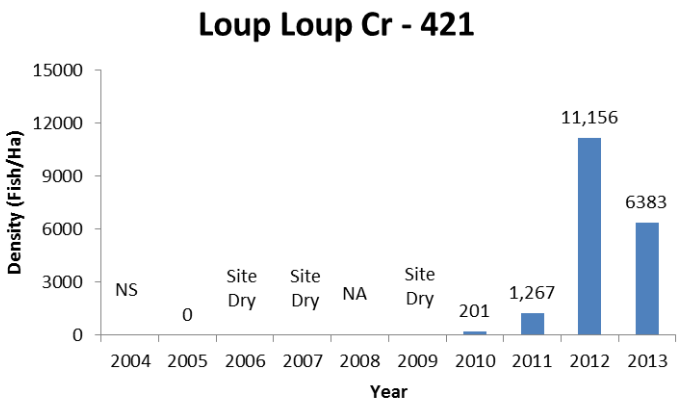


Figure 25. Observed densities of juvenile (<300mm) *O. mykiss* in Loup Loup Creek, in the town of Malott, WA.

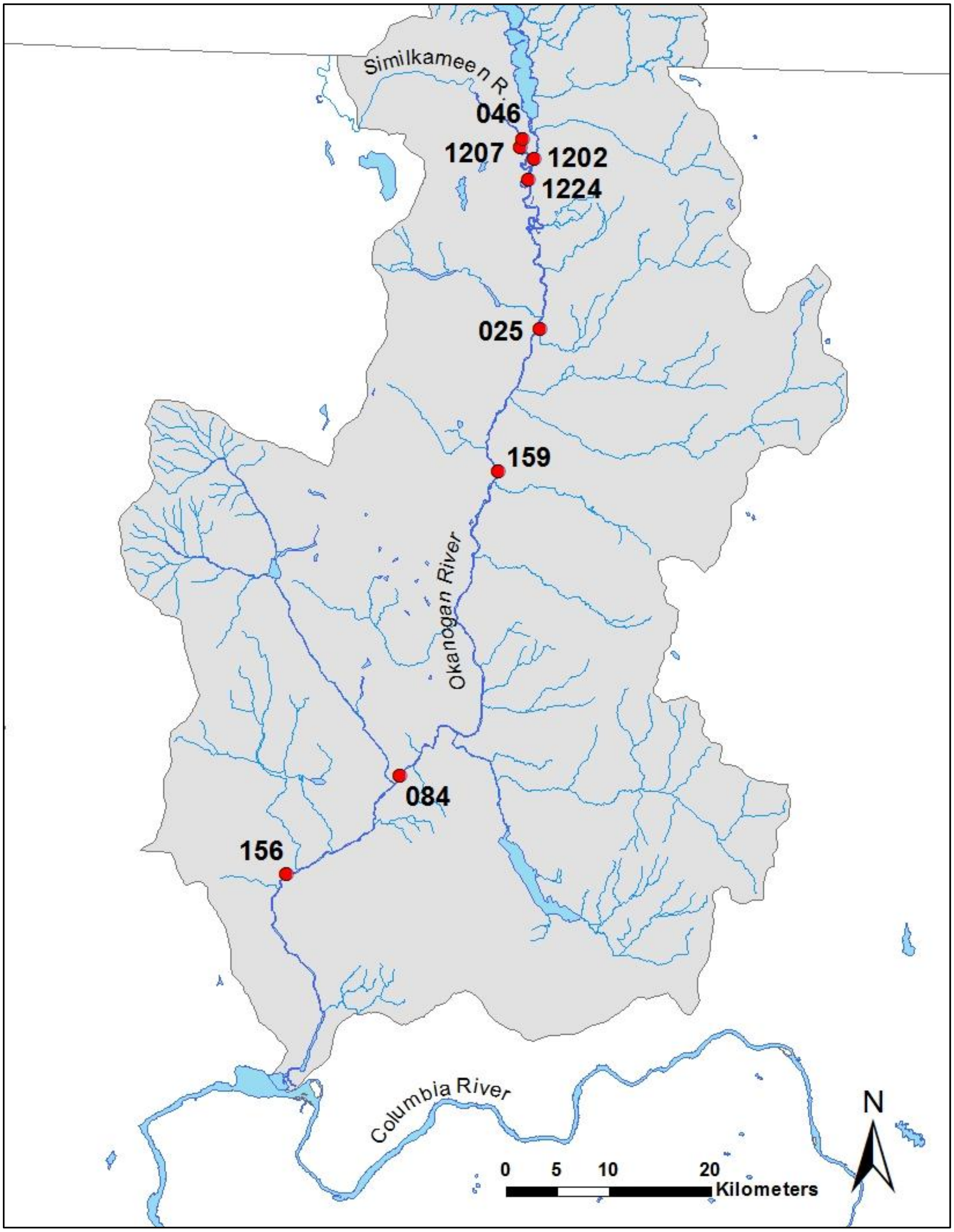


Figure 26. Location of annual snorkel survey sites on the mainstem Okanogan and Similkameen Rivers. Rotating panel sites are not shown due to fewer years of data.

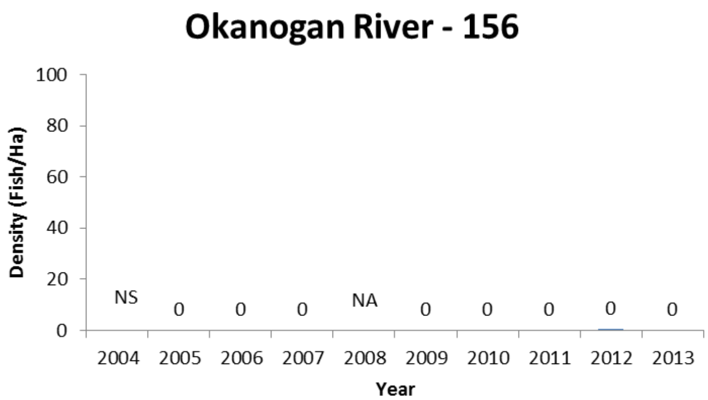


Figure 27. Observed densities of juvenile (<300mm) *O. mykiss* in the Okanogan River, downstream of the confluence with Loup Loup Creek.

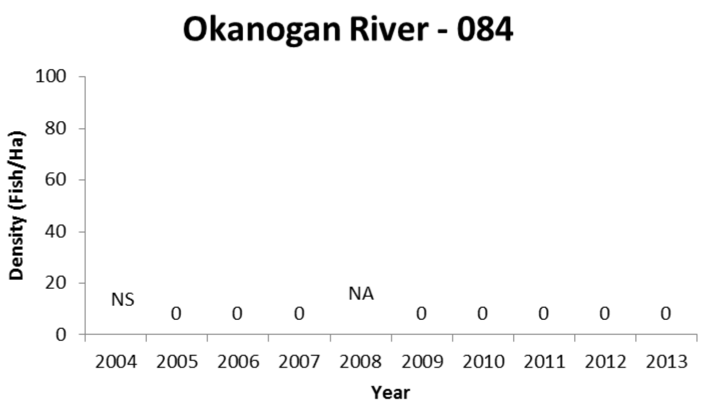


Figure 28. Observed densities of juvenile (<300mm) *O. mykiss* in the Okanogan River, upstream of the confluence with Salmon Creek.

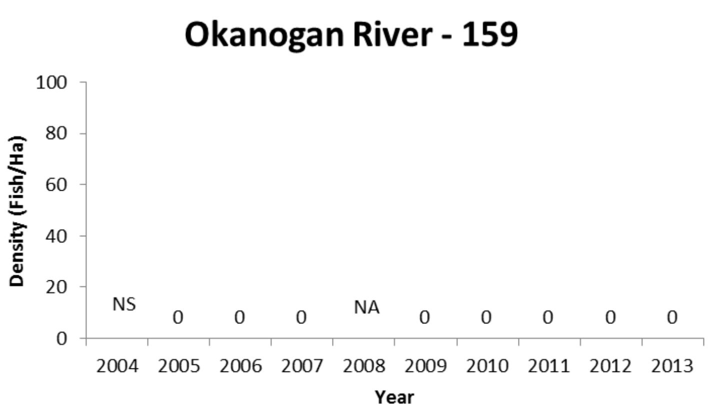


Figure 29. Observed densities of juvenile (<300mm) *O. mykiss* in the Okanogan River, south of Tonasket, WA, below Janis Bridge.

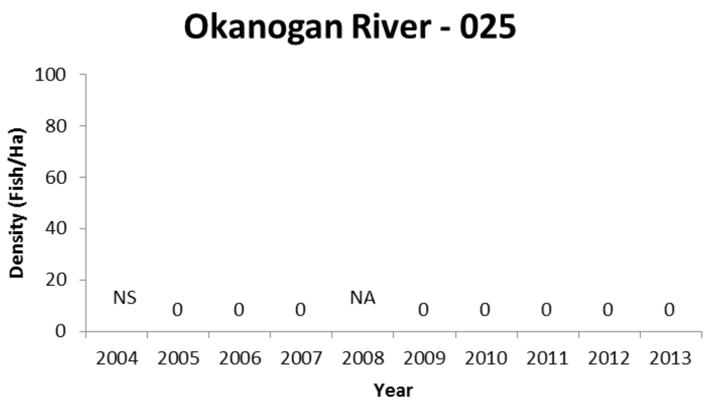


Figure 30. Observed densities of juvenile (<300mm) *O. mykiss* in the Okanogan River, upstream of the confluence with Antoine Creek.

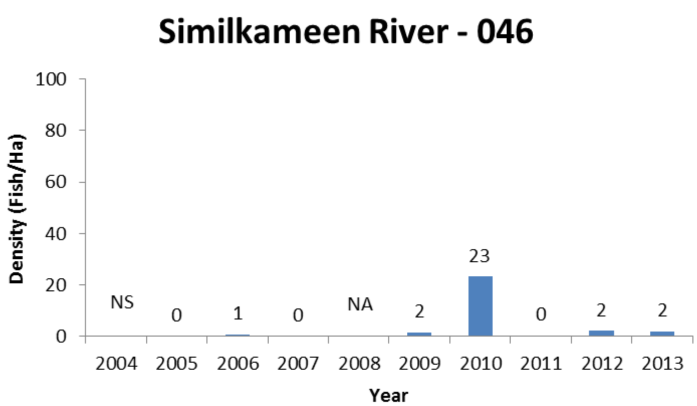


Figure 31. Observed densities of juvenile (<300mm) *O. mykiss* in the Similkameen River, near the city of Oroville, WA.

Juvenile *O. mykiss* densities in the Canadian portion of the Okanagan.

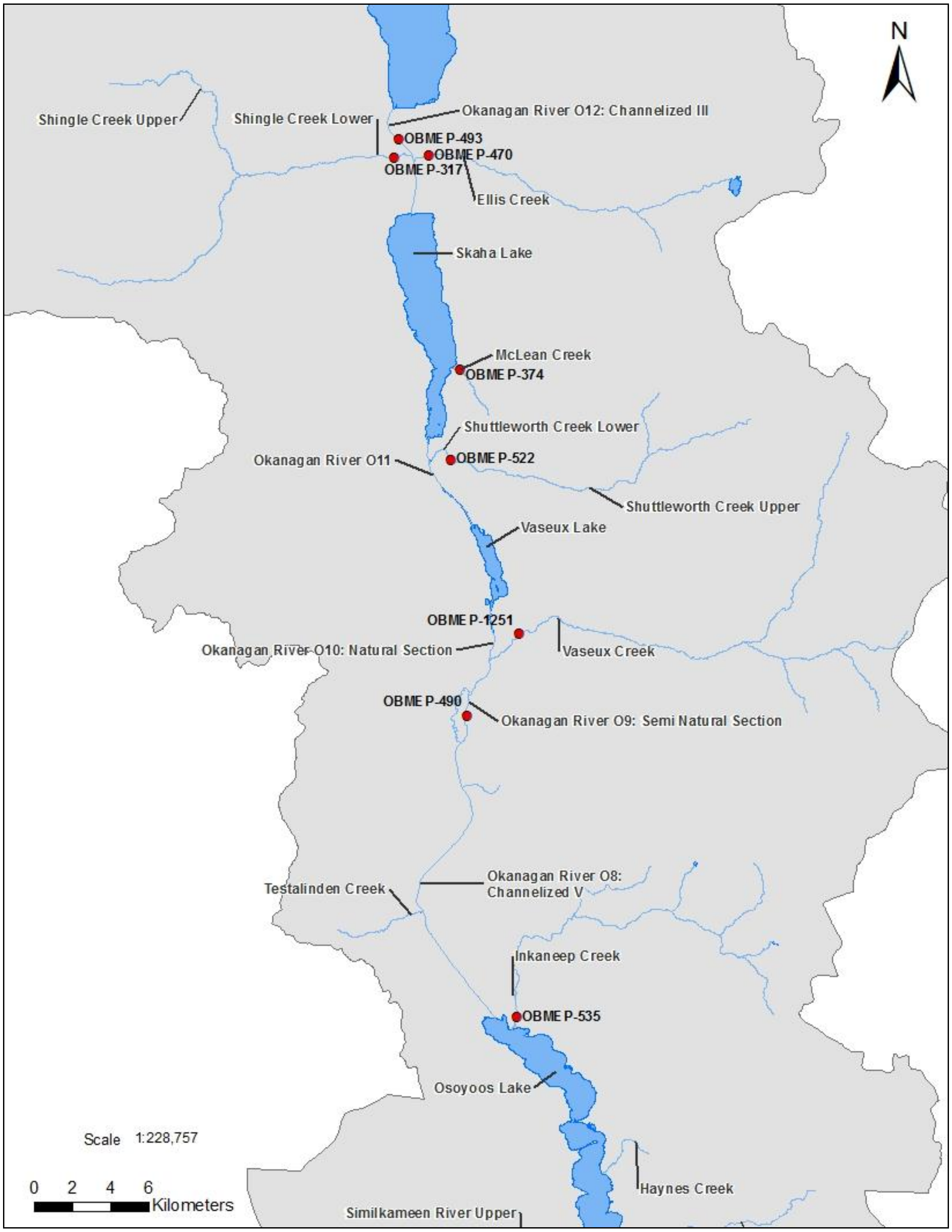


Figure 32. Location of annual snorkel survey sites on the British Columbia portion of the Okanogan subbasin. Rotating panel sites are not shown due to fewer years of data.

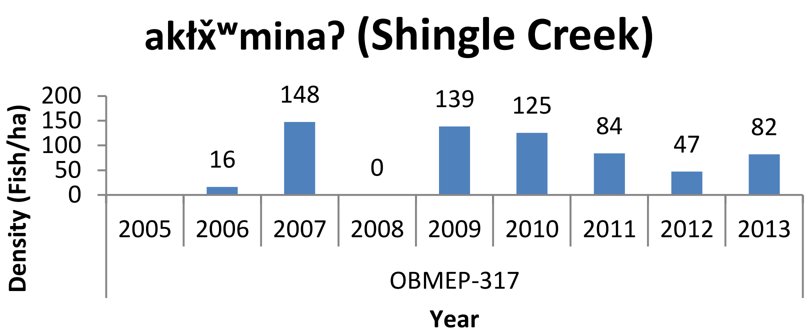


Figure 33. Observed densities of juvenile (<300mm) *O. mykiss* in lower akłx̌ʷminaʔ (Shingle Creek) at site OBMEP-317.

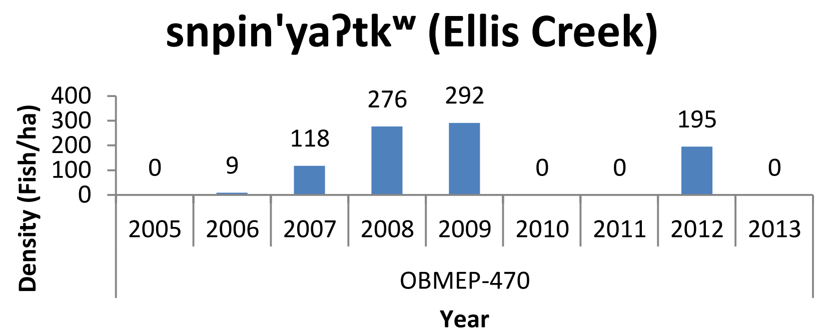


Figure 34. Observed densities of juvenile (<300mm) *O. mykiss* in lower snpin'yaʔtkʷ (Ellis Creek) at site OBMEP-470.

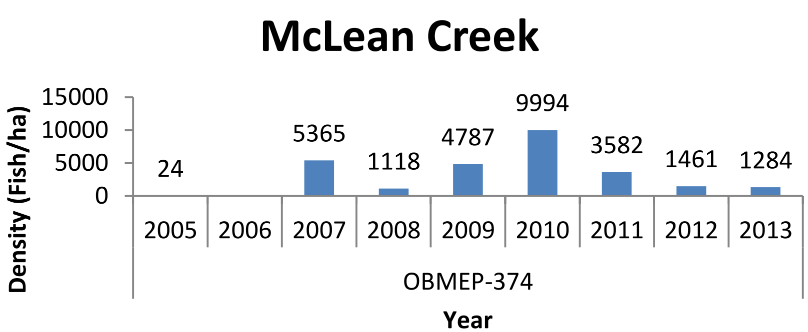


Figure 35. Observed densities of juvenile (<300mm) *O. mykiss* in McLean Creek at site OBMEP-374.

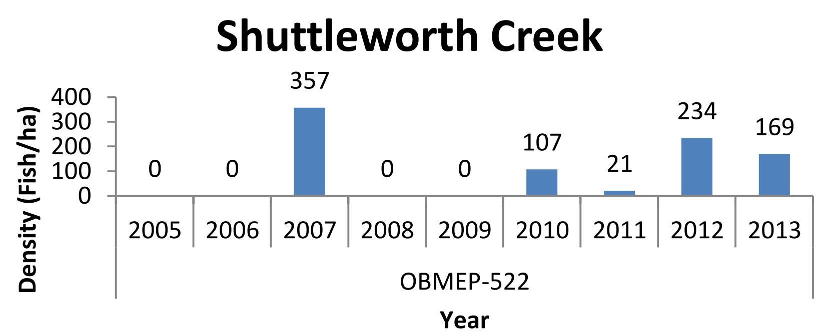


Figure 36. Observed densities of juvenile (<300mm) *O. mykiss* Shuttleworth Creek at site OBMEP-522.

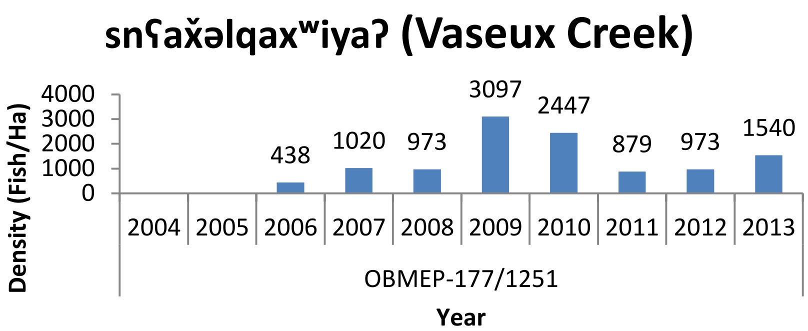


Figure 37. Observed densities of juvenile (<300mm) *O. mykiss* snʕax̌əlqaxʷiyaʔ (Vaseux Creek) at site OBMEP-177/1251.

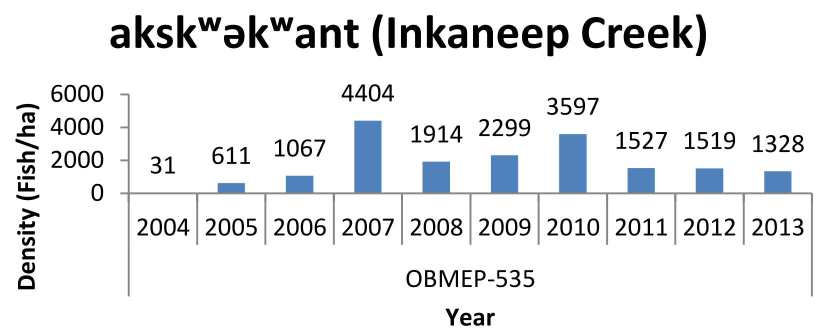


Figure 38. Observed densities of juvenile (<300mm) *O. mykiss* akskʷəkʷant (Inkaneep Creek) at site OBMEP-535.

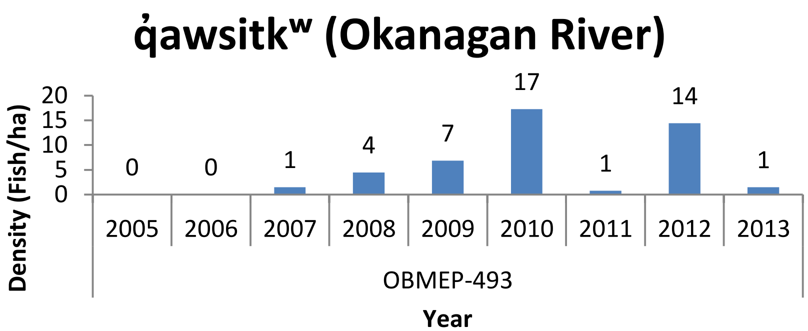


Figure 39. Observed densities of juvenile (<300mm) *O. mykiss* q̓awsitkʷ (Okanagan River) at site OBMEP-493 (Penticton channel).

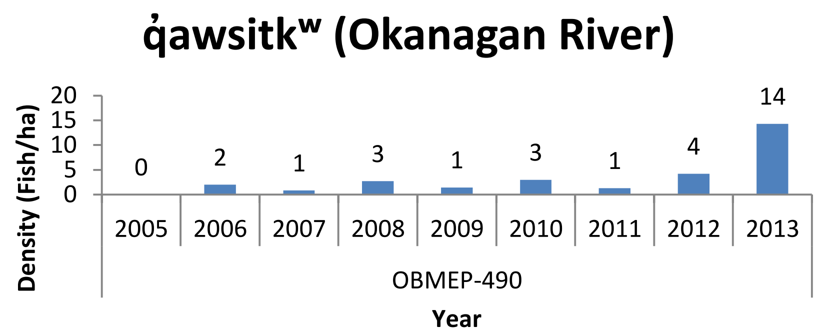


Figure 40. Observed densities of juvenile (<300mm) *O. mykiss* q̓awsitkʷ (Okanagan River) at site OBMEP-490 (near Oliver).

Appendix G: 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 H: Detailed Results from Rapid Assessment Habitat Surveys

Table 8. Breakdown of the number of reaches and length available to anadromous salmon and resident fishes in the Okanogan subbasin and the sampling done through OBMEP in 2013.

Reaches Available to Anadromous Salmon[11]						
	Number of Okanogan Reaches[12]		EMAP-generated Reaches in 2013		Rapid Assessment Reaches in 2012/2013	
	Mainstem	Tributary	Mainstem	Tributary	Mainstem	Tributary
British Columbia	61 (35.0 km)	76 (88.9 km)	4 (10 total)	11 (27 total)	0	17 (8.3 km)
Washington State	66 (107.2 km)	136 (166.9 km)	16 (36 total)	18 (49 total)	17 (5.6 km)	32 (9.5 km)
Total	**127 (142.2 km)**	**212 (255.8 km)**	**46**	**76**	**17 (5.6 km)**	**49 (17.8 km)**
Reaches Available to Resident Fish Only						
British Columbia	0	71 (104.8 km)	0	1 (3 total)	0	0
Washington State	0	176 (185.3 km)	0	0	0	0
Total	**0**	**247 (290.1 km)**	**0**		**0**	**0**

[11] Includes reaches defined as "Anad 10-Year" by EDT.
[12] Reach lengths listed are a product of an office mapping assessment and do not represent a completely accurate representation of lengths.

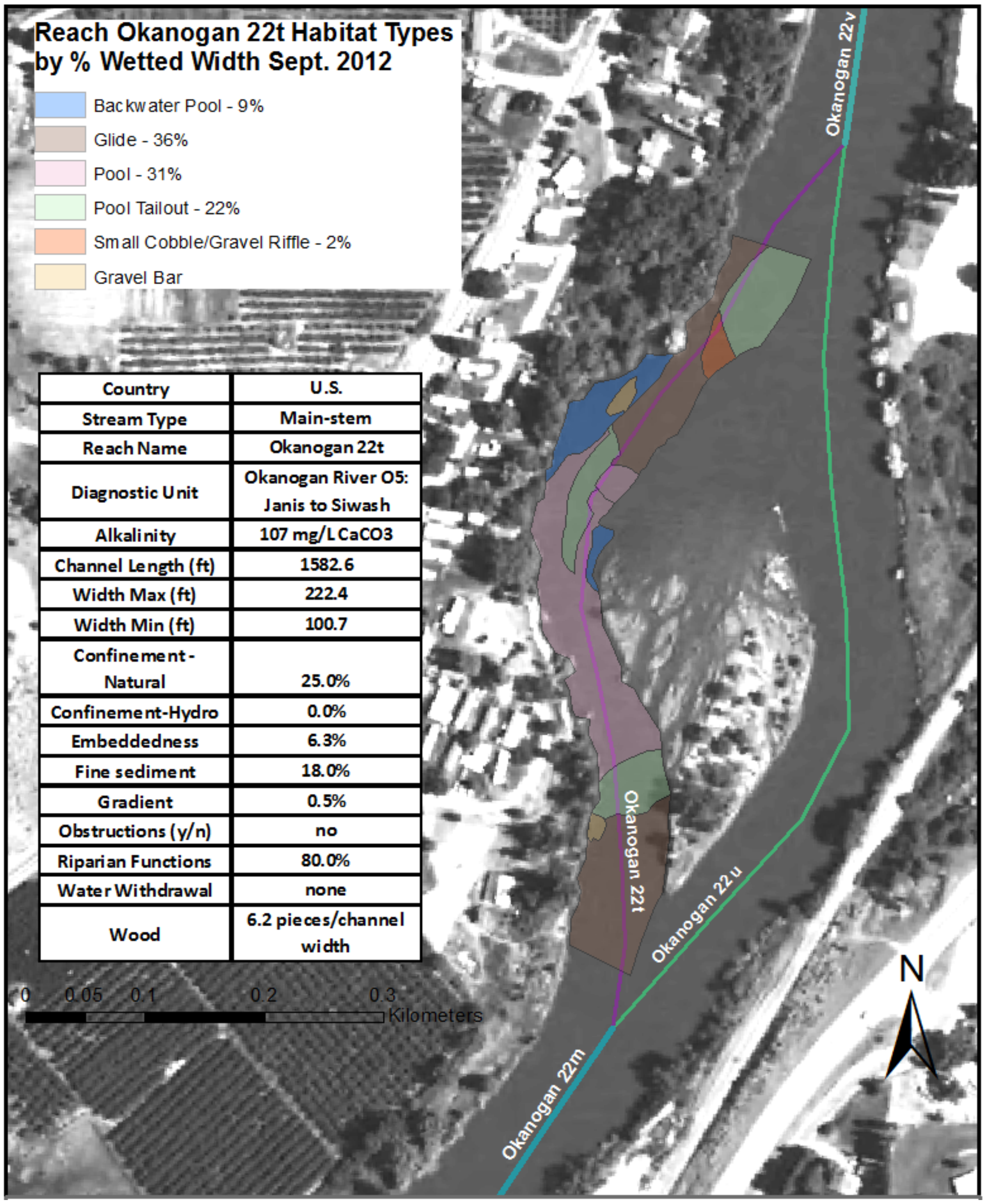
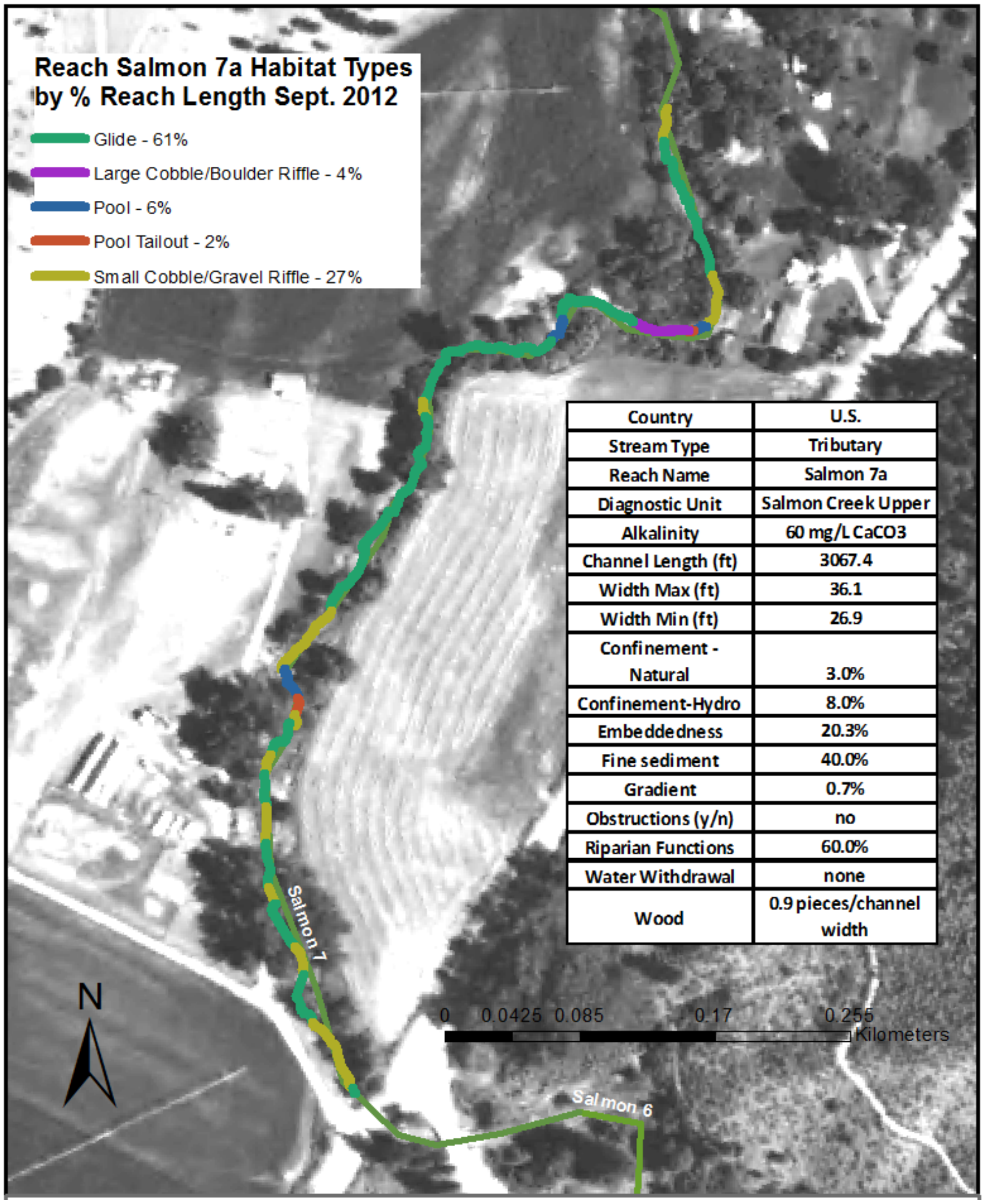


Figure 41. Reach Okanogan 22t near Tonasket, WA. Habitat types are shown as different colored polygons representing the wetted width measured during the Rapid Assessment performed September 2012.



Country	U.S.
Stream Type	Tributary
Reach Name	Salmon 7a
Diagnostic Unit	Salmon Creek Upper
Alkalinity	60 mg/L CaCO3
Channel Length (ft)	3067.4
Width Max (ft)	36.1
Width Min (ft)	26.9
Confinement - Natural	3.0%
Confinement-Hydro	8.0%
Embeddedness	20.3%
Fine sediment	40.0%
Gradient	0.7%
Obstructions (y/n)	no
Riparian Functions	60.0%
Water Withdrawal	none
Wood	0.9 pieces/channel width

Figure 42. Reach Salmon 7a near Okanogan, WA. Habitat types are shown as different line segments representing the reach length measured during the Rapid Assessment performed September 2012.

Appendix I: Detailed Results from Water Temperature and Discharge

Data links for temperature and discharge monitoring sites within the 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

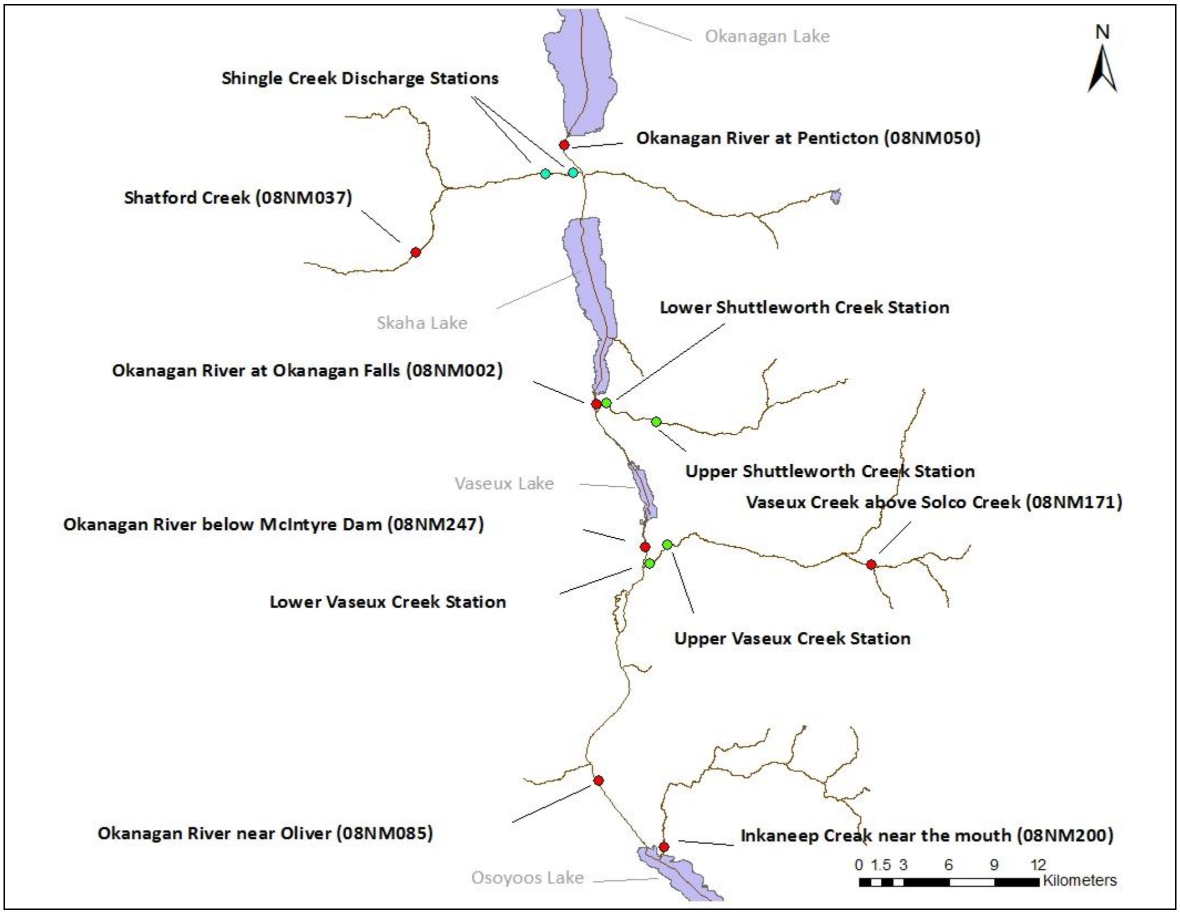


Figure 43. Map of the Canadian portion of the Okanagan subbasin showing geographic locations of discharge stations operated by OBMEP and Water Survey of Canada (Environment Canada 2013).

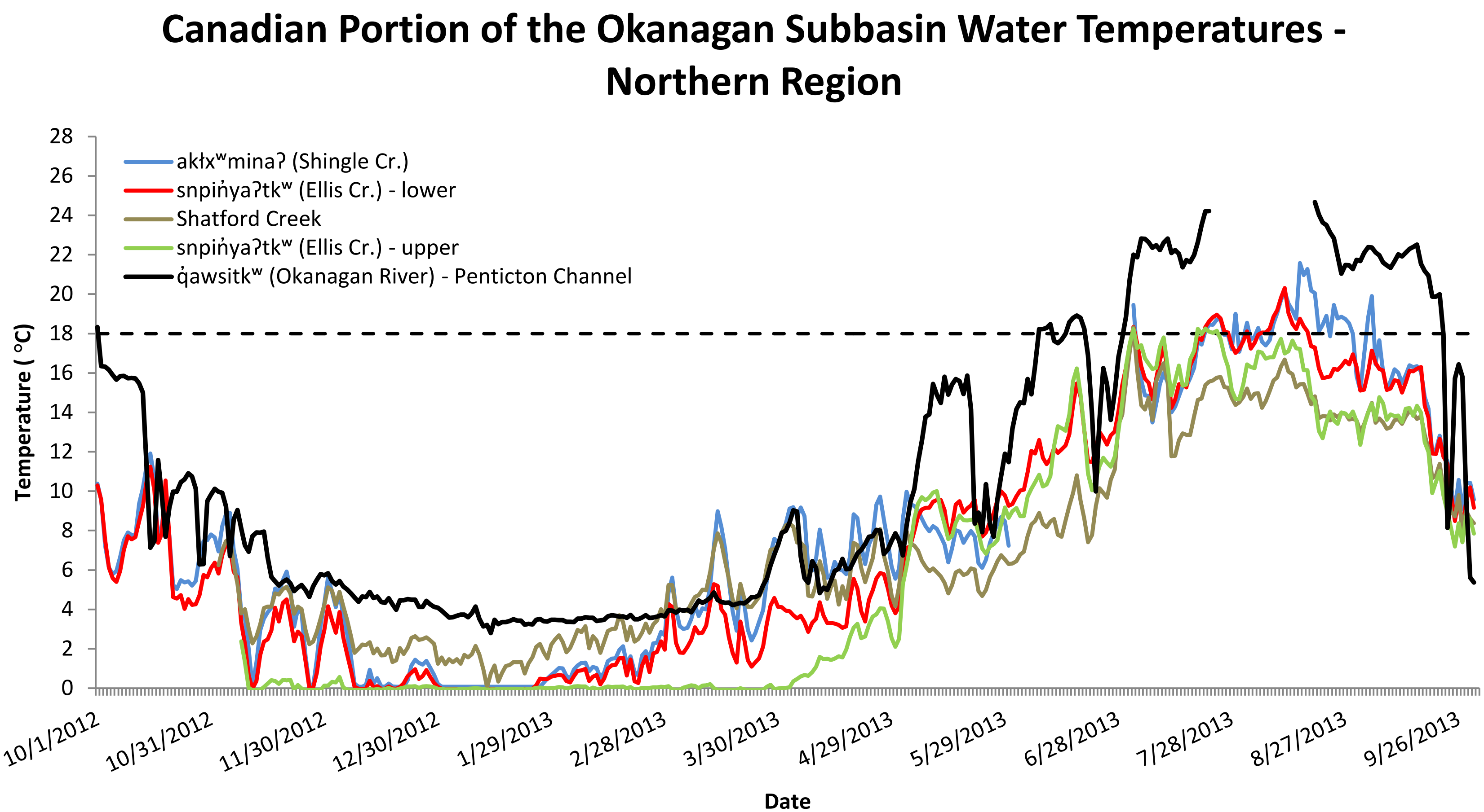


Figure 44. Mean daily temperatures of the central region of the Canadian Okanagan study area near snpintktn (Penticton) for 2013.

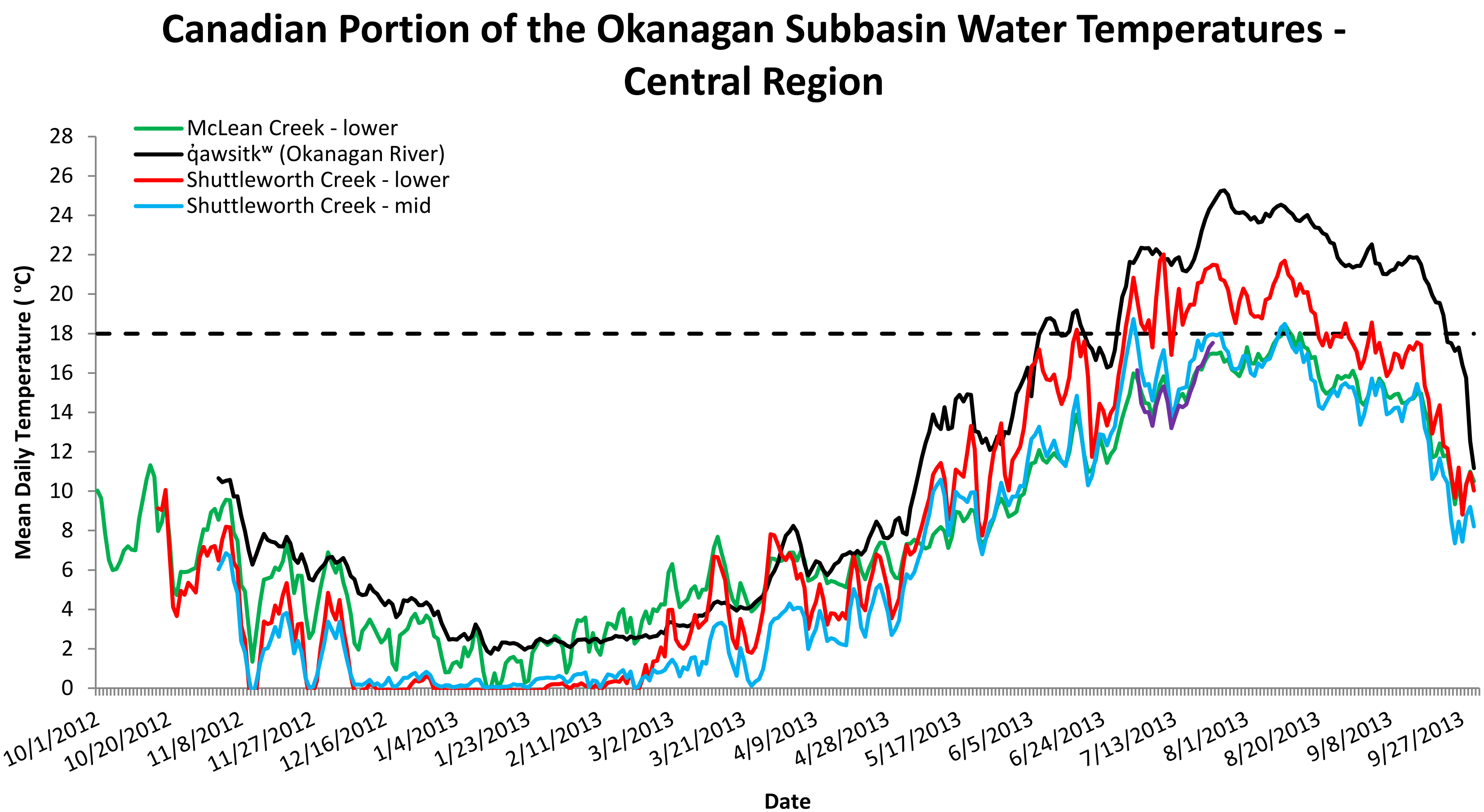


Figure 45. Mean daily temperatures of the central region of the Canadian Okanagan study area near sx̌ʷəx̌ʷnitkʷ (Okanagan Falls) for 2013.

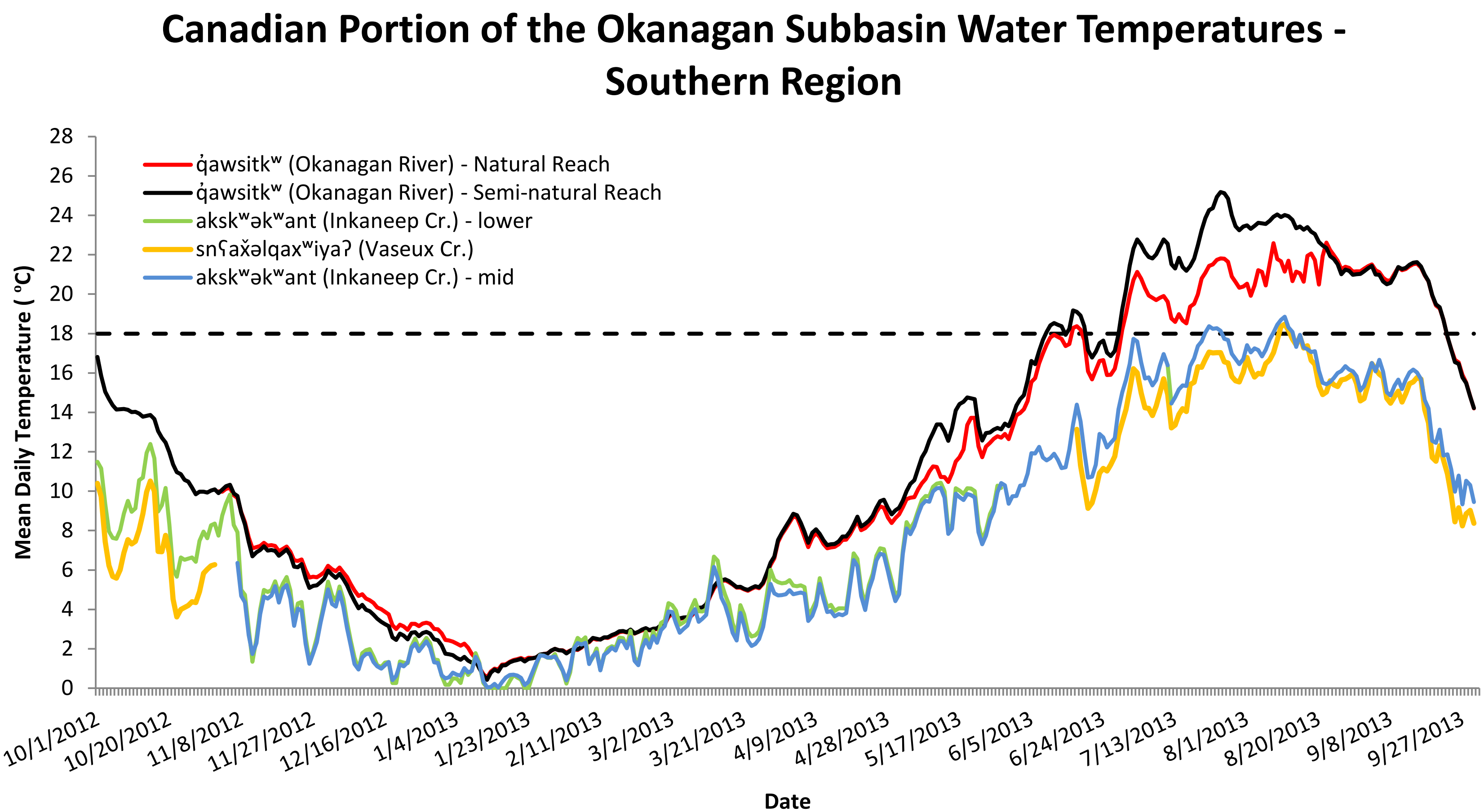


Figure 46. Mean daily temperatures of the southern region of the Canadian Okanagan study area near nʔaləm̓xnitkʷ (Oliver) for 2013.

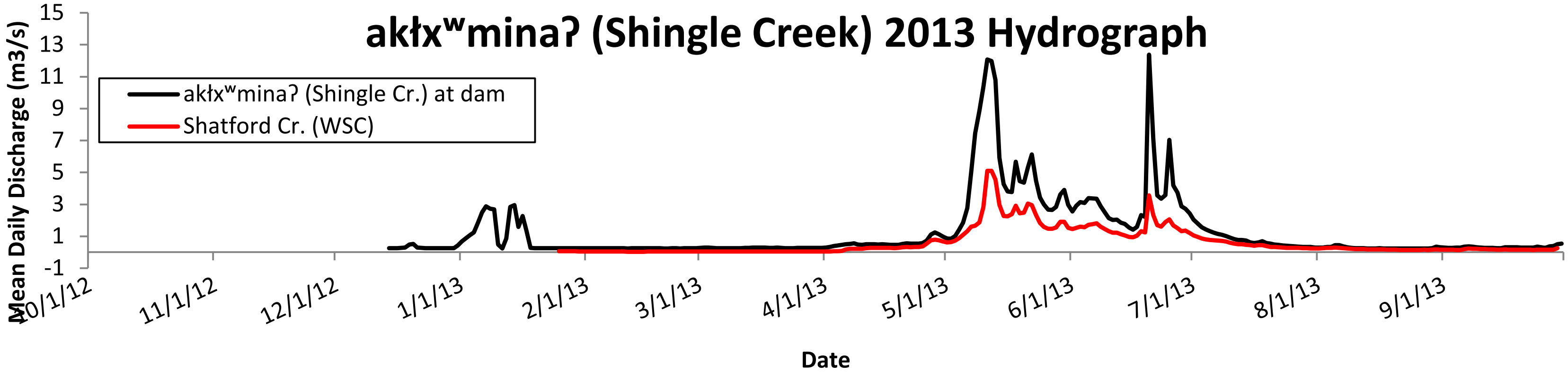


Figure 47. Hydrograph of mean daily discharge in akłxʷminaʔ (Shingle Creek) for 2013 showing the OBMEP monitored station and the station operated by the Water Survey of Canada at Shatford Creek 08NM037 (Environment Canada 2013).

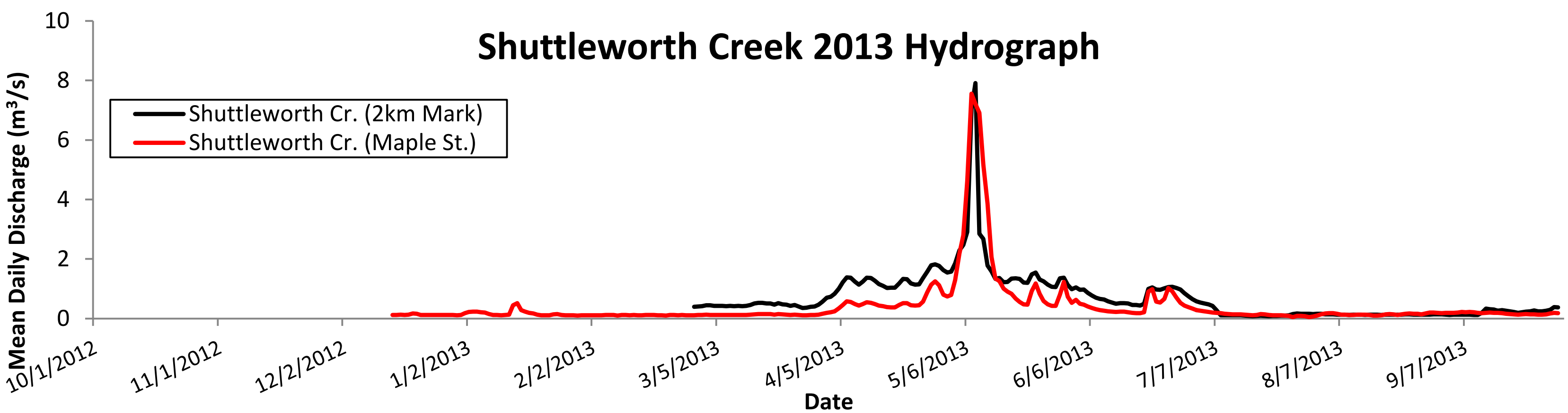


Figure 48. Hydrograph of mean daily discharge in Shuttleworth Creek for 2013 at two OBMEP monitored discharge stations.

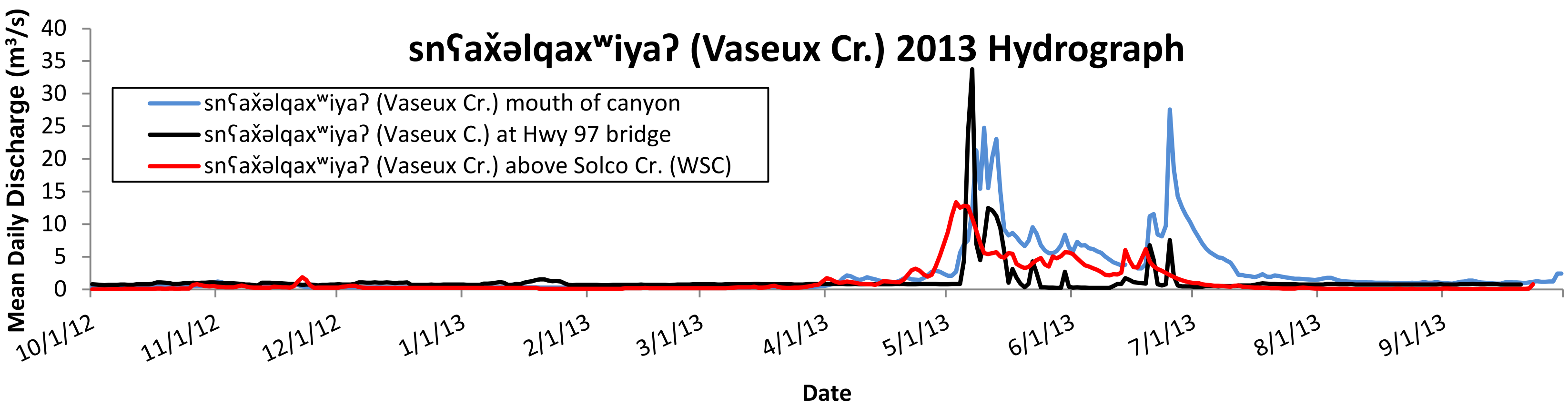


Figure 49. Hydrograph of mean daily discharge at two OBMEP monitored sites in snʕax̌əlqaxʷiyaʔ (Vaseux Creek) as well as the Water Survey Canada station (08NM171) above Solco Creek for the 2013 water year (Environment Canada 2013).

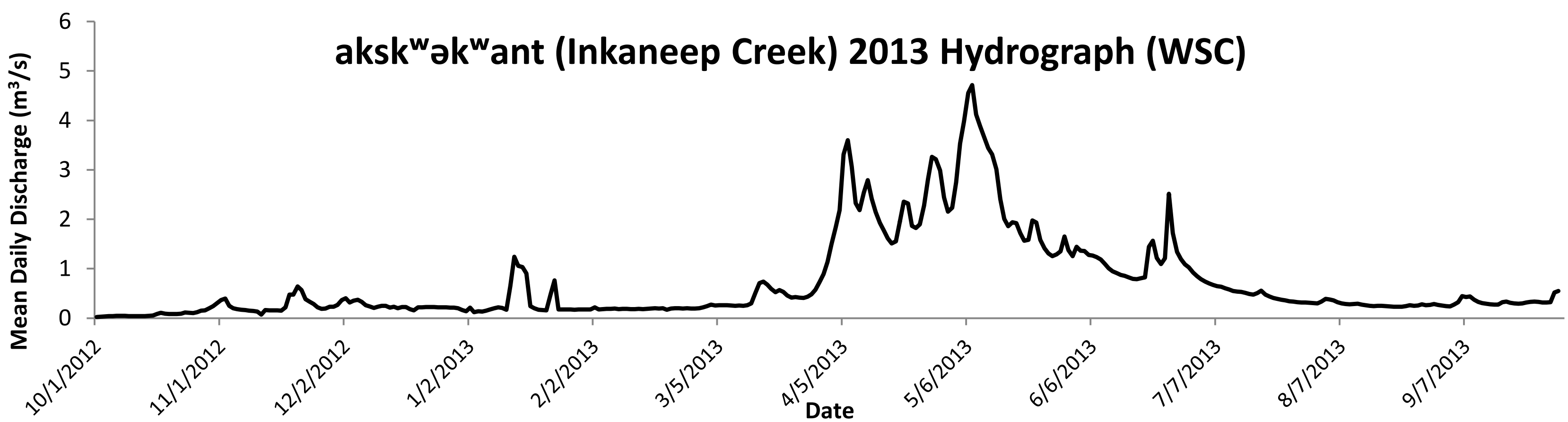


Figure 50. Hydrograph of the mean daily discharge in akskʷəkʷant (Inkaneep Creek) at the Water Survey Canada station (08NM200) for the 2013 water year (Environment Canada 2013).

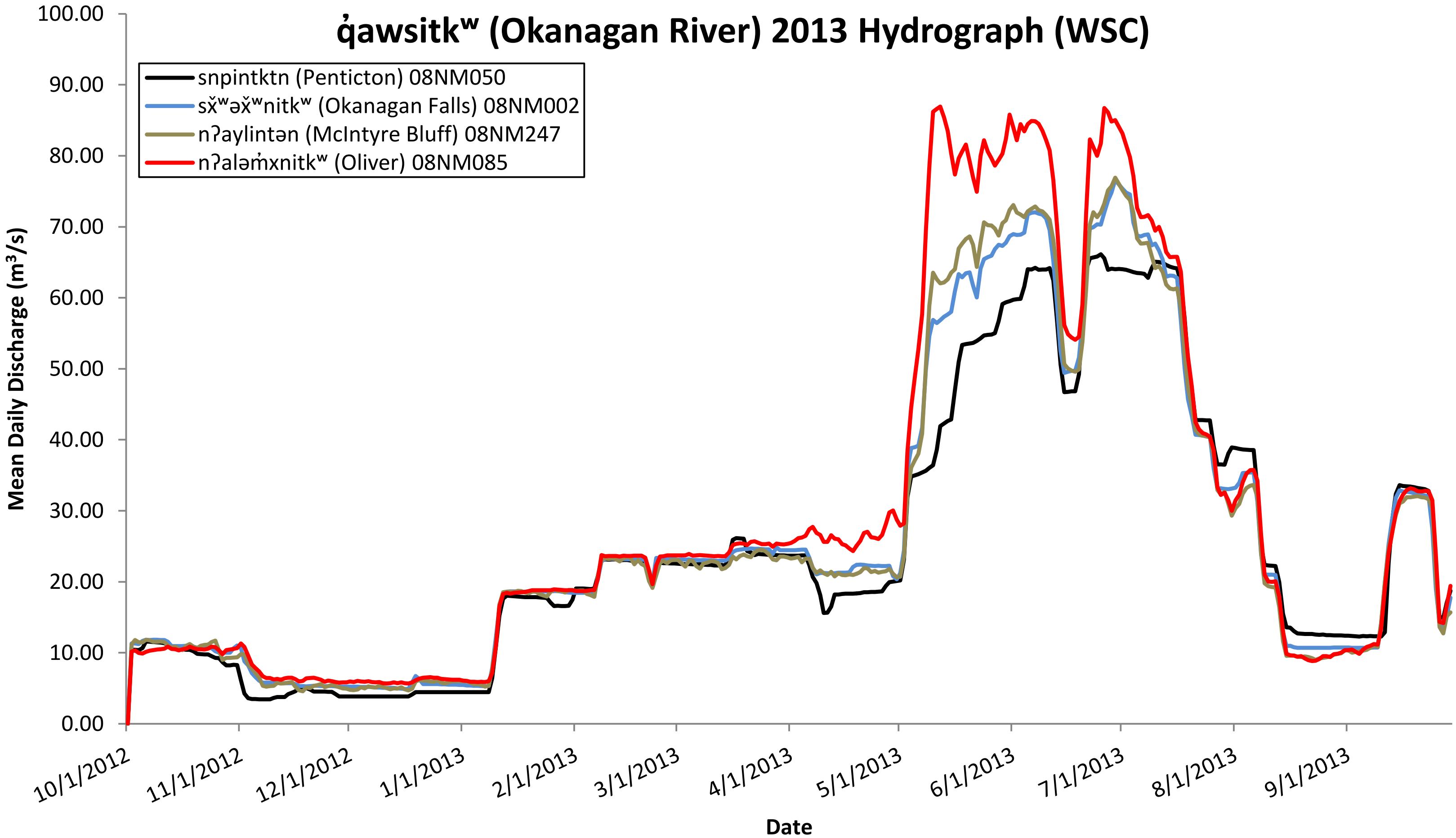
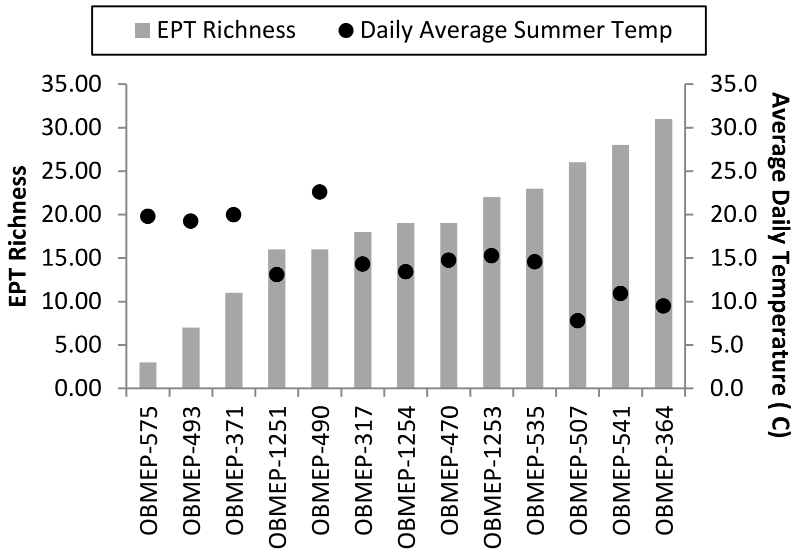
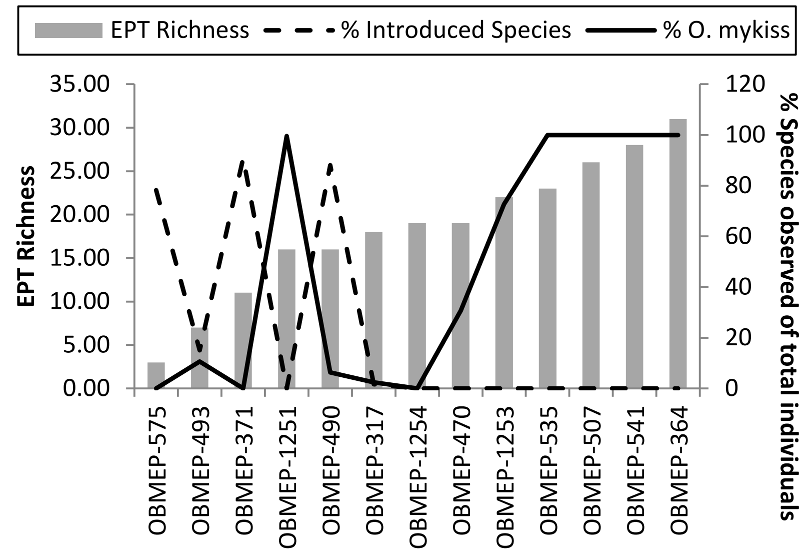


Figure 51. q̓awsitkʷ (Okanagan River) hydrograph for 2013 monitored at Water Survey Canada stations (Environment Canada 2013).

Appendix J: Benthic Macroinvertebrate Diversity





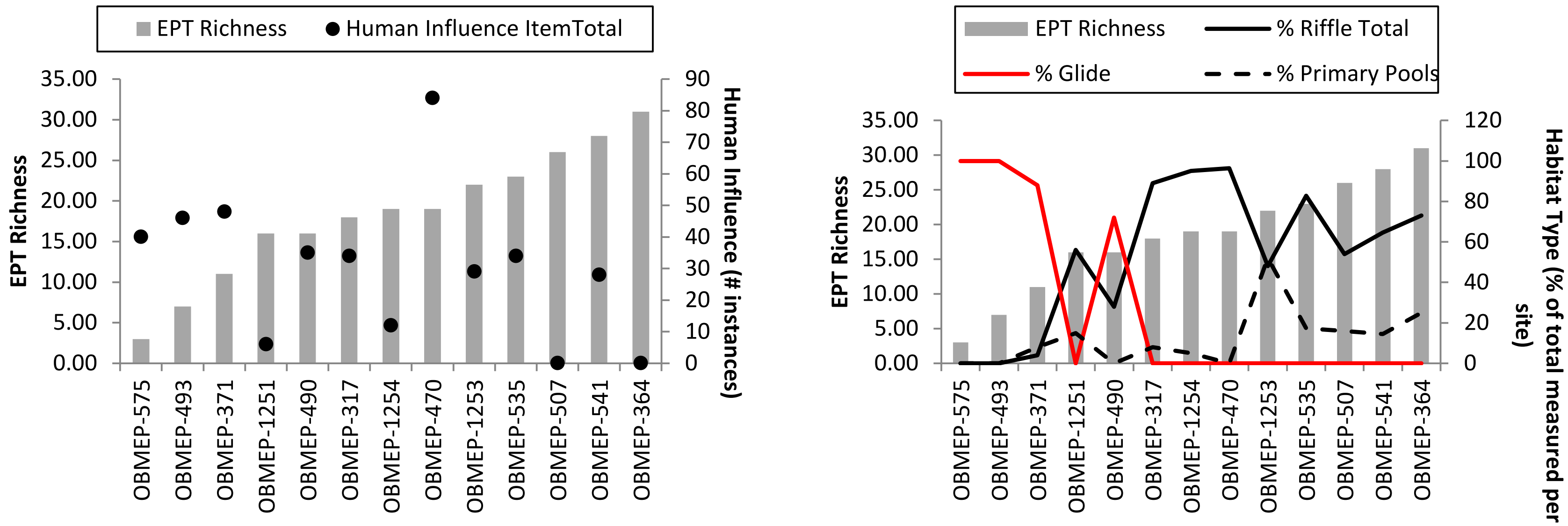


Figure 52. Graphs summarizing benthic macroinvertebrate taxa (Ephemeroptera, Plecoptera and Trichoptera (EPT)) richness compared to fish species composition, habitat, human influence, and water quality parameters for Canadian sites sampled through OBMEP in 2012.