CRITFC

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Limiting Factors of the Abundance of Okanagan an Wenatchee Sockeye Salmon in 2012

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Columbia River Inter-Tribal Fish Commission Technical Report for BPA Project 2008-503-00

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EXECUTIVE SUMMARY

A total of 1610 sockeye salmon, *Oncorhynchus nerka*, were PIT tagged at the Bonneville Dam Adult Fish Facility in 2012. An additional 752 sockeye salmon were PIT tagged at the east bank Priest Rapids Dam ladder trapping facility. These fish, along with previously PIT tagged sockeye also sampled, were tracked upstream using data from detection arrays at mainstem Columbia River dam fish ladders as in-river arrays in the Wenatchee and Okanagan basins. Using data from PIT tags deployed at Bonneville Dam, the estimated stock composition of sockeye salmon was 82.4% Okanagan and 17.6% Wenatchee. Using data from PIT tags deployed at Priest Rapids Dam, the estimated stock composition was 80.3% Okanagan and 19.7% Wenatchee.

In 2012 GSI was used to classify sockeye salmon PIT tagged at Bonneville Dam. The concurrence between the GSI and classifications based on final PIT tag detection site was 99.8% for the Okanagan stock and 97.9% for the Wenatchee stock. The GSI estimated stock composition at Bonneville Dam was 80.3% Okanagan, 19.6% Wenatchee, and 0.1% Snake River. The estimated survival rate from Bonneville Dam to terminal areas was 75.5% for the Okanagan stock, 64.3% for the Wenatchee stock, and 0% (n=3) for the Snake River stock. Sockeye salmon tagged at Bonneville Dam had an estimated survival of 85.3% to McNary Dam which was higher than three of four groups of returning sockeye salmon tagged as juveniles at locations upstream of McNary Dam (range=68.9% to 86.2%). Sockeye salmon tagged at the Bonneville Dam for this study passing Tumwater Dam also had a better detection rate at spawning ground PIT tag arrays (45.4%) than sockeye tagged as juveniles (12.5%-36.7%).

PIT tag data from Bonneville tagged fish estimated fallback rates at mainstem dams that ranged from 0.4% at Bonneville Dam to 7.9% at Rocky Reach Dam. At Bonneville Dam, the fallback rate for sockeye that crossed over to the Oregon side was 43.8% (n=16) compared to 0.3% on the Washington side. A similar trend was seen with previously tagged sockeye passing Bonneville Dam with a fallback rate of 10.1% on the Oregon side and 0.7% on the Washington side.

The median travel time of sockeye salmon between Bonneville and Rock Island dams was 15.7 days, resulting in a median migration rate of 31.0 km per day. Fish passing Bonneville Dam later in the migration traveled upstream faster than those earlier in the migration.

In the Okanagan Basin, PIT tag antennas installed and maintained by this project at Zosel Dam (ZSL) and the Okanagan Channel (OKC) were operational for the entire year with the exception of some outages at OKC during periods minimal fish passage would be expected. Between April 1, 2012 and March 31, 2013, at Zosel Dam, 21 Chinook, 38 steelhead, and 215 sockeye were detected, while at OKC 4 Chinook, 5 steelhead, and 1017 sockeye were detected. Most sockeye salmon, as well as some Chinook salmon, passed Zosel Dam during periods of high flow when it was possible to move upstream through the spillways, bypassing PIT tag detection in the fish ladders.

At Wells Dam, 771 sockeye salmon were sampled and 762 PIT tags and 60 acoustic tags deployed. The detection rate at the Okanagan Channel PIT tag detection array (OKC) for fish only PIT tagged at Wells Dam was 41.8% compared to 44.1 for sockeye passing Wells Dam that we PIT tagged at Priest Rapids Dam and 41.4% for sockeye PIT tagged at Bonneville Dam. Sockeye tagged at Wells Dam with both PIT and acoustic tags were 7.2% less likely to be detected at OKC than those only tagged at Wells Dam with PIT tags only. The OKC PIT tag array detected 88.9% of sockeye with both an acoustic and PIT tags.

A total of 21 acoustic receivers were deployed between Wells Dam and Okanagan Lake and 20 acoustic tags implanted at Wells Dam. Survival was 80.4% to the Monse Bridge site on the Okanagan River just upstream of Wells Dam, 68.4% to the North Basin of Osoyoos Lake, and 15.4% to McIntyre Dam. Sockeye salmon did not pass the Monse Bridge site when the Okanagan River temperature was above 22. 0^{o}C, choosing to hold in the Okanagan River. Of the 60 sockeye acoustic tagged, 30 were estimated to be on the spawning grounds during the spawning period, 21 were missing on the upstream migration, 7 were captured in fisheries and two were last detected just upstream of Osoyoos Lake but not detected on the spawning grounds.

Data from acoustic tags was used for in-season harvest management in Osoyoos Lake. When acoustic data suggested escapement was not as high as had been expected based on Wells Dam counts, the decision was made to stop sockeye fisheries on September 1, 2012 rather than two weeks later as had been planned. If the fishery had continued, it is estimated that the sockeye escapement would have been driven well below the 100,000 goal.

Lake Wenatchee acoustic trawl surveys, funded by this project, found that Lake Wenatchee was 63% as productive, in terms of juvenile nerkids per hectare, as

Osoyoos Lake. A Lake Wenatchee limnology survey was also funded by this project and estimated a zooplankton biomass only 50% as high as that in Osoyoos Lake but a higher proportion of edible zooplankton such as *Hesperodiaptomus kenai*.

For the first time in 2012, juvenile sockeye PIT tagging took place in the Canadian portion of the Okanagan Basin. A total of 559 sockeye smolts were PIT tagged, with estimated survival to Rocky Reach Dam of 53.6% (s=7.7%) and a mean migration time of 7.7 days (s=0.2). Survival to Bonneville was 14.9% (s=8.4%) with a mean migration time from tagging of 15.5 days (s=0.6).

Detection data from sockeye salmon acoustic and PIT tagged by this project was combined with dam counts, harvest estimates and escapement estimates to partition to estimate the number of sockeye unaccounted for. In total, 215,881 sockeye were considered unaccounted (or 41.8% of the run), with the Wells-Zosel (70,326), Bonneville-McNary (44,033), and above Tumwater (24,012) reaches having the largest number unaccounted for. There was also a large number (55,185) of sockeye unaccounted for above OKC, however this is likely due to the number of spawning sockeye being underestimated. Of the entire estimated run of 517,154, 41.8% were estimated to be unaccounted for, 32.6% were harvested, and 25.6% were estimated as escapement.

This project is proposed to continue and evolve through at least 2017. Past work has created the infrastructure through funding PIT tag antennas at OKC and Zosel Dam as well as acoustic arrays to better determine where losses of Okanagan sockeye salmon are occurring upstream of Wells Dam. However, low sample sizes of acoustic tagged sockeye, possible acoustic tagging impacts, as well as the lack of any PIT tag detection between Wells Dam and Zosel Dam and OKC still leaves considerable uncertainty in quantifying mortality. This gap should begin to be filled in when the Colville Tribe implements a PIT tag array in the lower Okanagan River beginning in 2014. We hope to work with the Colville Tribe in the future on expanding PIT tag detection in the Okanagan Basin. In addition, we have been investigating possible PIT tag detection at the Highway 3 bridge in Osoyoos between the north and central basins of Osoyoos Lake. It is hoped that better PIT tag detection at some of these sites could eliminate the need for acoustic tags providing better data at lower cost.

The differential survival between Bonneville and terminal areas noted in 2012 is something we will explore further in future years. Higher harvest rates of Wenatchee

(and Snake River) sockeye relative to Okanagan sockeye has been speculated to be a possible reason for the large increase of the Okanagan portion of the Columbia Basin run in recent years. Results in 2012 provide a small degree of support, with estimated survival to terminal areas of 75.5% for the Okanagan stock, 64.3% for the Wenatchee stock, and 0% for the Snake River stock (the latter based on only two fish). Thus we are going to continue GSI work, in addition to GSI of sockeye salmon captured in harvest, in future years. (Preliminary 2013 results indicate little difference between survival rates for the Okanagan and Wenatchee stocks.)

We also expect to continue with Wenatchee acoustic trawl surveys and limnological work to better estimate the production and productive potential of Wenatchee sockeye salmon. Acoustic trawl surveys in both Lake Wenatchee and Osoyoos Lake are also being used in Columbia Basin run forecasting. There are several unanswered questions regarding Lake Wenatchee sockeye that we hope to address for this project. A primary question is why Lake Wenatchee sockeye have not increased in relative abundance as much as Okanagan sockeye, or even Snake River sockeye, in recent years. Our limnology and ATS work will help in answering this question, but it is also uncertain what the optimal spawning escapement goal is for this stock. An optimal escapement analysis is being compiled separate of this project for Osoyoos and Skaha sockeye and we plan to consider this for the Wenatchee stock as part of this project.

Another unanswered question is how current production for both Osoyoos and Wenatchee sockeye salmon compares to historical production. Peak historical Columbia Basin sockeye runs have been estimated at 2.6 million to 4.3 million (Chapman 1986, NPPC 1986, Fryer 1995); however the 2012 run of over 510,000 sockeye salmon with less than 5% of historical Columbia Basin habitat available makes those peak estimates appear conservative. To answer this question, we plan to work with the Okanagan Nation, Department of Fisheries and Oceans Canada, and Grant, Chelan, and Douglas Public Utility District to fund paleolimnological work in Wenatchee, Osoyoos, Skaha, and Okanagan lakes beginning in 2014.

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INTRODUCTION

Sockeye salmon, *Oncorhynchus nerka,* is one of the species of Pacific salmon native to the Columbia River Basin. Prior to European settlement of the region, it is estimated the Columbia Basin supported an annual sockeye salmon run averaging over three million fish (Northwest Power Planning Council 1986, Fryer 1995). Since the mid-1800's, however, the sockeye salmon run has severely declined, reaching a low of fewer than 9,200 fish in 1995 before rebounding in recent years to record highs. In 2012, a record 515,673 sockeye salmon were counted at Bonneville Dam (DART 2012, Fish Passage Center 2012).

The Columbia Basin sockeye salmon run was once composed of at least eight principal stocks (Fulton 1970, Fryer 1995). Today, only two major stocks remain (Figure 1); the first originating in the Wenatchee River-Lake Wenatchee System (Wenatchee stock) and the second in the Okanagan[1] River-Osoyoos Lake System (Okanagan stock). A third remnant stock, comprising well under 0.1% of the run, returns to Snake River-Redfish Lake (Snake stock) and is listed under the Endangered Species Act.

Okanagan sockeye salmon spawn in the Canadian portion of the Okanagan River and then rear in Osoyoos Lake, through which runs the border between the United States and Canada. This run has persisted despite one of the longest, most difficult migrations of any salmon stock in the world. The stock migrates 986 km between the spawning grounds and the ocean through one dam and a series of irrigation control structures on the Okanagan River as well as nine mainstem Columbia River dams. The production of this run is believed to be limited by upstream and downstream migration survival as well as habitat factors in the spawning and rearing areas (Fryer 1995; Hyatt and Rankin 1999, Hyatt and Stockwell 2009).

[1] The Canadian spelling for Okanagan will be used throughout this document as opposed to the American spelling (Okanogan).

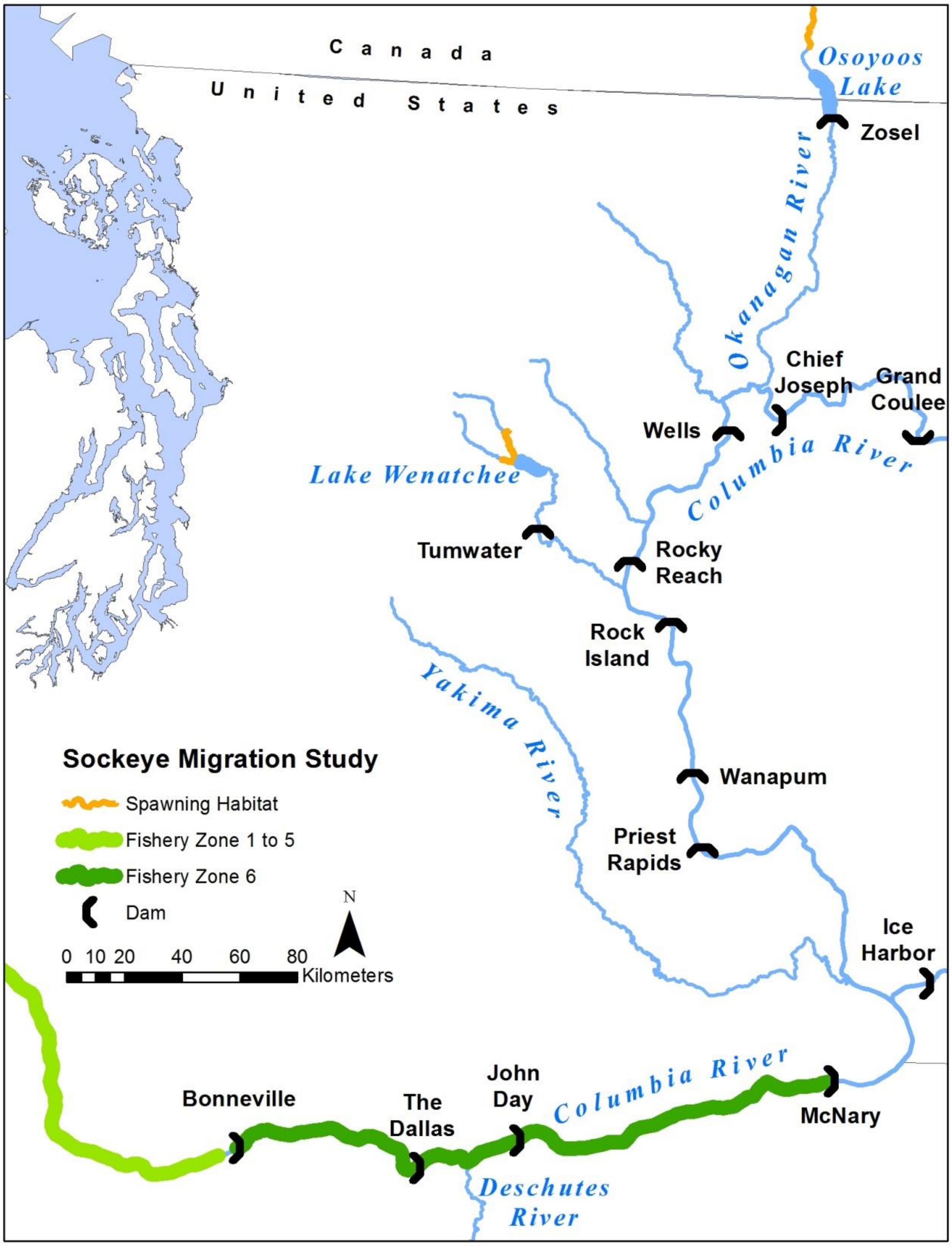

Figure 1. Map of the Columbia Basin showing fishery Zones 1-5 and 6, the two major sockeye salmon production areas and significant dams on their migration route.

The Wenatchee stock spawns in tributaries to Lake Wenatchee and rears in the lake. This stock migrates 842 km through two Wenatchee River dams and seven mainstem Columbia River dams. Since the spawning grounds and lake are relatively pristine, the production of this run is believed to be limited by upstream and downstream survival as well as the low productivity of the oligotrophic Lake Wenatchee (Fryer 1995).

This Columbia River Inter-Tribal Fish Commission (CRITFC) study, funded by the Columbia Basin Fish Accords, seeks to expand our knowledge of factors limiting production of Okanagan and Wenatchee sockeye salmon stocks. This study expands upon previous work, funded by the Pacific Salmon Commission from 2006-2008, to examine upstream survival and timing by inserting Passive Integrated Transponder (PIT) tags in sockeye sampled at Bonneville Dam as part of the annual Pacific Salmon Commission (PSC)-funded sockeye stock identification project. These PIT tagged fish can then be detected at several upstream dam fish ladders with detection capability (McNary, Priest, Rock Island, Rocky Reach, and Wells dams on the Columbia River, Ice Harbor and Lower Granite dams on the Snake River, and Tumwater Dam on the Wenatchee River) as well as at in-stream tributary antennas.

The fact that there are only two significant Columbia Basin sockeye salmon stocks passing through multiple Columbia River dams with PIT tag detection makes the species ideal for a PIT tag study. Determination of migration timing and mortality for other salmon and steelhead species is difficult, since many tributaries are without detection facilities, or with detection facilities that only detect a fraction of fish passing, meaning that fish can escape undetected. The run timing of the adult Columbia Basin sockeye salmon migration is of particular interest because the migration timing has shifted to earlier in the year over the past 70 years (Fryer 1995, Quinn et al. 1997). A 1997 radio-tagging study also found high mortality of the latter portion of the run (Naughton et al. 2005) as well as no difference in stock-specific migration timing. The radio tag study was conducted in an unusually high flow year that may not be typical of other years. Results of PIT tagging studies between 2006 and 2010 (Fryer 2007b, 2009, Fryer et al. 2010, 2011) concurred with the 1997 radio-tagging results (Naughton et al. 2005) regarding higher mortality during the latter portion of the run.

In 2009, PIT tag detection antennas were installed by Washington Department of Fish and Wildlife (PTAGIS 2010) in natal streams in the Wenatchee Basin (Little Wenatchee and White rivers), making it possible to track Wenatchee sockeye to the spawning grounds. No similar detection system was available in the Okanagan Basin; therefore in 2009 this project funded installation of a PIT tag antenna on the Okanagan River upstream of Osoyoos Lake (known at www.ptagis.org as OKC – see Appendix Table A4 for site information) and in 2010 funded installation of antennas at both Zosel Dam fishways (ZSL). In 2011, this project funded maintenance of these antennas. To further investigate the mortality rate of Okanagan sockeye in the Okanagan Basin, since 2009 this project has funded an acoustic network in the Okanagan basin and acoustic tagged sockeye salmon at Wells Dam.

Since 2010 this project has funded a hydroacoustic survey of Lake Wenatchee to initiate standardized sockeye salmon smolt abundance estimation for the Wenatchee stock for comparison with similar estimates already available for Okanagan sockeye in Lake Osoyoos. This estimate will be used to estimate juvenile survival and compared to Wenatchee River smolt trap smolt estimates. In 2012, the project began limnology surveys of Lake Wenatchee with the goal of estimating potential smolt capacity of the lake.

In 2012, two additional components were added to this project. The first was adult sockeye salmon trapping and PIT tagging at the Priest Rapids Dam east bank fish ladder. This was a cooperative project with the Colville Tribe with a goal of providing additional PIT tagged fish that could be detected at Zosel Dam to allow escapement to be estimated using PIT tags. The second was PIT tagging juvenile Okanagan sockeye salmon juvenile to estimate survival to Rocky Reach and McNary dams.

METHODS

Adult PIT and acoustic tag detection infrastructure

Okanagan River (Canada) PIT tag detection

This project has installed two Okanagan River PIT tag detection sites. The first site (OKC), installed in November 2009 (Fryer et al. 2010), is a channel width array at river km 147, just downstream of Vertical Diversion Structure 3 near Oliver, BC. The second (ZSL), installed in September 2010, consists of two antennas in each of the two fish ladders at Zosel Dam in Oroville, WA (Fryer et al. 2011). These systems were designed to detect PIT-tagged adult sockeye salmon as they ascend the Okanagan River

Okanagan acoustic tag network

An acoustic tag network was deployed in the Okanagan Basin to monitor survival and timing of adult sockeye acoustically tagged at Wells Dam. The system consisted of Vemco VR2W receivers deployed from Pateros, just upstream of Wells Dam through the Okanagan Basin to Penticton Channel between Skaha Lake and Okanagan Lake. The receivers in the U.S. portion of the basin were deployed and maintained by Confederated Tribes of the Colville Reservation staff, while the receivers in the Canadian portion of the basin were deployed and maintained by Okanagan Nation Alliance staff. Data from these receivers were used to estimate mortality and passage time upstream of Wells Dam.

Adult sampling at Bonneville, Priest Rapids, and Wells dams

Bonneville Dam

Sockeye salmon were sampled and tagged at the Adult Fish Facility located adjacent to the Second Powerhouse at Bonneville Dam (river km 235) in conjunction with the sampling of steelhead (*O. mykiss)* and summer Chinook salmon (*O. tshawytscha)*. Sampling and tagging typically occurred between approximately 0800 and 1300 hours four to five days per week. A picket weir diverts fish ascending the Washington Shore fish ladder into the adult sampling facility collection pool. An attraction flow is used to draw fish through a false weir

where they may be selected for sampling. Fish not selected and fish that have recovered from sampling then migrate back to the Washington Shore fish ladder above the picket weir.

Sockeye selected for tagging were examined for tags (including scanning for existing PIT tags), fin clips, wounds, and condition. They were measured for length, and four scales were removed for later age analysis (Fryer 2007a). PIT tags were inserted into the body cavity (if not already present) of the sockeye salmon using standard techniques (CBFWA 1999). The fish were scanned for the PIT tag number, which was stored in a Destron Fearing FS 2001 PIT tag reader. If there was no tag detected, due to either the tag being shed or a malfunction, then no effort was made to implant another tag to eliminate the possibility of double tagging. Sockeye salmon were allowed to recover prior to release. All PIT tag and sampling information was uploaded to the Columbia Basin PIT Tag Information System (PTAGIS) database (www.ptagis.org).

PIT tagged sockeye salmon were detected by existing detection arrays in adult fish ladders at Bonneville, McNary, Priest Rapids, Rock Island, Rocky Reach, and Wells dams on the Columbia River; Ice Harbor and Lower Granite dams on the Snake River; Zosel Dam on the Okanagan River, and Tumwater Dam on the Wenatchee River (array configurations are available at www.ptagis.org) as well as several in-stream detection arrays. PIT tag detection data from these arrays are automatically uploaded several times daily to the PTAGIS database where they are immediately accessible to users of the site. If a tag was not detected after the fish was released, we removed it from further analysis.

Wells Dam Sampling

Sockeye were trapped at the Wells East Bank ladder fish trap. At this site sockeye were diverted into a large holding tank, then netted out of this tank and placed in a small anesthetic tank. As at Bonneville Dam, sockeye were examined for tags (including PIT tags), fin clips, wounds, and condition. They were also measured for length and had four scales removed and placed on scale cards for later age analysis. All data were recorded onto datasheets. All sockeye salmon sampled at Wells Dam were tagged with PIT tags (if not already present) and Floy tags.

Vemco© V9 2H acoustic tags (29 x 9 mm, weight 4.7 grams) with a projected battery life of 132 days were surgically implanted into the body cavities of 60 sockeye salmon (which were also PIT tagged). These acoustic tagged fish were distributed through the run with an emphasis on later migrating sockeye as, in earlier years of this study; they have had lower survival to the spawning grounds. Learning more about the migration strategy of these sockeye might suggest management strategies to boost their survival. Internal implantation followed methods of Langford et al. (1977) where an incision just smaller than the transmitter was made into the body cavity on the midline of the ventral surface halfway between the pectoral and pelvic fins. The transmitter was disinfected with a solution of Chlorhexidine before placement into the body cavity. Once the transmitter was secured inside the fish, the body-wall incision was closed utilizing two simple interrupted sutures of sterile non-absorbable monofilament suture.

At the request of Douglas County Public Utility District, which owns Wells Dam, all sampled sockeye were placed into a tanker truck and hauled approximately four kilometers upstream of Wells Dam on the western side of the forebay and released.

Priest Rapids Dam Sampling

Sockeye were trapped at the Priest Rapids East Bank ladder fish trap. At this site sockeye were diverted into a small holding tank, then netted out of this tank and placed in a small anesthetic tank. As at Bonneville and Wells dams, sockeye were examined for tags (including PIT tags), fin clips, wounds, and condition. They were also measured for length and had four scales removed and placed on scale cards for later age analysis. All data were recorded onto datasheets. All sockeye salmon sampled at Priest Rapids Dam were tagged with PIT tags (if not already present) and Floy tags.

Upstream migration analysis

In 2012, for the first time, we calculated some migratory characteristics of sockeye salmon PIT tagged as juveniles for comparison with sockeye PIT tagged by this project. These sockeye were from PIT tagging programs in the Snake River, the Wenatchee Eastbank Hatchery program, Wenatchee River smolt trap and mixed-stock juveniles moving through Rock Island and Wanapum dams.

Stock classification

Sockeye salmon stock determinations (Wenatchee, Okanagan, Snake, or Unknown - mortalities) were made by the last detection point. Those individuals last observed at or upstream of Rocky Reach Dam were classified as being Okanagan stock. Individuals which were last observed at or upstream of Tumwater Dam were classified as Wenatchee stock. Sockeye which were last observed at or upstream of Ice Harbor or Lower Granite Dam were classified as being Snake River stock. All remaining sockeye salmon last observed downstream of the aforementioned sites were recorded as mortalities. Released tagged fish not detected at or upstream of PIT tag detectors located near the fish viewing windows at Bonneville Dam were removed from the number of fish tagged for subsequent analysis.

Escapement

Escapement to upstream sites dams was estimated as:

$$N = \sum_i \frac{B_i R_i}{T_i}$$

where N was the estimated escapement at a particular upstream site, B_i is the weekly visual count passing Bonneville Dam in week i (DART 2012, Fish Passage Center 2012), T_i is the number of fish PIT tagged at Bonneville Dam in week i, and R_i is the number of PIT tag detections at the dam where escapement is being estimated of those fish tagged in week i.

Upstream survival/conversion rates

Survival/conversion rates were calculated for sockeye to upstream dams with PIT tag detection as:

$$S = \sum_i \frac{W_i D_i}{N_i}$$

Where W_i is the proportion of the sockeye run passing Bonneville Dam in week i, D_i is the number of sockeye detected at or above the dam in question, and N_i is the number of tagged sockeye salmon detected subsequent to release at Bonneville Dam. Given that the percentage of PIT tagged fish missed passing upstream through dams is typically very small, this provides a good

approximation of survival to upstream dams. However, at terminal in-stream antennas (such as OKC in the Okanagan and LWN and WTL in the Wenatchee) where the percentage of PIT tagged fish missed is much higher and there is no or insufficient detection of PIT tagged fish upstream to estimate this percentage, estimation using these techniques cannot be considered a survival rate. The nomenclature in the Columbia Basin is to call this a conversion rate and this term will be used in this report when referring to the percentage of tagged fish being detected at an in-stream antenna.

Detection Rate

We used the record of detections of PIT tagged fish to determine the detection rate at the fish ladders at dams[2]. PIT tag antennas in fish ladders are placed such that all fish must go through them, although at Bonneville, McNary, Ice Harbor, and Lower Granite dams it is possible for fish to use the navigation locks. PIT tagged fish going through PIT tag antennas can still be missed due to rare antenna outages, possible faulty tags or tag orientation, tag collision from two tagged fish passing through antennas simultaneously, or problems with antennas. Since CRITFC began PIT tagging salmon at Bonneville Dam in 2006, we have been computing detection efficiency at upstream dams. There has been some variation in methodology over these years, but currently we are calculating detection efficiency as the ratio of the number of fish detected upstream missed at the site in question, divided by the total number of fish detected upstream. For example, the percentage missed at Rocky Island Dam was calculated as:

$$P = \frac{R_m}{R_d}$$

where R_m was the number of fish missed at Rocky Island Dam but detected at sites upstream of Rock Island Dam divided by $R_{d,}$ the number of fish detected upstream of Rock Island Dam.

Compiled for placement in Appendix A (Table A1) of this report was the probability of detection at the different sites at dam fish ladders. PIT tag detection antennas in fish ladders are always located in close proximity in such a way that a PIT tagged fish must go through at least two antennas in sequence at

[2] A similar approach was used to estimate the detection rate at acoustic receiver sites.

each fish ladder. (At some ladders, one antenna covers the entire fishway width at a given point, while at other ladders two antennas in parallel cover the fishway width.) Therefore, if a fish is detected at one antenna, or a pair of antennas, it should also be detected at the rest of the antennas, or pairs of antennas, in that same ladder. (Exceptions are lower sites in Bonneville and McNary fish ladders where only underwater orifices have antennas which fish can bypass. However, upper sites at these ladders have 2-4 antennas which fish must pass through.) This allows a probability of detection at the individual antennas to be calculated by comparing it with other antennas in that same ladder. Detection probabilities were calculated as:

$$Pi = \frac{N_i}{Max(N_i)}$$

where N_i is the number of fish detected at a given antenna and $Max(N_i)$ is the total number of fish detected by any antenna in that ladder. An overall probability of detection was calculated as:

$$1 - \prod_i (1 - P_i)$$

Also calculated was the percentage of sockeye salmon using each ladder at dams with multiple ladders.

Migration timing and passage time

Run timing was estimated using the date and time of detection at the different dams. Migration rates were calculated between dam pairs as the time between the last detection at the lower dam and the first detection at the upper dam. The amount of time required to pass each dam was estimated as the difference between the first detection time at a dam and the last detection time at the same dam.

Bonneville stock composition estimates using PIT tag recoveries

The overall stock composition, P_i, for stock *i* (where *i* denotes the Wenatchee or Okanagan stock) at Bonneville Dam was estimated as:

$$P_i = \sum_j W_j * S_{ij}$$

where W_j is the proportion of the run passing Bonneville Dam in week *j*, and S_{ij} is the percentage of the run estimated in week *j* to belong to stock *i* based on upstream recoveries.

The stock composition estimated by PIT tag recoveries was compared with that estimated from two visual counts, the first estimating the Wenatchee stock abundance as the difference between the Rock Island and Rocky Reach Dam counts and the second using Tumwater Dam visual counts to estimate the Wenatchee stock abundance.

Okanagan and Wenatchee age and length-at-age composition

The age composition for the Okanagan and Wenatchee stocks was estimated as:

$$T_{i,j} = \sum_k A_{i,j,k} * W_k$$

where $T_{i,j}$ was the estimate for stock *i and age gro*up *j*, $A_{i,j,k}$ was the percentage of sockeye for stock *i* and age group *j* in week *k* and W_k was the percentage of the run that passed Bonneville Dam in week *k.*

The variance was estimated as

$$Var(T_{i,j}) = \sum_k Var(A_{i,j,k}) * W_k^{\ 2}$$

where

$$Var(A_{i,j}) = \frac{\sum_k A_{i,j,k}(1 - A_{i,j,k})}{n_{i,k}}$$

Night passage

Fish passing viewing windows at Columbia Basin dams are not always counted using the same time period. Fish passing Bonneville and McNary Dam fish viewing windows are counted by observers only from 0400 to 2000 hours Pacific Standard Time for 50 minutes of each hour and the counts expanded by a factor of 1.2. Video records of fish migration at Priest Rapids, Rock Island, Rocky Reach, and Wells dams are recorded 24 hours per day and subsequently reviewed to yield total counts of daily fish passage. In this study, night passage rates (where night is defined as 2000 to 0400 hours) were calculated by stock, for all dams passed, based on the last detection time for a given fish ladder. The last time at the uppermost antenna was used as an approximation for passage time as this antenna was closer to the fish counting window than the lowermost antenna (where the first detection would be made). This was the case at all sites

except at BO4 near the fish counting facility on the Washington shore at Bonneville Dam (Figure A1), where the distance between the uppermost and lowermost antennas is only about 15 meters so the uppermost antenna was still used for consistency.

Fallback

Three methods were used to estimate fallback, which is defined as a fish that ascends a fish ladder into the reservoir above the dam, then "falls back" to the downstream side of the dam either over the spillway, or through the navigation locks, juvenile bypass systems, or turbines. The first method was if an adult salmon or steelhead was detected in the juvenile bypass system. However, on the Columbia River, only Bonneville, John Day, McNary, Rocky Reach dams have juvenile bypass system PIT detection capability while all four dams in the Snake River have juvenile detection. Furthermore, there is no detection at any dam for fish falling back over the spillway or through the navigation locks or turbines. Therefore, a second method of estimating fallback was to look at each dam for fish detected at the uppermost antenna followed by detection more than two hours later at an antenna located downstream in the same ladder (or another ladder for multiple ladder dams). Finally, a third method of defining fallback was ascertained by fish that passed an upstream PIT tag detector at a given dam, then were next observed at a site downstream of the dam in question. Thus if a fish was detected at the upper antenna at Wells Dam and then subsequently detected at Tumwater Dam, it would be considered a fallback at both Wells and Rocky Reach dams. Similarly, if a fish was last detected the Wells Dam upper antenna and then detected at the Rocky Reach juvenile bypass, it would be considered a fallback at Wells and Rocky Reach dams.

A list of possible fallbacks was compiled using each of these methods and duplicates eliminated. Each fallback PIT tag detection record was examined to determine whether it met the criteria above. If a fish fell back over a dam multiple times, each time was considered a separate fallback. Fallbacks were compiled by dam and a fallback rate calculated by dividing the number of fallbacks by the total number of PIT tagged fish passing the dam in question. The resulting estimated fallback is almost certainly biased low as it will not include fish that fall back over a dam and are not subsequently detected.

Acoustic trawl surveys for juvenile sockeye abundance

Night-time juvenile sockeye salmon densities in Osoyoos Lake were estimated by executing specialized acoustics and trawl based survey (ATS) methods. Several whole-lake transects covering depth strata from the lake surface to bottom were traversed with hydro-acoustics gear (Simrad or Biosonics sounders operating at 70-200 kHz) deployed from a boat at night (Hyatt et al. 1984). Acoustic signal returns from juvenile sockeye were digitally recorded for subsequent population estimates of the total number of targets comprising pelagic fish located between the lake's bottom and surface. Echo counting is frequently confounded by fish schooling behavior during short nights in May–July; therefore, the best estimates are normally obtained during ice-free periods in the fall to early spring. Fish density estimates, in combination with species composition and biological traits (length, weight, age) information from trawl catches, are used to determine numbers and biomass of juvenile sockeye salmon found in the lake. Data from multiple surveys may be used to estimate salmon mortality between consecutive seasonal intervals (fall-spring, spring-summer, summer-fall).

Fish bio-samples were collected using a small, mid-water trawl net (2 x 2m mouth opening, 7.5-m length). Haul depths were based on echo-sounding results that indicate depths at which juvenile sockeye salmon were most likely to be caught.

Immediately upon capture, pelagic fish destined for laboratory analysis (biological traits, stomach contents, etc.) were placed into a 90% solution of ethanol and then subsequently frozen. Random samples of up to 150 juvenile sockeye and/or kokanee were normally retained from each survey date between November 2009 and April 2010. Trawl segment duration was adjusted to shorter or longer times depending on catch success. Larger catches triggered short trawl sets (10-15 minutes) such that most fish remained in good condition upon trawl retrieval. Following random withdrawal of a sub-sample of fish from a large catch, all other trawl caught fish were released unharmed.

Genetic Stock Identification (GSI)

Tissue samples in the form of a caudal fin punch were collected for genetic analyses from all adult sockeye salmon sampled at Bonneville, Priest Rapids, and Wells dams. Tissue samples were stored using a dry Whatman paper medium (LaHood et al. 2008). Genomic DNA was extracted from digested tissue samples using a standard Qiagen DNeasy protocol. Prior to amplification of single-nucleotide polymorphism (SNP) loci using primer-probe sets (fluorescent tags), an initial polymerase chain reaction (PCR) “pre-amp” step was implemented using whole genomic DNA to jumpstart SNP amplification via increased copy number of target DNA regions. The cycling regime and PCR conditions for the pre-amp step were as follows: one initial cycle of 95o C for 15 min, 14 cycles of 95o C for 15 seconds, 60 o C for four minutes, and a final dissociation step. For each data collection run, each panel of 96 SNP loci were arrayed with 96 samples using a Fluidigm® microfluidic 96.96 chip (including one genotype indicator and one no-template control sample) to generate high throughput genotyping. Sample cocktails included: 3.4µl GTXpress Taqman (Applied Biosystems), 0.30µl GT load buffer (including taq polymerase), 0.30µl H_2O and 2.0µl pre-amp DNA template. Single SNP assays were prepared in a 5.0µl reaction mix (per sample), containing the following reagents: 2.5µl DA load buffer, 0.25µl Rox 19 dye, 1µl H_2O, and 1.25µl primer/probe. Microfluidic chips were loaded with assay cocktail dispensed at 4.5µl per well, and sample cocktail dispensed at 5.0µl per well. Chip loading was completed following standard manufacturers protocol on a Fluidigm IFC controller. Amplification conditions using a fast-cycling protocol were; 70o C for 30 min, 25o C for 10 minutes, and 95 o C for one minutes, followed by 50 cycles of 95o C for 5 seconds, and 50o C for 25 seconds, and a final cool down step of 25o C for 10 minutes. Chips were imaged and scored on a Fluidigm EP1 imager using Fluidigm SNP Genotyping Analysis Software version 3.1.1. Carcass samples often provide poor quality and/or quantity of viable DNA relative to fresh tissue, and our final sample sizes were pared based on individual genotyping success. Successful genotyping for a given sample was defined proportionally as less than 10% missing data (i.e. fewer than ten missing SNP genotypes per individual for *O. nerka*).

For the *O. nerka* baseline data, the program LOSITAN (Antao *et al*. 2008) was used to evaluate the relationship between F_{ST} and *He* (expected

heterozygosity) for all loci in an island model, to identify outlier loci (candidates for selection) having excessively high or low *F*ST compared to neutral expectations. We used data simulations based on 50,000 replicates, and a 0.99 confidence interval for all SNP loci under an infinite alleles model. The method uses coalescent simulations to generate a null distribution under neutral expectations around observed *F*ST values (with confidence intervals), assuming a finite island model. For test settings in ARLEQUIN we used 1000 simulated demes and 150,000 coalescent simulations; the hierarchical island model was not used due to high error rate (Narum 20 and Hess 2011). Results using both methods were plotted to represent the 1% and 99% confidence quantiles. Loci lying above or below these quantiles (outliers) may be under directional or balancing selection (respectively) in some populations. Evaluating adaptive diversity (selection) is confounded by the need to scrutinize the underlying demographic processes that also influence diversity. Many population genetic parameters (e.g., *F*ST, Nm, Ne, gene flow) assume neutrality. Yet neutrality is difficult to determine. Relying solely on tests that detect "outliers" as a means of characterizing the selection candidacy of loci can often produce false positive results. This may occur for example, if loci are highly differentiated because of demography, substructure, or skewed patterns of isolation-by-distance (Akey 2009; Hermisson 2009; Narum and Hess 2011). In order to draw biological inferences from comparisons that reveal patterns of neutral genetic diversity it is important to account for, or eliminate adaptive influences contributed by non-neutral outlier loci (Luikart *et al*. 2003). This has been our practice for the steelhead trout baseline that is several years along in development. Since we have not yet begun to explore differences between adaptive and neutral divergence for *O. nerka* SNPs, the baseline analyses presented in this report were conducted without excluding any candidate loci. Determining which candidate loci are under selection will require additional computationally demanding tests to show statistical associations with certain traits or landscape features. At this point in our analyses we have not determined the appropriate confidence level threshold for assuming positive selection among our *O. nerka* baseline populations.

Juvenile PIT tagging

Sockeye smolts were captured downstream of Skaha Lake Outlet Dam during the smolt outmigration monitoring program (Benson and Warman 2012). Two rotary screw traps were set for 12-hour periods from 27 March to 20 April, 2012, then 24-hour periods from 20 April to 2 May, 2012. Live wells were checked one or two times daily, depending on smolt abundance. During morning checks, a sub-sample of captured smolts were kept in perforated aluminum boxes positioned in the river downstream of the RSTs until tagging was complete. Procedures developed by PTAGIS (1999) and Biomark (2012) for PIT tagging smolts. Cormack/Jolly-Seber survival estimates and travel times were estimated using a set of on-line tools developed by the University of Washington School of Aquatic and Fishery Sciences Columbia Basin Research (http://www.cbr.washington.edu/dart/query/pit_sum_tagfiles).

RESULTS

Zosel Dam and Okanagan Channel PIT tag antenna operation

A total of 1017 sockeye, 5 steelhead, and 2 Chinook were detected the OKC PIT tag array between April 1, 2012 and March 31, 2013 (Figure 2). In addition, one coho was detected. The coho, with tag 3D9.1C2D47F893, was released from Winthrop Hatchery on 4/15/2011, detected moving downstream at Rocky Reach and John Day in May, 2011; returned through Bonneville on 9/7/2012 and detected up through the system, arriving at Zosel on 10/30/12 and OKC between 11/01 and 11/06/12. Although coho have been counted passing through the fish ladder at Zosel Dam, this is the first documentation of coho in the Canadian portion of the Okanagan Basin in at least 70 years.

Only 215 sockeye, 38 steelhead, and 21 Chinook were detected passing Zosel Dam fish ladders (Figure 3 and 4) as high summer flows meant most fish passed by Zosel Dam undetected through the spillway rather than through the fishways where they could be detected by PIT tag antennas. One mountain whitefish tagged and released May 8, 2012 on the Twisp River, was detected at the lower antenna on the west bank Zosel Dam fish ladder on November 20, 2012. Salmon tagged by CRITFC tagging projects (adult Wells sockeye and adult Bonneville sockeye, Chinook, and steelhead tagging) comprised 78.1% of PIT tagged fish detected at Zosel and 95.0% of PIT tagged fish detected at OKC (Tables 1 and 2).

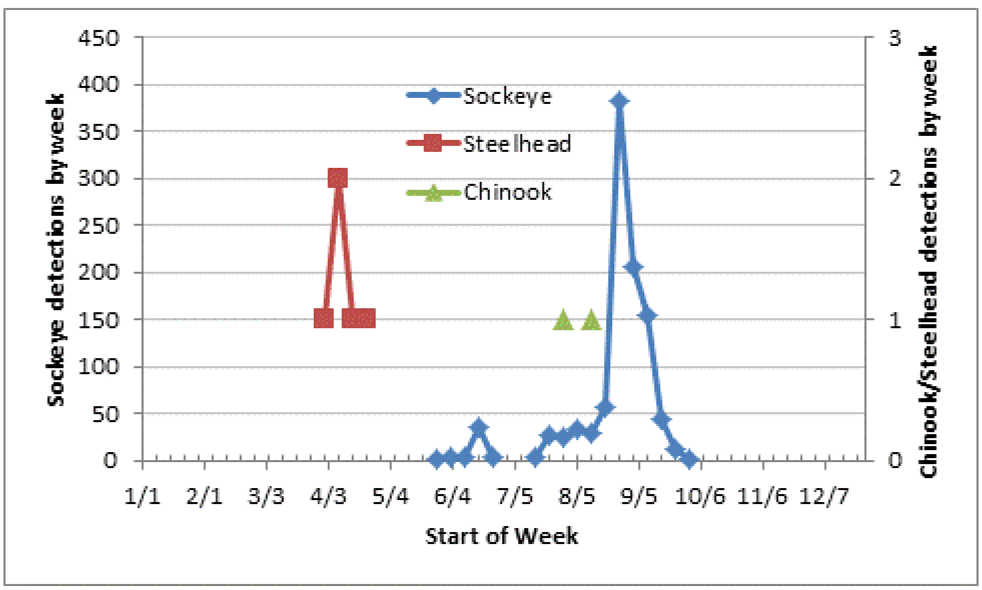

Figure 2. Number of PIT tagged sockeye detected passing the Okanagan Channel PIT tag site by week in 2012.

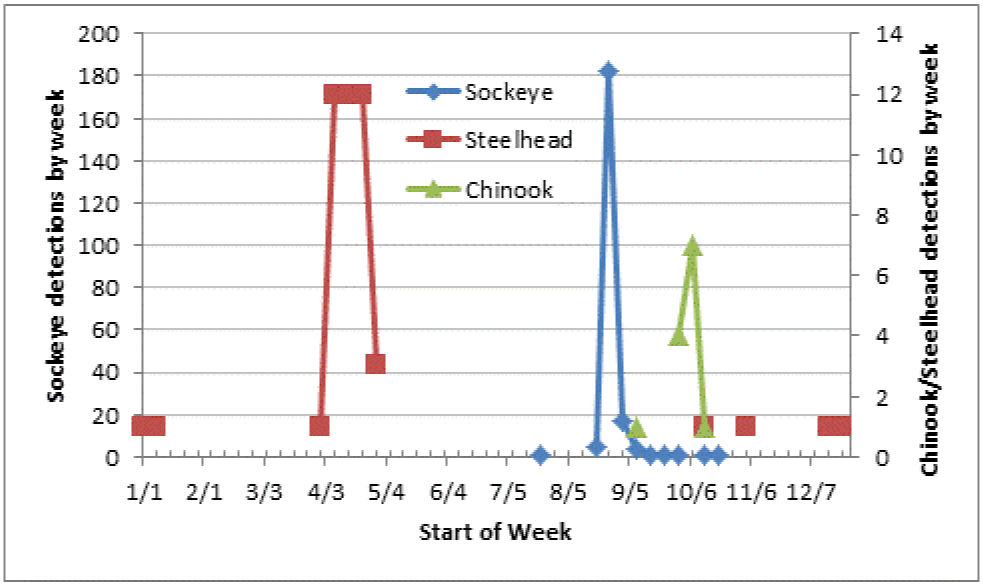

Figure 3. Number of PIT tagged sockeye and Chinook salmon, and steelhead detected passing the Zosel Dam PIT tag site in 2012.

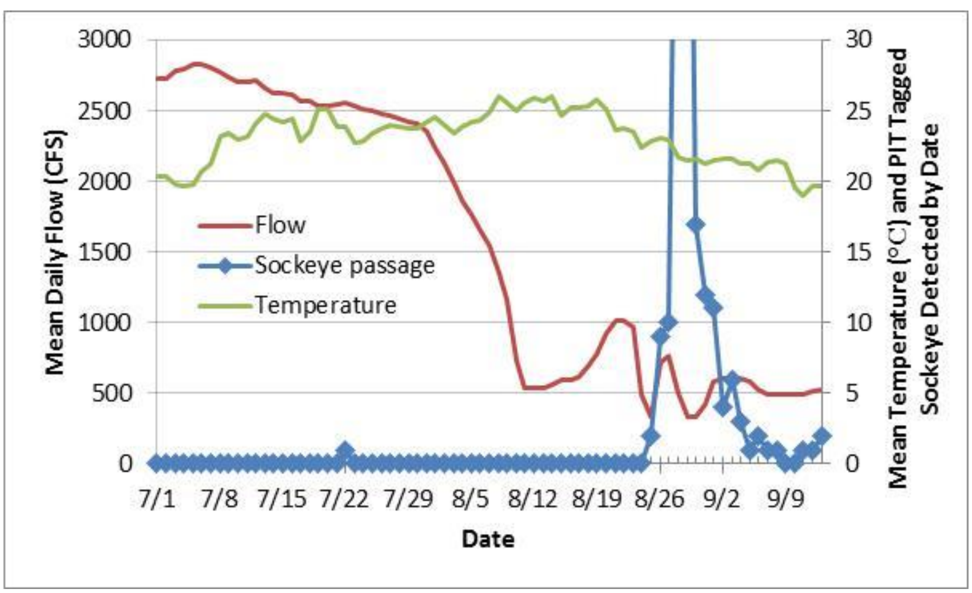

Figure 4. Number of PIT tagged sockeye salmon detected by date, mean daily flow, and mean daily temperature at Zosel Dam during sockeye migration in 2012. Sockeye passage peaked at 60 on August 28 and 65 on August 29.

Table 1. Number of PIT Tagged Chinook, Steelhead, and Sockeye detected at Zosel Dam ladders between April 1, 2012 and March 31, 2013 by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye	Total
Bonneville Dam	Adult	1	1	82	84
Priest Rapids Dam	Adult		33	61	94
Wells Dam	Adult	11		68	79
McNary Dam	Juvenile	1		2	3
Rock Island	Juvenile	4			4
Similkameen	Juvenile	2	1	2	5
Twisp River	Juvenile		1		1
Winthrop River	Juvenile	2	2		4
Total		**21**	**38**	**215**	**274**

Table 2. Number of PIT Tagged Chinook, Steelhead, and Sockeye detected at the Okanagan Channel (OKC) PIT tag array between April 1, 2012 and March 31, 2013 by release site and life stage at time of tagging.

Release Site	Life Stage at Release	Chinook	Steelhead	Sockeye	Total
Bonneville Dam	Adult	1		412	413
Priest Rapids Dam	Adult			250	250
Wells Dam	Adult	2		316	318
McNary Dam	Juvenile			13	13
Okanagan Falls	Juvenile			1	
Omak Creek	Juvenile		1		1
Priest Rapids/Wanapum	Juvenile		4	5	9
Rock Island	Juvenile			21	21
Winthrop	Juvenile	1			1
Total		**4**	**5**	**1017**	**1026**

Three sockeye PIT tags inserted in sockeye salmon in previous years by this project (3D9.1C2CF98675 tagged in 2008 and 3D9.1C2DAEAA84 and 3D9.1C2CDC5DCE, tagged in 2011) were detected between May 5 and 8, 2012 and were presumably washed downstream over the antenna by high flows.

Okanagan acoustic tag network installation and monitoring

A total of 21 receivers were deployed in the Okanagan Basin between Pateros, located 13 km upstream of Wells Dam on the Columbia River, and the Penticton Channel, upstream of Skaha Lake at rkm 189 (Table 3 and Figure 5). An additional five receiver sites were not deployed because of high flows.

Receivers at two sites were lost; the West Channel Similkameen site was likely lost due to high flows, and the Brewster Dock SE site when a bolt connecting a dock to a piling broke[3]. All receivers were checked and downloaded at least once per month.

Table 3. Acoustic receivers deployed in the Okanagan Basin, their location, and date of deployment in 2012. See Figure 5 for the map for this table.

Map No.	Location	rkm	Latitude	Longitude	Date Deployed	Date Retrieved
1	Pateros Dock (Columbia River)	843	48.054	-119.897	6/28/2012	9/12/2012
2	Brewster Bridge Dock (Columbia River)		48.090	-119.778	6/28/2012	10/12/2012
3	Brewster Dock SE (Columbia River)		48.081	-119.714	6/29/2012	Lost but recovered 11/13/2013
4	Monse Bridge, west	6	48.140	-119.674	7/3/2012	10/23/2012
5	Monse Bridge, east	6	48.140	-119.673	7/3/2012	10/23/2012
6	Highway 20 Bridge east		48.353	-119.593	River too high, not deployed	
7	Highway 20 Bridge west		48.353	-119.594	River too high, not deployed	
8	Sim/Oka confluence east		48.869	-119.416	River too high, not deployed	
9	Siml/Oka confluence west		48.869	-119.416	River too high, not deployed	
10	Cross Channel Pool	120	48.918	-119.424	River too high, not deployed	
11	West Channel Similkameen	5	48.911	-119.442	7/18/2012	Lost
12	Similkameen Canyon	11	48.949	-119.465	6/27/2012	10/23/2012
13	Zosel RR bridge east		48.932	-119.420	River too high, not deployed	
14	Zosel RR bridge west		48.931	-119.420	7/18/2012	10/23/2012
15	Pump Intake, east bank	124	48.946	-119.432	6/27/2012	10/23/2012
16	Pump Intake, west bank	124	48.946	-119.432	6/27/2012	10/23/2012
17	Haynes Point West	132	49.018	-119.443	7/10/2012	11/29/2012
18	Haynes Point Nav Buoy	132	49.021	-119.438	7/10/2012	11/29/2012
19	Central Basin Hwy 3 bridge	134	49.028	-119.460	7/10/2012	11/29/2012
20	North Basin Ink Creek	140	49.069	-119.502	7/10/2012	11/29/2012
21	OKR Mouth East	141	49.079	-119.521	7/10/2012	11/29/2012
22	OKR Mouth West	141	49.079	-119.522	7/10/2012	11/29/2012

[3] The Brewster Dock SE site receiver was recovered by a diver in November, 2013.

23	OKR Hwy 97 Bridge	162	49.230	-119.542	7/10/2012	11/29/2012
24	McIntyre Dam	165	49.257	-119.528	7/10/2012	11/29/2012
25	Skaha Dam Downstream	176	49.345	-119.580	7/10/2012	11/29/2012
26	Skaha Dam Upstream	176	49.345	-119.580	7/10/2012	11/29/2012
27	Penticton Channel Outlet	189	49.451	-119.599	7/10/2012	11/29/2012

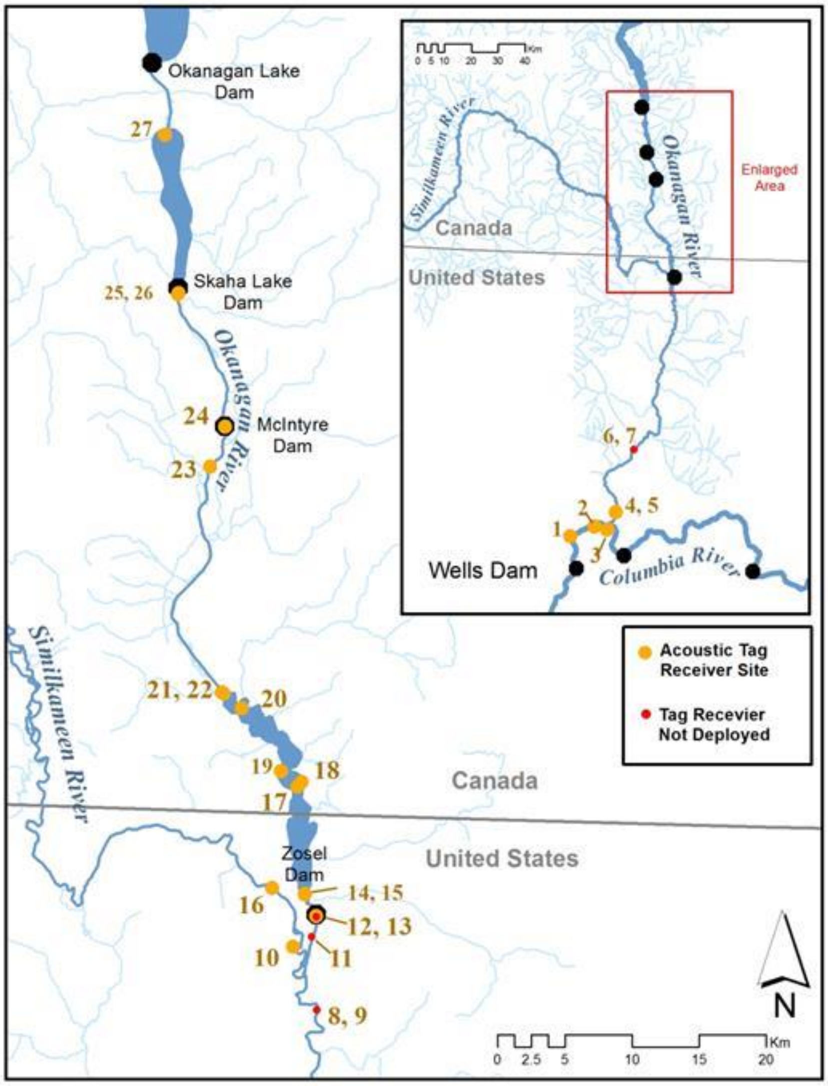

Figure 5. Okanagan Basin acoustic receiver sites in 2012. Location numbers reference sites listed in Table 3.

Upstream migration analysis

Mixed stock sample size and age composition

In 2012, mixed stock sockeye salmon were sampled and PIT tagged at both Bonneville and Priest Rapids dams (Figure 1). A total of 1610 sockeye salmon were PIT tagged and successfully scanned for those tags at Bonneville Dam between May 30 and August 1, 2012 (Table 4). Of the tagged sockeye, nine were not detected after release. These fish may have shed their tags, had defective tags, or died. It was also possible that sockeye salmon passed downstream without being detected as they often pass over the top of weirs in the fish ladder rather than through the underwater slots where PIT tag antennas are located in the lower portions of Bonneville Dam fish ladders. It is less likely that sockeye salmon pass upstream undetected as, at Bonneville Dam, they must pass through PIT tag antennas near the fish counting window. At Bonneville Dam (as well as McNary, Ice Harbor, and Lower Granite dams) fish can pass upstream through the navigation locks. All other dams with PIT tag detection have antennas in fish ladders that sockeye salmon must pass through, however data from 2006-2012 indicates that PIT tagged sockeye salmon are missed, although the percentage is normally low (Table 5). Of the 1601 sockeye tracked, 9 were not detected at the uppermost PIT tag antennas at Bonneville Dam suggesting that they may not have passed upstream. These sockeye were included in subsequent analyses.

Table 4. Number of sockeye salmon sampled and PIT tagged at Bonneville Dam and tracked upstream by date and statistical week in 2012.

Sampling Dates	Statistical Week	Sampled (n)	Tagged	Detected after tagging and tracked
5/30,31; 6/1,4-8	22-23	69	66	61
6/11,12,13,14,15	24	201	193	193
6/18,19,20,21,22	25	408	404	401
6/25,26,27,28,29	26	426	423	420
7/2,3,4,5,6	27	374	368	366
7/9,10,11,12,13	28	119	117	117
7/16,17,18,19,20	29	24	24	24
7/23,24,25,26; 8/1	30-31	16	15	15
Total		**1637**	**1610**	**1601**

Table 5. Number and percentage of PIT tagged fish not detected at dam detection sites as estimated from upstream detections in 2012 along with comparison data for 2006-2011.

Dam	2012		2011	2010	2009	2008	2007	2006
	N	%						
Bonneville	7	0.5%	1.8%	0.7%	0.6%	0.4%	2.1%	0.2%
McNary	20	1.6%	12.1%	3.8%	5.0%	10.1%	6.5%	3.1%
Priest Rapids	2	0.2%	0.4%	0.6%	0.3%	0.3%	0.8%	0.0%
Rock Island	53	4.4%	5.4%	6.2%	2.6%	6.9%	6.8%	1.3%
Rocky Reach	7	0.7%	1.4%	0.5%	0.0%	0.2%	0.7%	12.3%
Wells	0	0.0%	0.0%	0.0%	--	--	--	--
Ice Harbor		NA	0.0%	0.0%	20.0%	0.0%	--	--

In 2012 we also PIT tagged 752 sockeye salmon at the Priest Rapids Dam east ladder fish trap. After adding two previously tagged (at Bonneville) sockeye to our sample and subtracting three sockeye not subsequently detected, the number of fish tracked was 751 (Table 6).

Table 6. Number of sockeye salmon sampled and PIT tagged at Priest Rapids Dam and tracked upstream by date and statistical week in 2012.

Sampling Dates	Statistical Week	Sampled (n)	Tagged	Previously tagged	Detected after tagging and tracked
6/27,28,29	23	133	133	0	132
7/2,3	24	179	178	0	178
7/9,11	25	225	224	1	225
7/16	26	110	108	1	108
7/23	27	109	109	0	108
Total		**756**	**752**	**2**	**751**

The estimated age composition from sockeye sampled at both Bonneville and Priest Rapids dam was very similar, with the predominate Age 1.2 age class differing by only 0.2% and estimates for other age classes differed by 1.5 percentage points or less between the two sites (Tables 7 and 8).

Table 7. Weekly and total age composition of sockeye salmon at Bonneville Dam as estimated from scale patterns in 2012.

Statistical Week	N Ageable	Age Class				
		1.1	1.2	1.3	2.1	2.2
23	66	0.0%	93.9%	6.1%	0.0%	0.0%
24	192	1.0%	95.8%	2.6%	0.0%	0.5%
25	395	0.8%	96.2%	2.0%	0.3%	0.8%
26	422	2.1%	95.5%	0.5%	0.2%	1.7%
27	365	0.5%	97.0%	0.0%	1.1%	1.4%
28	114	0.9%	95.6%	0.9%	0.9%	1.8%
29	23	4.3%	91.3%	4.3%	0.0%	0.0%
30	16	6.3%	81.3%	0.0%	6.3%	6.3%
Composite	**1593**	**1.3%**	**95.9%**	**1.1%**	**0.4%**	**1.3%**
Std. Dev.		**0.6%**	**1.0%**	**0.5%**	**0.3%**	**0.6%**

Table 8. Weekly and total age composition of sockeye salmon at Priest Rapids Dam as estimated from scale patterns in 2012.

Statistical Week	N Ageable	Age Class				
		1.1	1.2	1.3	2.1	2.2
26	133	0.0%	88.4%	10.1%	0.8%	0.8%
27	178	0.0%	97.2%	2.8%	0.0%	0.0%
28	224	2.2%	96.9%	0.9%	0.0%	0.0%
29	108	0.9%	94.4%	2.8%	0.0%	1.9%
30	109	1.9%	96.2%	0.9%	0.0%	0.9%
Composite	**752**	**0.9%**	**96.1%**	**2.6%**	**0.0%**	**0.4%**
Std. Dev.		**0.3%**	**0.8%**	**0.6%**	**0.0%**	**0.2%**

Upstream recoveries, mortality, and escapement:

Most of the Bonneville tagged sockeye salmon that were not detected at Rock Island Dam were lost before reaching McNary Dam (Table 9, Figure 6). The reach of river below McNary is where the tribal Zone 6 fishery occurs that was estimated to harvest 45,747 sockeye salmon (Table A3) with an additional 434 sockeye harvested by sport anglers (Stuart Ellis, U.S. v. Oregon Technical Advisory Committee, personal communication). However, adding this harvest to our estimated escapement to McNary Dam (424,719) still leaves 44,777 sockeye salmon unaccounted for between Bonneville and McNary dams.

Table 9. Percentage of PIT tagged sockeye salmon detected at upstream dams subsequent to tagging at upstream dams, estimated escapement from both PIT tags (12.5 mm only) and visual means, and the difference between the PIT tag and visual escapement estimate in 2012.

Dam	Estimated Percentage Reaching Dam	Estimated Escapement Using Bonneville PIT Tagged Sockeye	Visual Dam Count	Difference Between Bonneville PIT Tag and Visual Estimate	Escapement estimate using Priest Rapids PIT tagged sockeye
Bonneville	100.0%	--	515,673	--	--
McNary	82.4%	424,719	364,147	16.6%	--
Priest Rapids[4]	77.3%	398,505	408,258	-2.4%	--
Rock Island	75.0%	386,778	410,614	-5.8%	394,208
Rocky Reach	62.1%	320,241	363,297	-11.9%	319,056
Wells	60.8%	313,566	326,084	-3.8%	311,020
Tumwater	12.9%	66,272	66,520[5]	1.9%	76,733
Ice Harbor	0.0%	0	453	--	--
Lower Granite	0.0%	0	470	--	--

[4] 29 tagged sockeye last detected at the Priest Rapids adult fish trap, and presumably among the 10,000 sockeye collected for a Cle Elum Lake sockeye reintroduction program, are not included. Trapped fish are also not included in Priest Dam visual counts. Including these 29 sockeye increases the percentage to 78.9% and the PIT tag escapement estimate to 406,917.

[5] The actual visual count was 42,411, however the video record was lost for three peak passage dates. Estimating escapement for these dates using PIT tagged sockeye detected at Tumwater Dam suggests a total escapement of 66,520 (Todd Miller, WDFW personal communication)

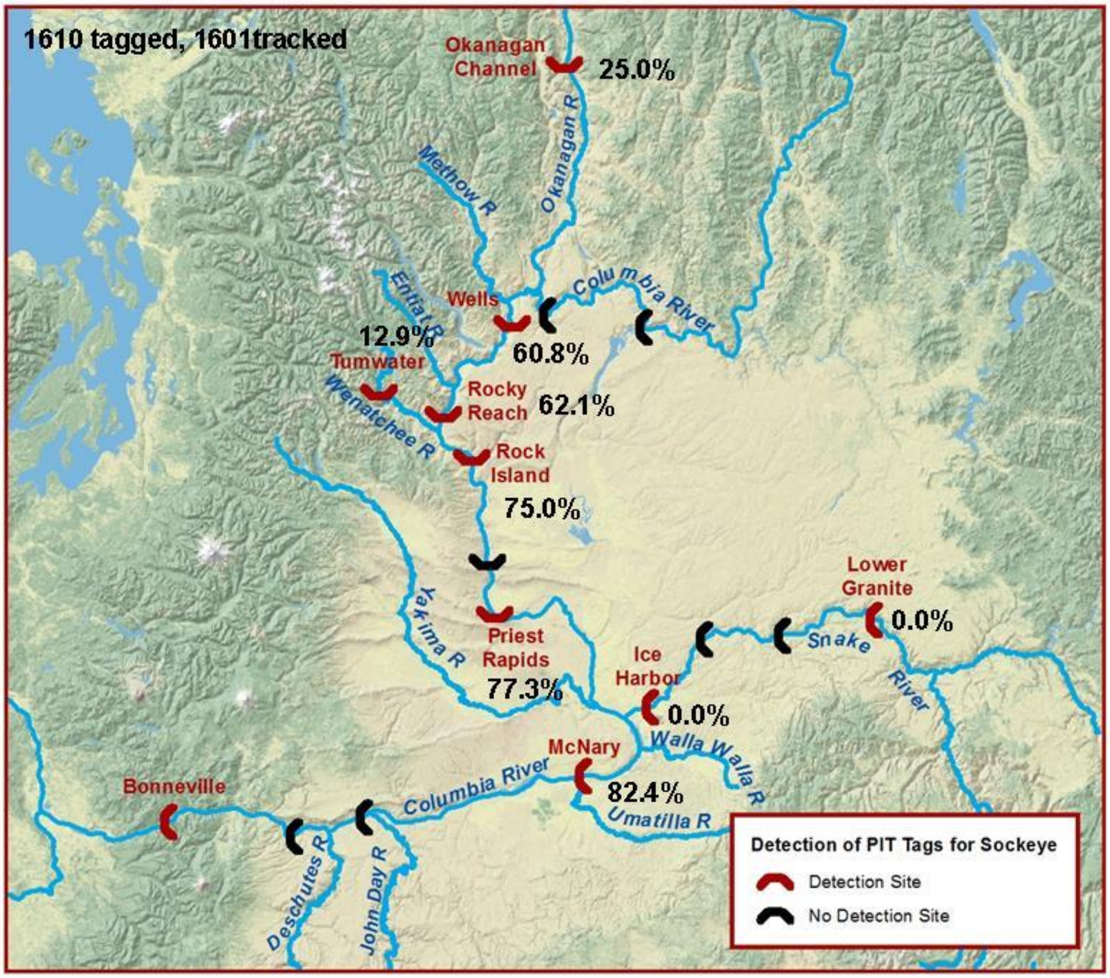

Figure 6. Map of the Columbia River Basin from Bonneville to Wells and Lower Granite dams showing the number of fish PIT tagged at Bonneville Dam, and the percentage of the run estimated to pass McNary, Priest Rapids, Rock Island, Rocky Reach, Wells, Ice Harbor, Lower Granite, and Tumwater dams and the Okanagan Channel in 2012.

Using detections of fish PIT tagged by this project at Bonneville Dam to estimate fish counts at dams resulted in estimates that varied from actual visual fish counts by (-11.9%) at Rocky Reach Dam to 16.6% at McNary Dam (Table 9). At McNary Dam it is possible for fish to use navigation locks to bypass fish ladders, thus avoiding both PIT tag detection and visual detection; however we only estimated 1.6% of sockeye were missed at McNary Dam (Table 5). At all other dams except Tumwater (where the visual count was partially estimated using PIT tags), visual counts exceeded PIT tag estimates. Estimates derived using Priest Rapids tagged sockeye and Priest Rapids visual counts were within

2% of the Bonneville estimates at Rock Island, Rocky Reach, and Wells dams; however the Tumwater sockeye escapement estimate using Priest Rapids PIT tagged sockeye was 14.4% greater than that estimated using Bonneville tagged sockeye.

As in most years of this study, and also true in 2012, survival from Bonneville to Priest Rapids dams showed a significant relationship with week tagged at Bonneville Dam (Table 10, Figure 7). The relationships for survival from Bonneville to McNary and Rock Island dams, or Rocky Reach to Wells dam were not significantly related to statistical week.

Table 10. Sockeye salmon survival through selected reaches by statistical week as estimated by PIT tag detections in 2012 and the p-value for a linear regression between weekly reach survival and statistical week.

Statistical Week at Bonneville Dam	Bonneville-McNary	Bonneville-Priest Rapids[6]	Bonneville-Rock Island	Rocky Reach-Wells
23	95.4%	95.4%	93.8%	96.6%
24	91.2%	89.1%	82.9%	98.0%
25	82.8%	80.0%	74.3%	98.9%
26	81.4%	78.8%	74.3%	95.6%
27	80.1%	75.1%	73.2%	98.1%
28	79.5%	77.8%	74.4%	98.6%
29	91.7%	83.3%	83.3%	94.7%
30	73.3%	73.3%	73.3%	90.0%
Composite	**82.4%**	**79.4%**	**75.0%**	**97.3%**
p-value	**0.092**	**0.028**	**0.149**	**0.118**

[6] Includes sockeye salmon only detected in the Priest Rapids Dam trap that likely were collected for the Cle Elum sockeye reintroduction project.

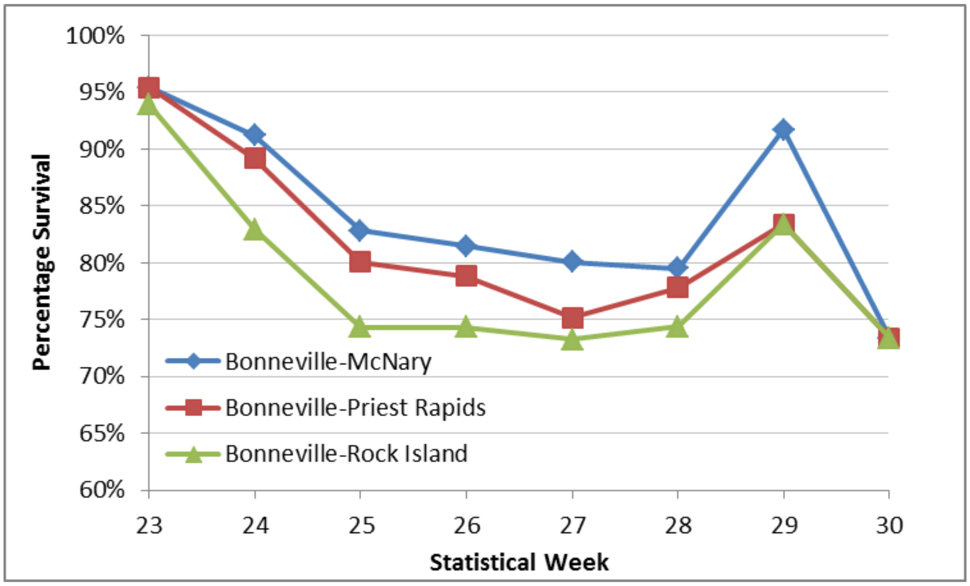

Figure 7. Survival from to McNary, Priest Rapids, and Rock Island dams by statistical week tagged at Bonneville Dam as estimated by PIT tags in 2012.

Migration rates and passage time

Adult sockeye salmon travel quickly upstream with a median migration rates between mainstem dams ranging between 21.7 and 43.2 km/day for sockeye tagged at Bonneville Dam (Table 11). Returning adults tagged as smolts have slightly slower migration rates (Table 11), with their median migration rate from Bonneville to Rock Island Dam being 2.1 km per day less than sockeye tagged as adults. Sockeye tagged at Priest Rapids Dam have a slower migration rate to Rock Island Dam than do either of other groups, but migration rates upstream of Rock Island are similar to those of sockeye tagged at Bonneville.

Sockeye salmon tagged at Bonneville Dam later in the migration travel upstream faster than those earlier in the migration (Table 12). There is a significant (α=0.05) linear relationship between statistical week passing Bonneville Dam and migration time from Bonneville to Rock Island, Rocky Reach, Tumwater, and Wells dams as well as between McNary and Rock Island, Rock Island and Rocky Reach, and Rocky Reach and Wells dams. The median difference in travel time from Bonneville Dam to all upstream mainstem dams except Wells Dam (where only four sockeye classified as Wenatchee stock were detected) was one day or less between the two major stocks (Table 12).

Table 11. Median sockeye salmon migration rates and travel time between dams as estimated by PIT tag detections in 2012.

		Tagging Location and Life Stage at Tagging			
		Adults at Bonneville Dam		Adults at Priest Rapids	Smolts above McNary Dam
Dam Pair	**Distance (km)**	**Median Travel Time (days)**	**Median Migration Rate (km/day)**	**Median Migration Rate (km/day)**	**Median Migration Rate (km/day)**
Bonneville-McNary	231	5.3	43.2		41.3
McNary-Priest Rapids	167	6.0	27.7		24.7
Priest Rapids-Rock Island	89	3.3	26.7	22.3	23.1
Rock Island-Rocky Reach	33	1.5	21.7	21.7	21.3
Rocky Reach-Wells	65	2.3	28.6	28.2	24.8
Rock Island-Tumwater	73	16.0	4.6	4.8	4.3
Bonneville-Rock Island	487	15.7	31.0		28.9
Bonneville-Tumwater	560	32.0	17.5		16.1
Bonneville-Wells	585	20.2	29.0		28.2

Table 12. Adult sockeye salmon travel median time in days between dam pairs by statistical week tagged at Bonneville Dam, the p-value for a linear regression between travel time and statistical week, and mean travel time by stock as estimated using PIT tags in 2012.

Statistical Week at Bonneville Dam	Bonneville-McNary	Bonneville-Priest Rapids	Bonneville-Rock Island	Bonneville-Rocky Reach	Bonneville-Tumwater	Bonneville-Wells	McNary-Rock Island	Rock Island-Rocky Reach	Rocky Reach-Wells	Wells to Okanagan Channel
23	6.2	15.1	21.8	27.1	50.9	30.0	14.7	4.1	2.7	89.7
24	5.3	16.1	20.9	23.8	44.0	26.1	15.8	2.2	2.3	89.3
25	5.3	14.4	18.0	19.8	39.1	22.0	12.3	1.5	2.3	85.5
26	5.2	10.9	14.2	15.8	31.2	18.3	8.8	1.3	2.3	81.4
27	5.7	10.7	13.8	15.0	26.0	17.9	8.0	1.3	2.3	75.4
28	5.1	10.1	13.5	15.0	23.0	17.0	8.0	1.3	2.0	68.9
29	5.3	10.2	12.8	14.0	19.0	16.0	7.3	1.1	2.0	62.6
30	4.9	9.8	12.0	13.5	19.9	16.1	7.5	1.2	1.9	49.9
P-value	**0.07**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**<0.01**	**0.03**	**<0.01**	**<0.1**
Stock										
Okanagan	5.3	11.8	15.7	17.6	--	20.2	9.8	1.5	2.3	82.5
Wenatchee	5.4	11.8	15.9	15.4	32.0	23.1	10.0	1.1	3.0	--
Unknown[7]	5.7	12.5	15.9	--	--	--	8.6	--	--	--

The median passage time at a dam (defined as the difference between the first and last detection at a dam) for sockeye tagged at Bonneville Dam and those tagged as smolt was six minutes or less at all dams except for Bonneville and Lower Granite dams (Table 13). Bonneville Dam, unlike many dams which only have PIT tag antennas in the upper ladder, has an extensive array of

[7] Unknown stock sockeye salmon are those that passed Bonneville but were not detected at Tumwater, Rocky Reach, Wells, Ice Harbor, or Lower Granite dams.

antennas that include the lower ladders resulting in earlier detection than most other dams and thus a more complete record of passage times in the ladders. At Lower Granite, sockeye may be diverted into a trap where they may spend many hours prior to sampling thus inflating passage times.

Priest Rapids tagged sockeye similar passage times similar to those of Bonneville tagged sockeye at Rock Island, Rocky Reach, Wells, and Tumwater dams. At Priest Rapids Dam, passage time was nine minutes compared to five minutes for Bonneville-tagged sockeye.

Table 13. Sockeye salmon median passage time from time of first detection at a dam to last detection at a dam and the percentage of sockeye salmon taking greater than 12 hours between first detection and last detection in 2012.

	Adults Tagged at Bonneville Dam		Adults Tagged at Priest Rapids Dam		Returning Sockeye Tagged as Juveniles	
Dam	Median Passage (Minutes)	%>12 hours	Median Passage (Minutes)	%>12 hours	Median Passage (Minutes)	%>12 hours
Bonneville	66	0.3%	--	--	64	6.9%
McNary	0	2.0%	--	--	0	1.5%
Priest Rapids	5	1.0%	9	1.2%	6	2.0%
Rock Island	3	1.5%	3	1.3%	4	3.4%
Rocky Reach	1	5.8%	2	5.8%	1	3.7%
Wells	2	1.7%	2	2.3%	1	3.0%
Tumwater	6	4.1%	6	5.1%	6	7.4%
Ice Harbor	--	--	--	--	4	8.6%
Lower Granite	--	--	--	--	219	32.8%

Night passage

Okanagan sockeye salmon stock tagged at Bonneville Dam generally passed PIT tag antennas at night (2000-0400 hours) at a higher rate than Wenatchee sockeye salmon stock (Table 14). As Okanagan sockeye salmon got closer to natal areas night migration increased, reaching 31.1% passing the Okanagan Channel PIT antenna during night hours. The Bonneville Dam estimate of night passage is likely biased low because tagging occurred between about 0800 and 1300 hours, and with a median passage time of 66 minutes from tagging to final detection at Bonneville Dam (Table 13), fish would be expected to pass the counting window prior to 2000 hours. Sockeye tagged as adults at Priest Rapids Dam had night passage rates at mainstem dams that differed by 1.4 percentage points or less when compared to those tagged at Bonneville Dam. The greatest difference was at Priest Rapids Dam where, like at Bonneville, sockeye were tagged during the day likely biasing the night passage rate low at Priest Rapids. Night passage rates of returning adults, which were

tagged as juveniles, were lower than those of sockeye tagged as adults at both Rocky Reach and Wells dams. However, many of these juvenile-tagged sockeye salmon ultimately ended up in the Wenatchee River, suggesting they were Wenatchee stock which had lower night passage rates.

Table 14. Estimations for sockeye salmon stocks' nighttime passage (2000-0400 standard time) in 2012 at mainstem Columbia River dams as estimated by last PIT tag detection time.

Dam	Adults Tagged at Bonneville Dam				Adults Tagged at Priest Rapids Dam	Juveniles Tagged Upstream of McNary Dam
	Okanagan Stock	Wenatchee Stock	Unknown	All Sockeye		
Bonneville	0.3%	0.0%	0.3%	0.3%	--	2.0%
McNary-OR shore	4.1%	0.9%	3.6%	3.5%	--	1.8%
McNary-WA shore	9.4%	1.1%	11.9%	8.5%	--	1.9%
Okanagan Channel	31.1%	--	--	31.1%	36.6%	32.6%
Priest Rapids	1.9%	2.1%	2.7%	2.0%	0.8%	1.8%
Rock Island	1.8%	1.0%	0.0%	1.6%	2.7%	2.1%
Rocky Reach	3.7%	0.0%	--	3.6%	4.6%	1.2%
Wells	10.3%	25.0%[a]	--	10.4%	9.0%	7.6%
Tumwater	--	1.0%	--	1.0%	1.4%	2.5%
Zosel	17.1%	--	--	17.1%	11.5%	0.0%[8]
Mean of McNary, Priest Rapids and Rock Island	3.4%	1.4%	3.6%	3.2%	NA	1.9%

Fallback

Fallback rates for adults tagged at Bonneville Dam ranged from 0.4% at Bonneville Dam to 7.9% at Rocky Reach Dam (Table 15). Fallback on the Bonneville Dam Oregon shore ladder was 43.8% (7 out of 16) compared to 0.3% on the Washington shore (resulting in a combined fallback rate of 0.4%). Visual counts suggested that 39.1% of sockeye pass the Oregon shore ladder (DART 2013). Fallback rates of sockeye tagged as juveniles were generally higher than those tagged as adults, reaching a high of 31.7% at Lower Granite Dam (20 out of 63 sockeye passing). The fallback rate at Zosel dam was 33.3%, however this was based on only three sockeye detected at this site. As with Bonneville Dam tagged adults, fallback at Bonneville Dam among returning sockeye tagged as juveniles was higher on the Oregon side (10.1%) than the Washington side (0.7%).

[8] Based on three detections.

Table 15. Estimated fallback rates for sockeye salmon at dams in 2012[9].

Dam	Adults Tagged at Bonneville	Adults Tagged at Priest Rapids	Tagged as Juveniles
Bonneville	0.4%	NA	4.6%
McNary	2.5%	NA	1.9%
Priest Rapids	1.2%	0.8%	2.0%
Rock Island	1.1%	1.6%	2.4%
Rocky Reach	7.9%	8.2%	15.6%
Wells	1.3%	2.3%	13.0%
Tumwater	0.5%	3.3%	0.4%
Zosel	0.0%	0.0%	33.3%
Ice Harbor	No tagged sockeye detected	No tagged sockeye detected	10.6%
Lower Granite	No tagged sockeye detected	No tagged sockeye detected	31.7%

Stock composition estimates

The percentage of Wenatchee sockeye salmon stock was higher during the middle of the run at Bonneville Dam when compared to the beginning and end with no significant linear relationship between weekly stock composition and statistical week (p=0.85, Table 16). The overall stock composition estimate at Bonneville Dam was 17.6% Wenatchee, 82.4% Okanagan, and 0% Snake River. This stock composition estimate differed by 6.1 percentage points from that estimated by Rocky Reach Dam counts and 1.4 percentage points from that estimated using Tumwater Dam (Table 16).

Thirteen sockeye salmon last detected at, or upstream of, Tumwater dam were previously detected at Rocky Reach Dam with four of these also detected at Wells Dam. There were no sockeye detected at Tumwater Dam that were subsequently detected anywhere downstream of Tumwater Dam or in the Columbia Basin upstream of the Wenatchee River.

[9] Does not include sockeye salmon that fell back over a dam and were not subsequently detected.

Table 16. Weekly and composite sockeye salmon stock composition at Bonneville Dam as estimated by PIT tags in 2012 and a comparison to stock composition estimates estimated using visual dam counts

Statistical Week and Dates	Run Size from Bonneville Dam visual counts	Sample size for PIT tag stock composition estimates[10]	Percent Okanagan	Percent Wenatchee	Percent Snake River
23 (May 30-June 8))	5987	61	95.1%	4.9%	0.0%
24 (June 11-14)	40159	159	91.2%	8.8%	0.0%
25 (June 18-22)	140621	298	86.2%	13.8%	0.0%
26 (June 25-29)	196832	310	79.4%	20.6%	0.0%
27 (June 27-July 1)	98658	266	77.8%	22.2%	0.0%
28 (July 5-8)	30577	84	84.5%	15.5%	0.0%
29 (July 11-14)	2901	20	95.0%	5.0%	0.0%
30 (July 18-19)	879	11	90.9%	9.1%	0.0%
Composite		**1209**	**82.4%**	**17.6%**	**0.0%**
Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach counts to estimate proportion Wenatchee)			88.5%	11.5%	
Visual Fish Counts at dams (Tumwater count to estimate the proportion Wenatchee)			83.8%	16.2%	

Weekly and cumulative stock composition was estimated at Priest Rapids Dam using sockeye salmon PIT tagged at both Bonneville and Priest Rapids dams (Table 17). Using Bonneville-tagged sockeye to estimate escapement at Priest Rapids Dam resulted in a slightly greater estimate of the Okanagan portion of the run than at Bonneville Dam (83.3% versus 82.4%, Tables 15 and 16). The estimate of the Okanagan portion of the run at Priest Rapids using Priest Rapids tagged fish was 80.3%.

A total of 21 adipose clipped sockeye salmon PIT tagged[11] at Bonneville Dam were adipose clipped with 2 recorded as right maxillary clipped and 1 ventral fin clipped (Table 18). Of these sockeye, 8 were last detected in the Wenatchee Basin, 3 in the Okanagan Basin, 9 downstream of McNary Dam, and 1 at Rock Island Dam. Only one fin clipped sockeye salmon was sampled at Priest Rapids Dam. This adipose-clipped sockeye salmon was last detected exiting the Priest Rapids Dam fish ladders.

[10] Sockeye passing Tumwater or Rocky Reach dams.
[11] Juvenile sockeye salmon are adipose clipped in Snake River and Lake Wenatchee hatchery programs.

Table 17. Weekly and composite sockeye salmon stock composition at Priest Rapids Dam as estimated by PIT tags in 2012 and a comparison to stock composition estimates estimated using visual dam counts.

		Priest Rapids			Bonneville Dam		
Statistical Week	**Priest Rapids Visual Counts**	**PIT Tag Sample Size**	**Percent Okanagan**	**Percent Wenatchee**	**PIT Tag sample size at Priest Rapids Dam**	**Percent Okanagan**	**Percent Wenatchee**
Prior to Week 26	6137				56	94.6%	5.4%
26	23801	133	90.3%	9.7%	86	94.1%	5.9%
27	181772	178	84.8%	15.2%	447	87.2%	12.8%
28	126809	225	72.3%	27.7%	347	77.7%	22.3%
29	60343	109	80.0%	20.0%	41	79.2%	20.8%
30	15533	109	78.6%	21.4%	86	78.0%	22.0%
After Week 30	3098				24	95.8%	4.2%
Composite	**408258**	**754**	**80.3%**	**19.7%**	**1217**	**83.3%**	**16.7%**
Visual Fish Counts at dams (using difference between Rock Island and Rocky Reach counts to estimate proportion Wenatchee)			88.5%	11.5%		88.5%	11.5%
Visual Fish Counts at dams (Tumwater count to estimate the proportion Wenatchee)			83.8%	16.2%		83.8%	16.2%

Table 18. Last detection site of clipped sockeye salmon tagged at Bonneville Dam in 2012.

Last Detection Site	Right Maxillary Clip	Right Ventral Fin	Adipose Clipped
Bonneville Dam Fish Ladder	0	0	1
Upstream antenna Bonneville	2	0	8
Upstream antenna Rock Island	0	0	1
Upstream antenna Tumwater	0	0	4
White River antenna	0	0	4
Upstream antenna Wells	0	1	2
Okanagan Channel antenna (OKC)	0	0	1
Total	**2**	**1**	**21**

Wells Dam sampling

A total of 771 sockeye were sampled at the Wells Dam east bank trap, of which 762 were PIT tagged with an additional 7 previously tagged fish added to our study group. Of these 769 PIT tagged fish, 60 were also acoustic tagged. All sampled fish were transported by truck and released approximately 4 km upstream of Wells Dam along the west shore of Lake Pateros (Table 19). The age composition differed considerably from that at Priest Rapids and Bonneville

dams, with a much higher percentage of larger Age 1.3 sockeye at Wells Dam and a smaller percentage of Age 1.2 sockeye (Table 20). The tendency of the Wells Dam trap to select for larger fish has been noted in previous years (Fryer et al. 2011).

One fish tagged (3D9.1C2DE7B510) at Wells Dam was adipose clipped suggesting it may have been Wenatchee stock since no Okanagan stock sockeye are adipose-clipped. It was last detected at an array on the lower Methow River PIT tag array on September 8.

Table 19. Number of sockeye salmon sampled and PIT and acoustic tagged at Wells Dam by date and statistical week in 2012.

Sampling Dates	Statistical Week	Sampled (n)	PIT Tagged	Previously Tagged	Total PIT tag sample size	Acoustic tags deployed
7/2,3	27	62	62	0	62	10
7/9,10,11	28	339	336	1	338	12
7/16,17	29	201	199	1	200	14
7/23,24	30	102	101	2	102	14
7/30,31	31	67	64	3	67	10
Total		**771**	**762**	**7**	**769**	**60**

Table 20. Age composition by week and sex for sockeye salmon sampled at Wells Dam in 2012. Sex was visually estimated when the fish were sampled.

Stat Week	Sampling Dates	Run Size	N	N Ageable	1.1	1.2	1.3	2.2
≤27	7/6,7/7	8134	62	61	0.0%	95.1%	4.9%	0.0%
28	7/11,7/12	138286	338	327	0.3%	83.8%	15.3%	0.6%
29	7/18,7/19	110774	200	193	0.0%	88.1%	11.9%	0.0%
30	7/25,26,27	53673	102	98	0.0%	77.6%	22.4%	0.0%
≥31	8/1,2,3	15200	67	65	0.0%	96.9%	3.1%	0.0%
Composite		**326067**	**769**	**744**	**0.0%**	**85.1%**	**14.5%**	**0.3%**
Std. Dev.					**0.1%**	**1.4%**	**1.4%**	**0.2%**
Males			335	325	0.0%	79.7%	20.0%	0.3%
Females			434	419	0.2%	91.2%	8.4%	0.2%

Okanagan and Wenatchee age, and length-at-age composition

Okanagan and Wenatchee age composition was estimated from the age composition of sockeye PIT tagged by this project at Bonneville and Priest Rapids dams subsequently detected at Tumwater and Wells dams (Table 21). The two age composition estimates were similar, at Tumwater Dam varying by

1.3 percentage points and at Wells Dam varying by 2.4 percentage points or less. When compared to Wells Dam, the Tumwater Dam age composition had a greater percentage of Age 1.3 sockeye. As is typical with Columbia Basin sockeye salmon, one-ocean sockeye (age 1.1 and 2.1) were only detected at Wells Dam with none detected at Tumwater Dam. Sockeye sampled at Wells Dam had a much higher percentage of larger 1.3 fish and a smaller percentage of Age 1.2 fish than the age composition estimated from Bonneville and Priest Rapids deployed PIT tag detections at Wells would suggest. The tendency of the Wells Dam trap to select for larger fish has been noted in previous years (Fryer 2012).

Mean lengths estimated using Wells Dam measurements as well as Priest Rapids PIT tag data were generally greater than those estimated using Bonneville PIT tag data (Table 22). The aforementioned trap selectivity at Wells likely contributed as did morphometric changes caused by fish maturation as well as differences in the way the sockeye were measured. At Bonneville Dam, sockeye were held up against a measuring stick mounted on top edge of the sampling tank while at both Priest Rapids and Wells dams, sockeye were placed in a sling and a measuring tape used. In the former approach, a fish not held straight would likely have its length underestimated while the latter approach will measure the curvature of the fish resulting in length being overestimated.

Table 21. Age composition (%) of Columbia Basin sockeye salmon stocks as estimated by PIT tag recoveries as well as by sampling at Wells Dam in 2012. Standard deviations are in parentheses.

Stock	Methodology	Ageable Sample Size	Brood Year and Age Class				
			2009	2008		2007	
			1.1	1.2	2.1	1.3	2.2
Bonneville Mixed	Bonneville Dam Sampling	1593	1.3 (0.6)	95.9 (1.0)	0.4 (0.3)	1.1 (0.5)	1.3 (0.6)
Priest Rapids Mixed	Priest Rapids Dam Sampling	743	0.9 (0.3)	96.1 (0.8)	0.0 (0.0)	2.6 (0.7)	0.4 (0.2)
Wenatchee	Bonneville PIT tagged detected at Tumwater	186	--	91.8 (3.9)	--	8.2 (3.9)	--
	Priest Rapids PIT tagged detected at Tumwater	136	--	93.1 (2.6)	--	6.9 (2.6)	--
Okanagan	Bonneville PIT tagged detected at Wells	1005	1.7 (0.9)	96.0 (1.4)	0.6 (0.5)	0.1 (0.2)	1.7 (0.9)
	Priest Rapids PIT tagged detected at Wells	577	1.1 (0.4)	95.4 (0.7)	0.4 (0.1)	2.5 (0.5)	0.9 (0.2)
	Wells Dam Sampling	746	0.1 (0.1)	85.1 (1.4)	--	14.5 (1.4)	0.3 (1.8)

Table 22. Length-at-age composition of Wenatchee and Okanagan sockeye salmon stocks estimated by detection of sockeye salmon previously PIT tagged at Bonneville and Priest Rapids dams and sampling at Wells dams in 2012.

Stock	Statistic	Brood Year and Age Class				
		2009	2008		2007	
		1.1	1.2	2.1	1.3	2.2
Bonneville Dam-Mixed Stock	Mean	39.5	49.6	41.6	56.4	50.8
	St. Dev.	2.3	2.2	2.9	2.3	2.5
	N	19	1526	8	21	19
Priest Rapids Dam Mixed Stock	Mean	38.8	50.3	38.0	56.9	50.3
	St. Dev.	1.4	2.5	--	2.3	3.7
	N	8	706	1	24	4
Okanagan-Bonneville PIT tags	Mean	39.7	49.4	42.1	54.2	51.3
	St. Dev.	2.4	2.1	3.3	2.5	2.5
	N	16	955	6	3	14
Okanagan-Priest Rapids PIT tags	Mean	39.0	50.2	38.0	56.3	50.3
	St. Dev.	1.3	2.6	-	2.6	3.7
	N	7	538	1	12	4
Okanagan-Wells Sampling[12]	Mean	43	52.2		55.6	53.5
	St. Dev.	--	2.3		2.4	0.7
	N	1	641		100	2
Wenatchee-Bonneville PIT tags	Mean		50.4		56.4	
	St. Dev.		2.1		2.3	
	N		174		14	
Wenatchee-Priest Rapids PIT tags	Mean		50.8		57.2	
	St. Dev.		1.8		2.1	
	N		127		9	

Detections in natal areas

Okanagan stock

An estimated 41.1% of the sockeye tagged at Wells Dam were detected at the Okanagan Channel PIT array (OKC, Table 23). This was slightly less than the Wells to OKC conversion rate of 41.4% for sockeye tagged at Bonneville Dam. Sockeye salmon PIT tagged at Priest Rapids Dam had the highest conversion rate to OKC of 43.9%. Less than 1% of sockeye passing Wells Dam tagged at Wells, Priest Rapids, or Bonneville dams were last detected in the Wenatchee, Entiat, or Methow rivers combined (Table 23).

An estimated 4.8% of both Priest Rapids and Wells dam tagged sockeye entering Wells Pool were reported captured and released in the Colville purse seine fishery at the mouth of the Okanagan River (Table 24). An estimated 7.2%

[12] The estimated Okanagan stock age composition determined from otoliths collected on the spawning ground (n=600) was .1.1=0.3%, 1.2=97.2%, 2.1=0.7%, 1.3=0.7%, 2.2 =1.1% (Margot Stockwell, personal communication).

of sockeye passing Wells Dam tagged at Priest Rapids Dam and 10.7% of those tagged at Wells Dam were reported captured and retained in the Okanagan Nation (ONA) Osoyoos Lake fishery. An additional eight Wells Dam and one Priest Rapids Dam-tagged sockeye were reported captured and retained in 2012 Columbia River sport fisheries above Wells Dam (Table 25) with one additional tagged fish reported retained but with no tag or capture data available.

A total of 60 floy tagged sockeye salmon were recovered in the Colville tribal fishery in the Columbia River at the mouth of the Okanagan River. Of these, 24 were tagged at Priest Rapids Dam and 36 were tagged at Wells Dam. Of the 24 Priest Rapids-tagged fish released after capture, 16 (66.7%) were subsequently detected at OKC compared to 13 out of 34 (38.2%) Wells-tagged fish.

Table 23. Number of tagged (PIT+floy, PIT+floy+acoustic) sockeye released at Wells Dam in 2012 with the estimated percentage last detected by site (weighted by weekly run size at Wells Dam). Rates for Priest Rapids and Bonneville dam tagged sockeye salmon are shown for comparison.

Week	Proportion of Run at Wells	N	Wenatchee River	Entiat River	Wells Dam	Methow River	Zosel Dam	OKC	Not Detected
27	2.5%	62	0.0%	0.0%	0.0%	0.0%	0.0%	43.5%	56.5%
28	42.4%	338	0.3%	0.0%	0.0%	0.0%	2.4%	41.3%	56.0%
29	34.0%	200	0.0%	0.0%	0.5%	0.5%	1.5%	42.3%	55.2%
30	16.5%	102	1.0%	0.0%	1.0%	0.0%	2.0%	37.3%	58.8%
31	4.7%	67	1.5%	1.5%	4.5%	1.5%	3.0%	43.3%	44.8%
Weighted Total		**769**	**0.4%**	**0.1%**	**0.5%**	**0.2%**	**2.0%**	**41.1%**	**55.7%**
Priest Rapids tagged sockeye detected at Wells		**562**	**0.3%**	**0.0%**	**NA**	**<0.1%**	**1.9%**	**43.9%**	**53.8%**
Bonneville tagged sockeye detected at Wells		**1001**	**0.2%**	**0.0%**	**NA**	**0.0%**	**1.5%**	**41.4%**	**57.0%**

Table 24. Percentage of sockeye tagged at Wells and Priest Rapids dams passing Wells Dam and reported harvested in Colville and Okanagan Nation Alliance fisheries in 2012.

	Colville Fishery Wells Pool (all released)		ONA Fishery-Osoyoos Lake (all retained)	
Week tagged at or passing Wells Dam	Tagged at		Tagged at	
	Priest Rapids	Wells	Priest Rapids	Wells
27	18.8%	0.0%	0.0%	19.4%
28	3.9%	3.6%	9.2%	13.0%
29	5.4%	6.0%	11.5%	12.5%
30	5.1%	5.9%	6.1%	2.9%
31	0.0%	9.0%	0.0%	0.0%
Weighted Total	**4.8%**	**4.8%**	**7.2%**	**10.7%**

Table 25. Number of sockeye salmon retained and released in Wells pool sockeye sport fishery by week in 2012.

Week	Statistical Week	Reported Sockeye Harvest				% of Run passing Wells retained by week
		Number Retained	Number Released	Retained plus Released	Tagged sockeye retained	
July 1-7	27	454	0	454		5.9%
July 8-14	28	1848	2	1850	6	1.3%
July 15-21	29	7661	8	7669	1	6.9%
July 22-28	30	8055	12	8067	1	15.0%
July 29-Aug. 4	31	3429	14	3443	1	28.4%
August 5-11	32	875	8	883	0	39.0%
August 12-18	33	502	2	504	0	87.3%
August 19-25	34	316	1	316	0	175.4%
August 26-September 1	35	56	0	56	0	89.0%
Totals		**23196**	**47**	**23242**	**9**[13]	**7.1%**

The percentage of sockeye salmon tagged at Wells Dam by statistical week detected upstream at OKC differed little (Figure 8). Both Bonneville- and Priest Rapids-tagged sockeye showed more variation in conversion rates to OKC by week passing Wells Dam. Bonneville-tagged fish had a lower conversion rate early at Wells Dam and higher later while Priest Rapids-tagged fish showed the opposite. There is no obvious explanation for these differences.

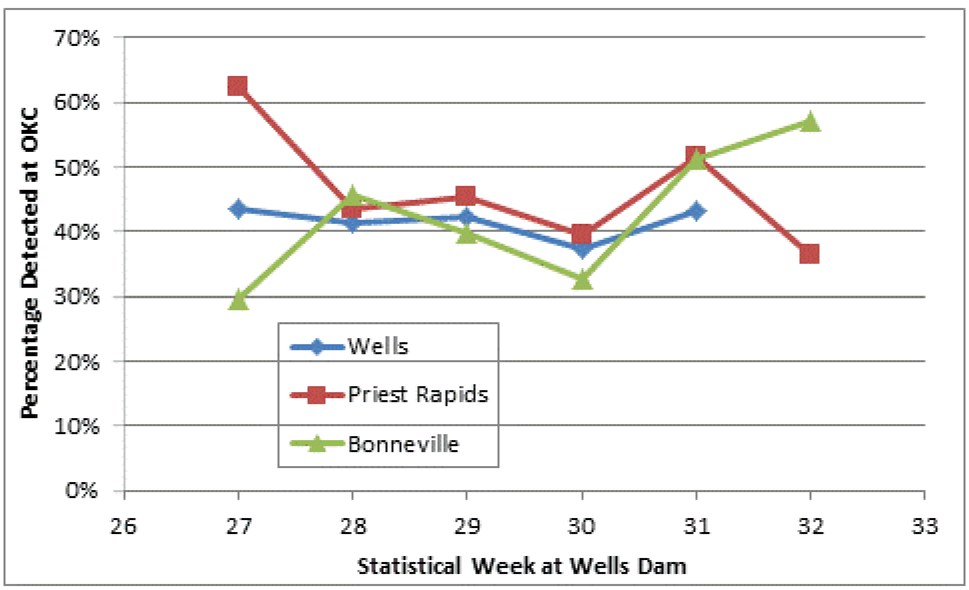

Figure 8. Percentage of sockeye tagged at Wells, Priest Rapids, and Bonneville passing Wells Dam by statistical week detected at OKC in 2012.

[13] One sockeye had no date available.

In-basin detection of PIT tagged Okanagan sockeye salmon

PIT tags from 14 sockeye salmon were recovered during Okanagan River spawning ground surveys and brood stock collection activities with an additional 4 recaptured at Tumwater Dam. Based on sex determined upon spawning ground recovery, the sex of sockeye was correctly identified on 60% of the sockeye tagged at Bonneville Dam (3 of 5 fish sampled), 70% at Priest Rapids Dam (7 of 10 fish sampled), and 80% at Wells Dam (4 out of 5 fish).

Sockeye salmon appeared to key in on Okanagan River water temperature in moving upstream to spawn. A temperature drop from 15.4C on October 2, 2012 to 14.3C on October 3 resulted in the number of sockeye first detected at OKC increasing from 10 to 168 (Figure 9).

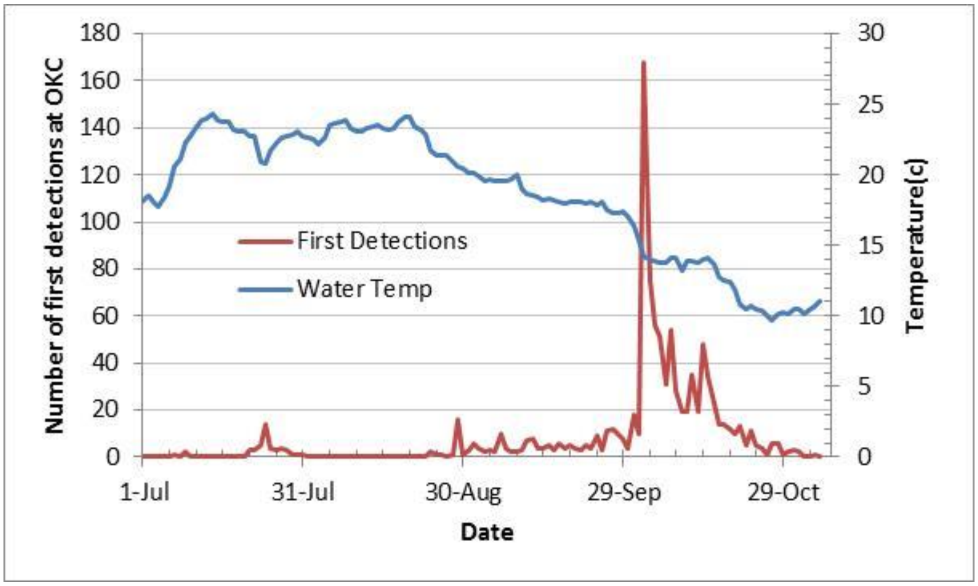

Figure 9. Number of PIT tagged sockeye first detected at OKC and Okanagan River water temperatures at Oliver, B.C. by date in 2012.

Genetic Stock Identification (GSI)

In 2012, 1209 of 1637 sockeye salmon samples were classified by stock based on where their PIT tags were last detected. This left 428 which could not be classified, of which 27 were not tagged, 9 were not detected after release, and 392 were last detected downstream of Rocky Reach or Tumwater dams. To classify these fish, we used genetics stock identification (GSI).

GSI was employed to identify the stock of all sockeye sampled at Bonneville except for 102 sockeye last detected at Tumwater Dam[14]. Only four fish were not classified similarly using GSI and PIT tag detections (Table 26). Two of these four were sockeye last detected at Tumwater Dam that were classified using GSI as Okanagan sockeye. GSI indicated that one of these had only a 56.7% probability of being Okanagan stock and 43.3% probability of being Wenatchee stock. This was one of only three sockeye with lower than 80% classification probability. Among the two sockeye classified by GSI as Wenatchee stock but classified as Okanagan by last PIT tag detection, neither was last detected in the Okanagan River. One was last detected at Rocky Reach Dam and the other at Wells Dam. In both cases, it is possible that either one or both of these fish may have been Wenatchee sockeye that overshot the Wenatchee River. Ultimately these fish may have returned to the Wenatchee River, as 13 other PIT tag sockeye passed Rocky Reach Dam and were then subsequently detected passing Tumwater Dam in 2012.

Table 26. Comparison classification by stock using GSI and PIT tags of sockeye salmon sampled at Bonneville Dam in 2012.

	GSI classification			
PIT Tag Classification	**Okanagan**	**Wenatchee**	**Snake**	**% Concurrence**
Okanagan	1009	2	0	99.8%
Wenatchee	2	94	0	97.9%
Unknown	289	88	2	
Not detected after release	16	6	0	
Not tagged or bad tag	19	7	1	

While no PIT tagged sockeye were last detected in the Snake River, three sampled sockeye were classified using GSI as being Snake River stock. One was not PIT tagged, a second was last detected above Bonneville Dam, and a third passed upstream of Bonneville Dam before falling back downstream and was last detected in the lower portion of the Oregon shore fish ladder at Bonneville Dam.

[14] These fish were excluded for budgetary reasons as well as the fact that PIT tag data from previous years have indicated that, unlike sockeye detected at Wells Dam, it is very rare for sockeye detected at Tumwater Dam to subsequently be detected in other basins.

GSI estimated a higher percentage of Wenatchee sockeye stock than did PIT tag estimates 19.6% versus 17.6% (Table 27). Among sockeye which could not be classified using PIT tags, 74.9% were classified using GSI as Okanagan, 24.7% Wenatchee, and 0.4% Snake (Table 28). Estimated upstream survival by stock was 75.5% for the Okanagan stock, 64.3% for the Wenatchee stock, and 0.0% for the Snake River stock (Table 29).

Table 27. Comparison of stock classification of sockeye sampled at Bonneville Dam using GSI and PIT tag detections in 2012.

	GSI Classification			PIT Tag Classification		
Statistical Week	**Okanagan**	**Wenatchee[15]**	**Snake**	**Okanagan**	**Wenatchee**	**Snake**
23	92.8%	7.2%	0.0%	95.1%	4.9%	0.0%
24	92.5%	7.5%	0.0%	91.2%	8.8%	0.0%
25	82.8%	17.2%	0.0%	86.2%	13.8%	0.0%
26	76.3%	23.4%	0.2%	79.4%	20.6%	0.0%
27	77.5%	22.2%	0.3%	77.8%	22.2%	0.0%
28	83.1%	16.9%	0.0%	84.5%	15.5%	0.0%
29	92.0%	4.0%	4.0%	95.0%	5.0%	0.0%
30	80.0%	20.0%	0.0%	90.9%	9.1%	0.0%
Composite	**80.3%**	**19.6%**	**0.1%**	**82.4%**	**17.6%**	**0.0%**

Table 28. Stock classification of sockeye salmon sampled at Bonneville Dam classified not classified by PIT tags weighted by weekly Bonneville Dam run size in 2012.

Statistical Week	**Number Unclassified Using PIT Tags**	**% of Sample**	**Stock Classification Using GSI**		
			Okanagan	**Wenatchee**	**Snake**
23	8	6.6%	75.0%	25.0%	0.0%
24	42	21.4%	95.2%	4.8%	0.0%
25	110	34.6%	74.5%	25.5%	0.0%
26	116	35.5%	69.8%	30.2%	0.0%
27	108	37.6%	76.9%	22.2%	0.9%
28	35	39.3%	74.3%	22.9%	2.9%
29	4	20.0%	100.0%	0.0%	0.0%
30	5	36.4%	40.0%	40.0%	20.0%
Composite	**428**	**34.4%**	**74.9%**	**24.7%**	**0.4%**

[15] Includes 102 sockeye classified as being Wenatchee stock by being detected by Tumwater Dam PIT tag antennas as genetics analyses were not conducted.

Table 29. Stock specific survival from sampling at Bonneville Dam to terminal areas weighted by weekly Bonneville Dam run size, as estimated by GSI and PIT tags in 2012.

	Stock Classification Using GSI			
Statistical Week	**Okanagan**	**Wenatchee**	**Snake**	**All Stocks**
23	95.1%	71.4%	-	90.3%
24	81.0%	51.9%	-	81.9%
25	76.2%	66.7%	-	71.8%
26	75.6%	65.6%	-	70.2%
27	72.4%	60.4%	0.0%	70.7%
28	71.1%	74.1%	-	65.0%
29	82.6%	50.0%	-	83.3%
30	83.3%	66.7%	0.0%	73.3%
Composite	**75.5%**	**64.3%**	**0.0%**	**71.6%**

Comparisons with sockeye tagged as juveniles

Mixed and Okanagan stock sockeye salmon tagged as adults at Bonneville Dam had a higher survival from Bonneville Dam to McNary, Priest Rapids, and Rock Island Dam than did returning sockeye salmon tagged as juveniles (Table 30) with the exception of juveniles tagged at Wanapum Dam for which the sample size was small. The Wenatchee hatchery stock tagged at Eastbank Hatchery had the lowest survival. Comparisons at dams above Rock Island are not possible due to the different stock compositions of the PIT tag groups.

Table 30. Survival of sockeye salmon PIT tagged adults at Bonneville Dam and as juveniles for other programs to McNary, Priest Rapids, and Rock Island dams in 2012.

PIT Tagging Site	Origin	Stock	Life Stage at Tagging	Number at Bonneville Dam	Estimated Survival from Bonneville Dam to		
					McNary Dam	Priest Rapids Dam	Rock Island Dam
Eastbank Hatchery	Hatchery	Wenatchee	Juvenile	257	68.9%	63.8%	61.1%
Wenatchee River	Wild	Wenatchee	Juvenile	150	74.7%	69.3%	62.7%
Rock Island Dam	Mixed	Mixed	Juvenile	107	73.8%	70.1%	70.1%
Wanapum Dam	Mixed	Mixed	Juvenile	58	86.2%	79.3%	77.6%
Bonneville AFF	Mixed	Mixed	Adult	1601	83.2%	80.1%	76.0%
Bonneville AFF	Mixed	Wenatchee	Adult	286	74.1%	72.7%	69.2%
Bonneville AFF	Mixed	Okanagan	Adult	1313	85.3%	81.8%	77.6%

For adult sockeye salmon detected in Tumwater Dam fish ladders, Bonneville-tagged sockeye had the highest combined detection rate at spawning ground PIT arrays on the Little Wenatchee and White rivers (Table 31, Figure 10) among groups of sockeye tagged as juveniles or tagged as adults. Sockeye tagged as adults at Tumwater Dam had the highest rate of detection on the White River spawning grounds, but the lowest on the Little Wenatchee spawning grounds, among the five groups.

Table 31. Distribution of sockeye salmon in the Wenatchee Basin in 2012, PIT tagged as both juveniles and adults.

				Percent Detected at Antenna Arrays Upstream of Tumwater Dam		
PIT Tag Location	**Hatchery / Wild**	**Life Stage at Tagging**	**Number at Tumwater Dam**	**Little Wenatchee (LWN)**	**White River (WTL)**	**Total**
Eastbank	Hatchery	Juvenile	141	9.9%	22.7%	32.6%
Wenatchee River	Wild	Juvenile	90	7.8%	28.9%	36.7%
Rock Island	Mixed	Juvenile	28	0.0%	32.1%	32.1%
Wanapum	Mixed	Juvenile	8	0.0%	12.5%	12.5%
Bonneville AFF	Mixed	Adult	194	14.9%	30.4%	45.4%
Priest Rapids	Mixed	Adult	84	10.1%	29.5%	39.6%
Tumwater	Mixed	Adult	960	6.7%	36.6%	43.2%

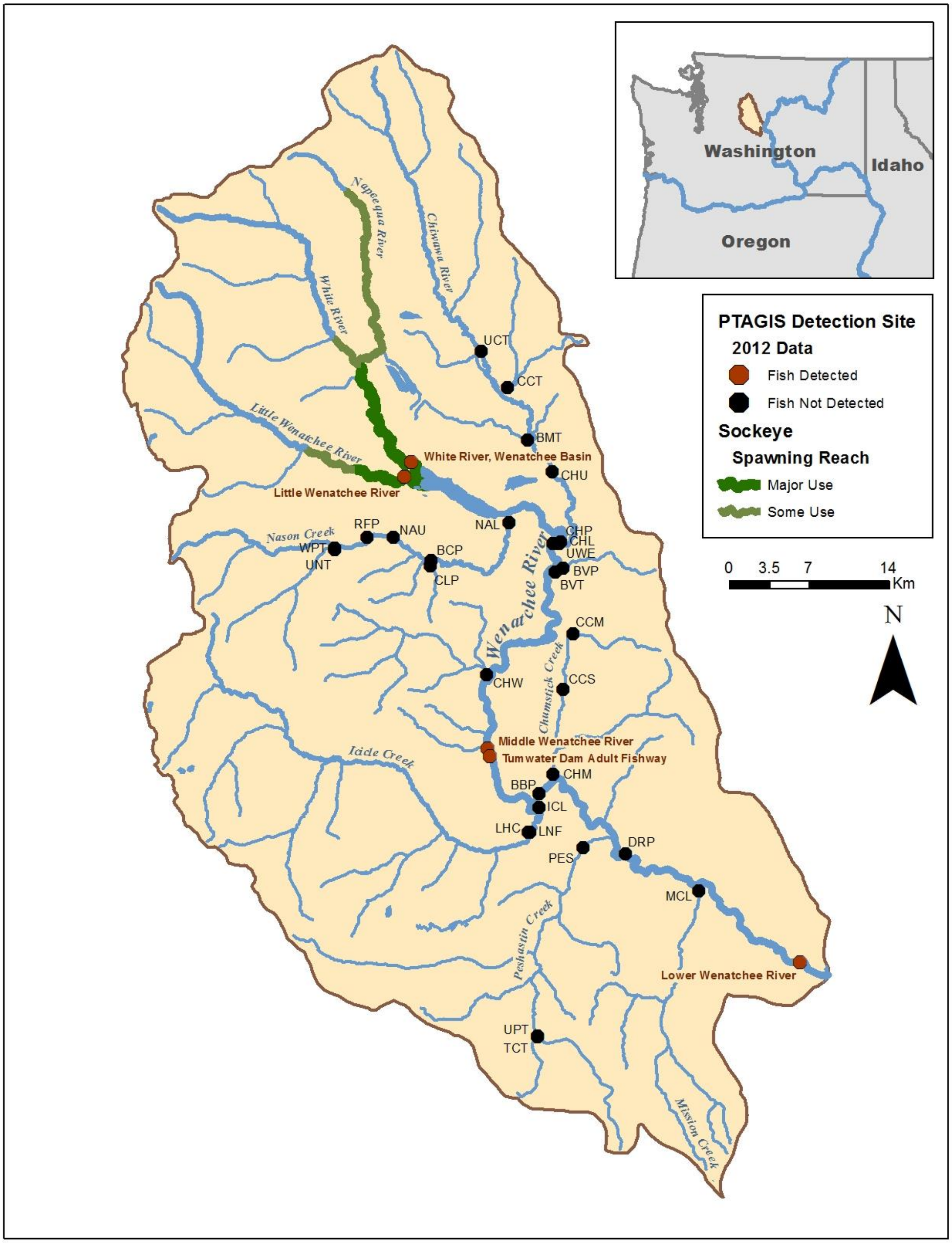

Figure 10. Portion of Wenatchee Basin with PIT detectors that could detect returning adult salmon or steelhead. Also displayed is the spawning area of sockeye. Appendix Table A4 has site information.

Median migration times between Priest Rapids and Rock Island dams differed by 0.7 day or less among the groups (Table 32). Sockeye PIT tagged as adults at Bonneville Dam migrated fastest between Priest Rapids and Rock Island dams, while the slowest were sockeye just tagged at Priest Rapids Dam suggesting a possible residual impact from tagging slowing migration. However, between Rock Island and Rocky Reach, as well as Rocky Reach and Wells, median migration time of the Bonneville- and Priest Rapids-tagged groups was the same.

Table 32. Median migration time in days between Columbia Basin PIT tag antenna sites for adult and juvenile sockeye tagged migrating upstream in 2012. Appendix table A4 has site information.

PIT Tagging Site	Rear Type	Stock	Life Stage at Tagging	PRD-RIS	RIS-RRH	RRH-WEA	WEA-OKC	RIS-TUF	PRD-WEA	PRD-TUF
Bonneville	Mixed	Mixed	Adult	3.3	1.5	2.3	82.5	16.0	7.9	20.0
Priest Rapids	Mixed	Mixed	Adult	4.0	1.5	2.3	83.0	15.3	8.6	20.2
Eastbank	Hatchery	Wenatchee	Juvenile	3.9	1.1	4.7		17.0	10.7	21.2
Rock Island	Mixed	Mixed	Juvenile	3.7	1.9	2.5	79.1	16.4	8.0	20.3
Wanapum	Mixed	Mixed	Juvenile	3.9	1.1	2.5	66.3	17.4	7.3	22.1
Wenatchee River	Wild	Wenatchee	Juvenile	3.8	1.4	2.1		17.7	8.5	22.4

Acoustic data analysis

A total of 60 sockeye salmon were implanted with acoustic tags in addition to PIT tags at the Wells Dam East fish ladder between July 2 and July 30, 2012 (Statistical weeks 27-31, Table 33). After weighting by weekly run size at Wells Dam, the weighted conversion rate to OKC was 38.8% compared to 41.8% for those fish PIT but not acoustic-tagged at Wells Dam, 44.1% for sockeye PIT tagged at Priest Rapids and 41.4% for those sockeye PIT tagged at Bonneville Dam.

High flows prevented deployment of the acoustic receivers at the Highway 20 Bridge, one Zosel Dam railroad bridge site, and three sites near the confluence of the Similkameen and Okanagan rivers (Figure 5). In addition, the

east bank Zosel railroad bridge receiver was not deployed until July 18, 2012. Of the 60 sockeye acoustically tagged, 59 were subsequently detected. The single undetected acoustic tagged fish either had a defective acoustic tag or shed its acoustic tag as the Floy tag associated with that fish was recorded as captured and released by the Colville fishery and the PIT tag was detected at OKC.

Table 33. Estimated conversion rate from Wells Dam to OKC for sockeye salmon tagged at Bonneville, Priest Rapids, and Wells dams by statistical week and weighted by the Wells Dam weekly run size in 2012.

			Tagging Site								
			Wells Dam					Priest Rapids Dam		Bonneville Dam	
	Mean Temperature		PIT + Floy Tagged Only		PIT+ Floy+Acoustic Tagged		All PIT+ Floy tagged	PIT+ Floy Tagged		PIT Tagged Only	
Week	Wells	Okan. River (Mallot)	N	% at OKC	N	% detected at OKC	% to OKC	N	% detected at OKC	N	% at OKC
27	13.4	16.4	52	40.4%	10	60.0%	43.5%	16	62.5%	71	29.6%
28	14.7	20.6	326	40.5%	12	41.7%	41.3%	228	43.4%	405	45.7%
29	15.3	21.4	186	46.8%	14	35.7%	42.3%	148	45.3%	284	39.8%
30	16.3	21.5	88	29.5%	14	28.6%	37.3%	99	39.4%	175	32.6%
31	17.1	22.6	57	61.4%	10	60.0%	43.3%	60	51.7%	45	51.1%
32	17.3	23.7	0		0			11	36.4%	21	57.1%
Weighted			**709**	**41.8%**	**60**	**38.8%**	**41.1%**	**562**	**44.1%**	**1001**	**41.4%**

Many of our receivers were deployed at confined locations on the migration corridor where we expected to be able to detect all, or nearly all, passing sockeye salmon. The detection rates for passing acoustic tagged sockeye salmon were 93% or better at all acoustic receiver sites except the Highway 97 bridge site upstream of Lake Osoyoos (Table 34, Figure 5).

Acoustic tag detections upstream of OKC for PIT plus acoustic tagged sockeye can be used to estimate detection efficiency at the OKC PIT tag antenna. Of the 18 fish both acoustic and PIT tagged that were detected upstream of OKC, PIT tags were detected at OKC for 16, suggesting detection efficiency for the OKC PIT antenna of 88.9%.

Using the data from these acoustic tagged sockeye, we estimated 80.4% survival from Wells Dam to the Monse Bridge, 68.6% to our North Basin Osoyoos Lake receiver, and 15.4% to McIntyre Dam (Table 35). Harvest rates were estimated at 8.9% for the Colville purse seine fishery (all released), 11.1% for the

ONA fishery in Osoyoos Lake, and 3.5% in the sport fishery in Wells pool (Table 35). The sport fishery estimate is conservative as it is probable that not all acoustic tagged fish harvested by this fishery were reported.

Table 34. Detection rate at acoustic receiver sites and estimated survival to those sites for sockeye salmon PIT and acoustic tagged at Wells Dam in 2012.

Site	Number of Receivers	Estimated Detection Efficiency	Number Detected	Estimated Survival to Site
Pateros	1	100.0%	59	100.0%
Brewster Dock	1	93.8%	56	100.0%
Monse Bridge	2	100.0%	48	80.4%
Zosel Railroad Bridge (East Bank)	1	96.3%	34	76.9%
Oroville pumping station	2	100.0%	47	76.9%
Haynes Point	2	95.5%	47	76.9%
Central Basin Highway 3	1	100.0%	44	69.7%
Okanagan North Basin	1	100.0%	43	68.6%
Okanagan River Mouth	2	100.0%	31	46.6%
Okanagan River-Hwy 97	1	70.0%	18	27.9%
McIntyre Dam	1	100.0%	10	15.2%
Okanagan Falls	1	NA	5	1.3%

Table 35. Percentage of sockeye salmon acoustic tagged at Wells Dam passing upstream receivers in 2012.

							Captured and Released or Retained in Fisheries		
Tag Date	**N**	**Monse Bridge**	**Haynes Point**	**North Osoyoos Basin**	**OKC Array**[16]	**McIntrye Dam**	**Colville (Release)**	**U.S. Sport (Retain)**[17]	**ONA (Retain)**
July 2	10	100.0%	100.0%	100.0%	70.0%	10.0%	0.0%	0.0%	10.0%
July 9	12	75.0%	66.7%	58.3%	41.7%	16.7%	0.0%	8.3%	8.3%
July 16	14	85.7%	85.7%	78.6%	42.9%	14.3%	21.4%	0.0%	21.4%
July 23	14	85.7%	85.7%	71.4%	42.9%	7.1%	7.1%	0.0%	0.0%
July 30	10[18]	60.0%	60.0%	60.0%	60.0%	44.4%	10.0%	0.0%	0.0%
Weighted by Weekly Wells Run	**60**	**80.4%**	**76.9%**	**68.6%**	**43.9%**	**15.4%**	**8.9%**	**3.5%**	**11.1%**

[16] Includes two sockeye which were not detected by the OKC array, but were detected upstream.
[17] Additional unreported catch is likely.
[18] Includes one acoustic tag, which was not detected after release. However, the associated PIT tag was detected at OKC so this tag is counted as passing all intermediate acoustic receivers. This sockeye was omitted in calculating the percentage passing McIntyre Dam.

Although the median date detected at OKC was nearly identical for sockeye salmon acoustic tagged in different weeks at Wells Dam, median migration times from release to upstream sites varied considerably (Table 36). This was likely caused by high Okanagan River temperatures delaying sockeye salmon migration (Figure 11). Sockeye salmon did not pass the Monse receiver when the Okanagan River temperature was above 22.0^{o}C and would hold in Wells Pool until the river temperature dropped below this temperature. The sole sockeye salmon detected at Monse, but not Haynes Point (nor any other sites subsequent to Monse), passed Monse on July 27 when the river temperature was 22.0^{o}C on its way to a high of over 24^{o}C on August 8. Unlike 2010 and 2011, no sockeye were detected by receivers in the Similkameen River.

Table 36. Migration time to upstream receiver sites for sockeye acoustic tagged at Wells Dam by date in 2012.

Statistical Week Tagged	Median Days to Monse Bridge	Median Days to Haynes Point	Median Days to North Basin	Median Days to OKC	Median OKC Passage Date
July2	2.7	16.9	25.8	94.7	10/4
July 9	10.0	13.9	19.5	87.0	10/3
July 16	5.9	11.9	14.4	80.9	10/4
July 23	4.4	12.1	30.2	74.1	10/4
July 30	28.2	33.0	37.1	67.2	10/4
Overall	**5.0**	**17.1**	**26.7**	**74.2**	**10/4**

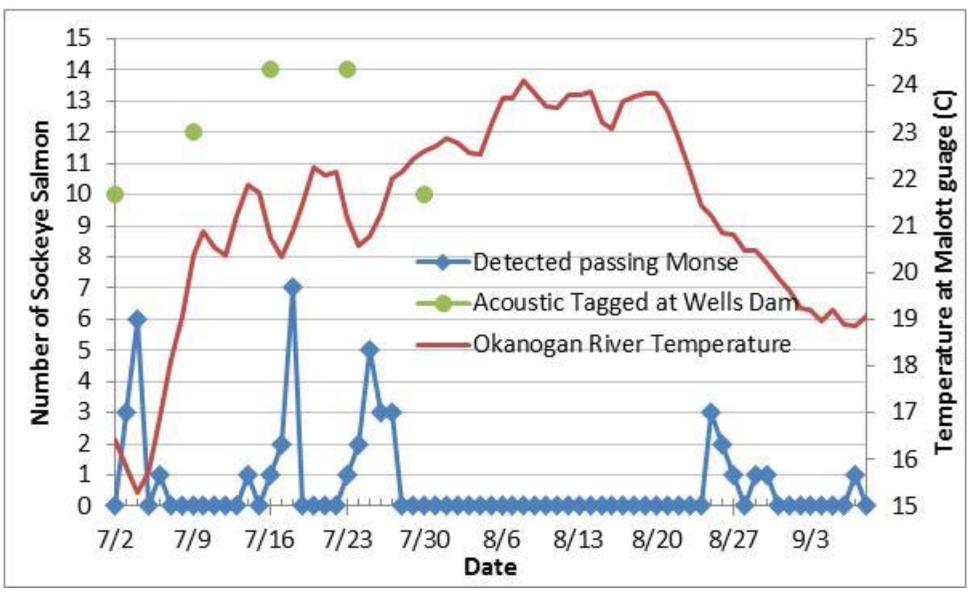

Figure 11. Number of sockeye acoustic tagged and number of those fish passing Okanogan River mouth receivers at Monse by date and Okanogan River temperature at Malott in 2012.

Thirty of the 60 fish tagged were estimated to be on the spawning grounds during the spawning period (Table 37), 21 were missing on the upstream migration, 7 were captured in fisheries, and 2 were last detected at the Okanagan River Mouth at Osoyoos Lake but not detected further upstream in spawning areas.

Table 37. Tagging data, last detection and date, and first PIT tag detection at OKC PIT tag array for sockeye salmon acoustic tagged at Wells Dam in 2012. (Green text indicates the fish was on the spawning grounds during the spawning period. Red text indicates confirmed captured in fisheries, blue text indicates missing on upstream migration, black text indicates last detected at Okanagan River mouth).

Tag Code	Date Tagged	Final Acoustic Detection Site	Date	First Detection at OKC	Comments
5887	7/2	OKC PIT array	10/15	10/15	
5888	7/2	Hwy97	10/6	9/28	Mobile tracked
5889	7/2	North Basin	8/25		ONA Osoyoos Fishery
5890	7/2	OKC PIT array	10/3	10/3	
5891	7/2	Okanagan Mouth (Canada)	8/30		
5892	7/2	North Basin	8/10		
5893	7/2	OKC PIT array	10/15	10/15	
5894	7/2	OKC PIT array	10/4	10/4	Mobile Tracked
5895	7/2	OK Falls	9/3		
5896	7/2	OKC PIT array	10/4	10/4	Mobile Tracked
5897	7/9	OKC PIT array	10/4	10/4	Mobile Tracked
5898	7/9	Hwy97	10/6	10/3	
5899	7/9	North Basin	8/27		ONA Osoyoos Fishery
5900	7/9	Wells Pool	7/15		Captured in sport harvest
5901	7/9	McIntyre Dam	10/8	9/27	
5902	7/9	Monse Bridge	7/18		
5903	7/9	OKC PIT array	10/3	10/3	Mobile Tracked
5904	7/9	Haynes Point	8/20		
5905	7/9	North Basin	8/15		
5906	7/9	Wells Pool	7/19		
5907	7/9	McIntyre Dam	10/5	8/29	Mobile Tracked
5908	7/9	Wells Pool	7/10		
5909	7/19	Okanagan Mouth (Canada)	9/27		
5910	7/16	Wells Pool	7/17		Colville capture and release
5911	7/16	North Basin	8/12		ONA Osoyoos Fishery
5912	7/16	North Basin	8/23		ONA Osoyoos Fishery

5913	7/16	Haynes Point	8/20		
5914	7/16	North Basin	8/29		ONA Osoyoos Fishery
5915	7/16	McIntyre Dam	10/13	10/4	
5916	7/16	North Basin	8/13		Colville capture and release, ONA Osoyoos Fishery
5917	7/16	OKC PIT array	10/12	10/12	Mobile Tracked Colville capture and release,
5918	7/16	Wells Pool	7/17		
5919	7/16	Wells Pool	10/4		Mobile Tracked
5920	7/16	McIntyre Dam	10/9	7/24	
5921	7/16	OKC PIT array	10/5	10/5	
5922	7/16	Haynes Point/Central Basin	10/15	9/27	
5923	7/23	North Basin	9/26		Colville capture and release
5924	7/23	North Basin	8/31		
5925	7/23	Hwy97	10/14	10/4	Mobile Tracked
5926	7/23	OKC PIT array	10/4	10/4	
5927	7/23	Wells Pool	9/12		
5928	7/23	Haynes Point	8/27		
5929	7/23	Haynes Point	9/27		
5930	7/23	North Basin	8/24		ONA Fishery
5931	7/23	Hwy97	10/7	9/29	Mobile Tracked
5932	7/23	Hwy97	10/8	10/4	
5933	7/23	McIntyre Dam	10/13	10/8	Mobile Tracked
5934	7/23	Wells pool	7/25		
5935	7/23	OKC PIT array	10/3	10/3	
5936	7/23	North Basin	8/19		
5937	7/30	McIntyre Dam	10/9	10/4	
5938	7/30	Hwy97	10/11	10/8	Mobile Tracked
5939	7/30	Wells Pool	7/31		
5940	7/30	Wells Pool	7/31		
5941	7/30	Wells Pool	9/8		
5942	7/30	OKC PIT array	10/9	10/9	Colville capture and release
5943	7/30	Hwy97	10/10	10/3	Mobile Tracked
5944	7/30	OK Falls	9/27	9/11	
5945	7/30	Hwy97	9/22	9/12	
5946	7/30	Wells Pool	9/12		

Acoustic trawl and limnology surveys

Lake Wenatchee Acoustic trawl surveys (ATS) were conducted on June 25 and September 18, 2012 to estimate juvenile sockeye abundance for comparison with six Osoyoos Lake surveys conducted between June 14, 2012 and February 15, 2013 (Table 38). No species other than juvenile nerkids were caught in the trawl surveys. Based on a comparison of the September 11 Osoyoos Lake and September 18 Lake Wenatchee surveys, Lake Wenatchee was estimated to be 63% as productive as Osoyoos Lake.

Table 38. Estimates of juvenile sockeye salmon abundance from Lake Wenatchee and Osoyoos Lake acoustic trawl surveys between June 2012 and February 2013.

Lake	Survey Date	Juvenile nerkids Abundance per Lake	Density (per ha)	Mean Length (cm)	Mean Weight (g)
Osoyoos	14-Jun-2012	3,713,573	3,980	3.98	0.58
Osoyoos	24-Jul-2012	3,959,197	4,244	4.83	1.12
Osoyoos	11-Sep-2012	3,998,044	4,285	6.06	2.35
Osoyoos	11-Oct-2012	2,867,774	3,074	6.56	3.05
Osoyoos	17-Nov-2012	2,213,428	2,372	7.11	3.72
Osoyoos	15-Feb-2013	2,310,465	2,476	7.60	4.10
Wenatchee	25-Jun-2012	1,700,000	1,700	3.1	0.27
Wenatchee	18-Sep-2012	2,800,000	2,800	5.6	1.89

Limnological surveys suggested that almost all available phytoplankton in Lake Wenatchee were edible by zooplankton in contrast to Osoyoos Lake where many species are large and/or gelatinous and could not be consumed by zooplankton. The Lake Wenatchee zooplankton biomass was only 50% as high as in Osoyoos Lake, but Lake Wenatchee had *Hesperodiaptomus kenai*, which is large-bodied and generally an important target for juvenile sockeye salmon.

Further details on the acoustic trawl and limnology surveys are found in Appendix B.

2012 Juvenile PIT tagging

A total 559 smolts were tagged in the Okanagan River immediately downstream of Skaha Lake during three tagging sessions: 24 April (n = 120), 30

April (n = 143), and 2 May (n = 296). Twenty-eight smolts died immediately after surgery or in recovery tanks before release. Ten smolts were subsequently recaptured in the rotary screw trap, euthanized, then bio-sampled

Mean overall survival from release to Bonneville Dam was 0.15 (SE 0.08) (Table 39, Figure 12). Mean survival between reaches ranged from 1.16 (Rocky Reach Dam to McNary Dam) to 0.28 (John Day Dam to Bonneville Dam). Mean overall migration time from release to Bonneville Dam was 15.5 days (Table 39, Figure 13).

Additional juvenile PIT and JSATs tagging results are found in Appendix C.

Table 39. Mean survival and migration time for PIT tagged sockeye smolts.

Period	Survival	SE	Migration Time	SE
Release to Rocky Reach	0.5365	0.0768	7.79	0.20
Rocky Reach to McNary	1.1556	0.4376	3.92	0.22
McNary to John Day	0.8765	0.6464	2.33	0.18
John Day to Bonneville	0.2750	0.2360	1.47	0.06
Overall	**0.1494**	**0.0844**	**15.52**	**0.62**

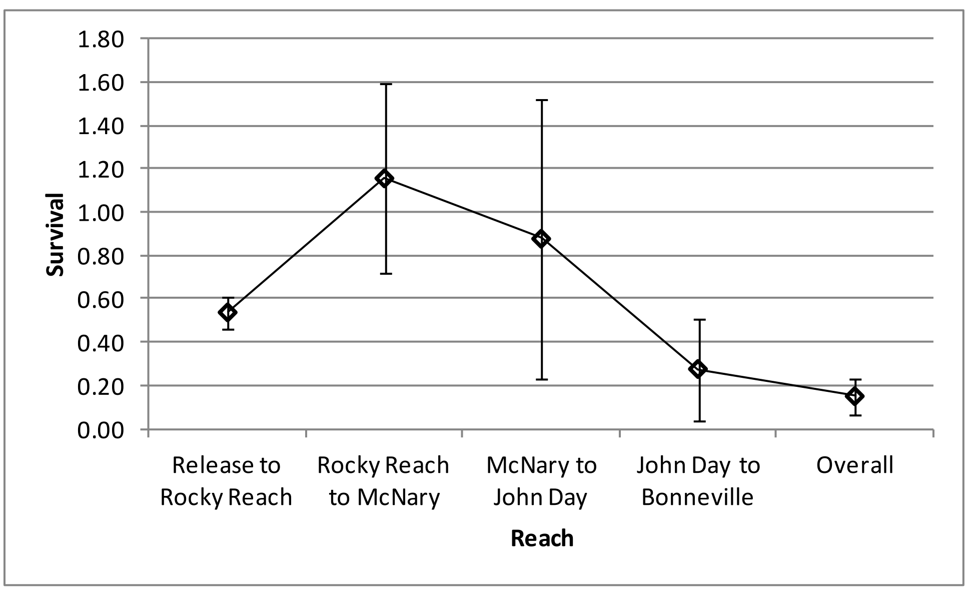

Figure 12. Mean survival for PIT tagged sockeye smolts.

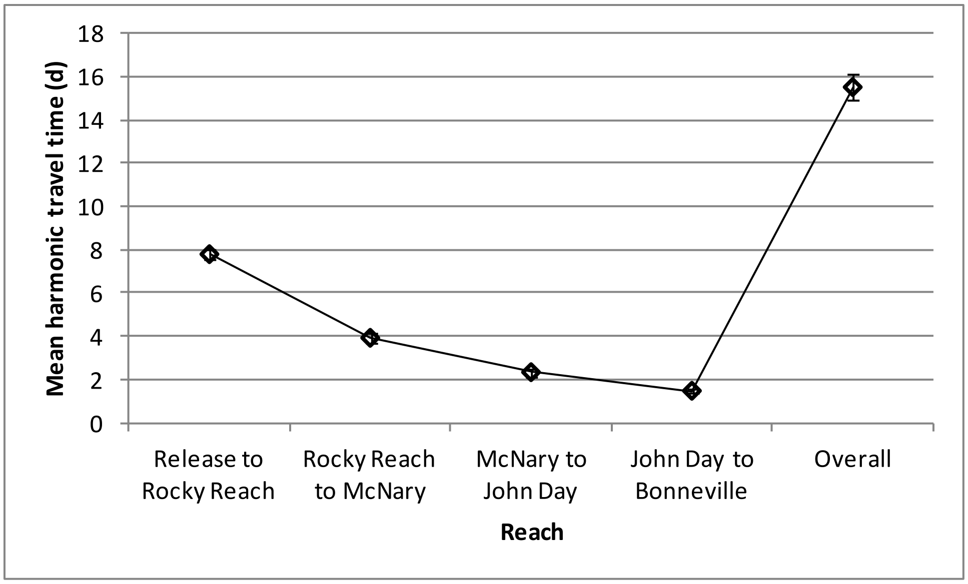

Figure 13. Mean migration time for PIT tagged sockeye smolts.

No comparisons between Okanogan and Wenatchee juvenile sockeye salmon survival to McNary Dam are possible in 2012 due to high Wenatchee River flows greatly resulting in very few juvenile sockeye being PIT tagged.

DISCUSSION

This completes the fourth year of this study. The year 2012 was the second full year in which we had fully operational PIT tag detection sites at Zosel Dam (ZSL) and OKC in the Okanagan River near Oliver, BC, both of which were funded by this project. The OKC site worked well during the sockeye migration, with a detection rate of 88.9% based on the percentage of both PIT and acoustic tagged fish detected upstream of the OKC PIT antenna. This compares to 87.5% in 2011 and 90.0% in 2010[19]. In 2012, OKC provided the first documented evidence of coho salmon in the Canadian section of the Columbia River since they were extirpated at least 50 years ago.

In contrast to OKC, PIT tag detection at ZSL was again low (20.0%), due to sockeye bypassing the fish ladder and ascending the spillway made passable by high flows. Adding detection to one or more spillways is recommended as this would not only detect adults using spillways, but would also detect smolts tagged above Zosel Dam that migrate downstream through the spillways.

PIT tag data was used in this report to estimate escapement at dams and compare this estimate with visual counts (Table 9). Visual counts are also affected by fallback and, at those dams so equipped, migration through navigation locks. Fallback means that viewing window counts will result in an inflated estimate of fish that ultimately pass, and stay upstream as an individual fish is counted more than once; or a fish with a single passage ends up falling back downstream and stays downstream. Conversely, navigation lock passage results in sockeye not being counted at fish viewing windows. Using PIT tag data provided by this project, it is possible to adjust the visual counts given in Table 9 (and publicly available at DART 2012 and FPC 2012) by accounting for fallback and, for Bonneville and McNary dams, passage at night (Table: 14). Bonneville and McNary estimates were also increased by the percentage of sockeye missing the counting window PIT arrays (Table 5) as at these dams the most likely reason a sockeye would not be detected is passage through the navigation locks. On the other hand, Priest Rapids, Rock Island, and Rocky Reach dams

[19] These estimates are slightly less than estimated in previous reports due to a change in calculation methods.

have no navigation locks for sockeye to bypass detection (or counting at viewing windows), but also generally have fewer PIT antennas with often lower detection rates for individual antennas (Appendix A Table A1) making it more likely that a tagged fish would pass undetected. Table 40 presents adjusted fish counting estimates by expanding by estimated navigation lock passage at Bonneville and McNary, while subtracting fallbacks at all dams. Since the PIT tag passage estimate is based on the Bonneville visual counts, adjusted PIT tag estimates are also presented for passage at each dam along with the OKC array.

Table 40. Estimated sockeye passage at mainstem dams using visual and PIT counts and counts adjusted to account for night passage, navigation lock passage and fallback in 2012.

Site	Visual Count	PIT Tag Estimate	Missed	Fall-back	Night Passage	Adjusted Visual Count	Adjusted PIT Tag Estimate	% Difference Between Adjusted Counts
Bonneville	515,673	--	1.82%[20]	4.6%[21]	2.05%[22]	514,482	513,096	--
McNary	364,147	424,805	1.56%	2.5%	6.0%	382,122	422,682	10.6%
Priest Rapids	408,258[23]	398,505	0.16%	1.2%	--	403,159	396,513	-1.6%
Rock Island	410,614	386,452	4.38%	1.1%	--	406,028	384,521	-5.3%
Rocky Reach	363,297	322,250	0.70%	7.9%	--	334,447	320,639	-4.1%
Wells	326,084	313,566	0.00%	1.2%	--	322,175	311,999	-3.2%
Tumwater	66,520	66,272	0.00%	0.5%	--	66,177	65,941	-0.4%
OKC array	--	145,317	--	--	--	--	144,591	--

Unexplained loss of salmon is an issue of concern to Columbia Basin fish managers. Combining harvest and escapement data can be used to explore where unexplained loss of the 2012 run of sockeye salmon is occurring, which was the largest on record since counting began at Bonneville Dam in 1938. In

[20] Based on the rate from previously tagged fish.
[21]Based on a fallback rate for returning sockeye salmon with PIT tags of 10.6% for the Oregon shore and 1.1% on the Washington shore, weighted by the visual count estimate of 39.1% of passage on the Oregon shore and 60.9% on the Washington shore.
[22] This estimate was from sockeye salmon PIT tagged as juveniles rather than sockeye tagged as part of this project since the latter were tagged early in the day and would be expected to be less likely to pass at night than fish tagged at other times. Previously tagged juveniles are likely more representative of the run at large.
[23] Estimate excludes PIT tagged sockeye last detected at the Priest Rapids Dam fish trap presumably transported to Cle Elum Lake as part of a sockeye reintroduction project.

2012, we estimate that, of the 517,154 sockeye starting the upstream migration (which includes a below-Bonneville harvest of 4,058 sockeye), 32.6% were harvested, 25.6% we classified as escapement (Wenatchee and Okanagan spawning grounds, and Snake and Deschutes turnoff, and fish trapped for Cle Elum program), leaving 41.8% unaccounted for (Table 41). The bulk of fish that were unaccounted were between Bonneville Dam and McNary dams, above Wells Dam, and above Tumwater Dam. All three areas are areas of significant harvest, suggesting that unreported or unaccounted for harvest mortality could be at least partly to blame. Two of these areas, Bonneville-McNary and above Wells Dam, cover large areas between reliable PIT tag array sites making it difficult to pin down mortality to any particular stretch of river. PIT tag detection at fish ladders at The Dalles Dam, begun in 2013, as well as better detection at Zosel Dam in low flow years, will hopefully help in future years to assess where mortality is occurring.

The number of unaccounted for fish in terminal areas (above OKC and above Tumwater) is affected by possible inaccurate spawning ground estimates. If these counts are underestimated, then the number of missing fish will be overestimated. Historically large spawning escapements, such as in 2012, may make estimates less reliable (Margot Stockwell, personal communication).

Fish managers have long used visual counts at dams to estimate escapement. The completion of Rocky Reach Dam in 1961 provided fish counts, in combination with Rock Island Dam completed in 1933, which allowed the calculation of the relative abundance of Okanagan and Wenatchee stock sockeye salmon. Since Okanagan sockeye pass Rocky Reach Dam, but not Rock Island Dam, the ratio of the Rocky Reach count to the Rock Island count is an approximate estimate of the Okanagan proportion at Rock Island Dam and the difference is that of the Wenatchee proportion. In recent years, counts at Tumwater Dam have provided another estimate of Wenatchee escapement which can be compared to Rocky Reach counts to provide another Okanagan to Wenatchee stock composition estimate.

Table 41. Estimated number of sockeye entering and leaving a reach with harvest, escapement and unaccounted for estimates in 2012.

Reach	Estimated Abundance at Reach Start[24]	Harvest	Escapement	Estimated Abundance at Reach End	Unaccounted (missing)
Below Bonneville	517,154[25]	4058	--	513,096	NA
Bonneville-McNary	513,096	46,281	100[26]	422,682	44,033
McNary-Priest Rapids	422,682	--	10,453[27]	396,513	15,716
Priest Rapids-Rock Island	396,513	2,663	--	384,521	9,330
Rock Island-Rocky Reach	384,521	134	--	320,639[28]	-872
Rocky Reach-Wells	320,639	1547	--	305,744	7,094
Wells-Zosel	305,744	38,930	--	242,885	70,326
Zosel-OKC	242,885	63,100	--	144,591	-8,941
OKC array	136,117	--	93,400	--	55,185
Tumwater	64,619	12,107	28,500	--	24,012
Totals	--	**168,820**	**132,453**	**--**	**215,881**
Percentage	--	**32.6%**	**25.6%**	**--**	**41.8%**

In 2012, based on the ratio of Rocky Reach to Rock Island counts, 88.5% of the run at Rock Island was Okanagan stock compared to 83.8% if Tumwater sockeye counts are used to estimate Wenatchee (Table 40). However, as shown in Table 15, the fallback rate at Rocky Reach was 7.9%, thus inflating the Rocky Reach escapement (Table 41). If this is taken into account, then the two dam count estimates of Okanagan escapement are much closer (82.4% and 84.7%, methods G and H), which in turn are close to that estimated using PIT tags (80.3% and 83.4%, methods A, and B) or GSI (82.1%, Method D) (Table 42).

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[24] Data from Table 40
[25] Estimated by adding below Bonneville harvest to Bonneville count from Table 40.
[26] Estimated escapement to Deschutes
[27] Ice Harbor count (453) plus 10,000 sockeye took at Priest Rapids Dam to plant in Cle Elum Lake.
[28] Excludes Tumwater turnoff of 64,619

Table 42. Comparison of different methods of estimating Okanagan and Wenatchee sockeye stock composition in 2012.

	Method	% Okanagan	% Wenatchee	Source Table
A	PIT tags deployed at Bonneville Dam detected at Rocky Reach and Tumwater Dams weighted by Priest Rapids	82.4%	17.6%	15
B	PIT tags deployed at Priest Rapids Dam detected at Rocky Reach and Tumwater Dams weighted by Priest Rapids visual counts	80.3%	19.7%	16
C	PIT tags deployed at Bonneville Dam detected at Rocky Reach and Tumwater Dams weighted by Priest Rapids visual counts	83.3%	16.7%	16
D	GSI on Bonneville samples (weighted by Bonneville visual counts)	80.3%	19.6%	26
E	Visual dam counts taking the Rock Island-Rocky Reach difference as Wenatchee	88.5%	11.5%	15
F	Visual dam counts taking Tumwater as Wenatchee	83.8%	16.2%	15
G	Method E using adjusted visual counts in Table 40	82.4%	17.6%	38
H	Method F using adjusted visual counts in Table 40	84.7%	15.3%	38

Sockeye salmon PIT tagged at Bonneville Dam were not classified by stock based on PIT tags unless they were subsequently detected at Rocky Reach or Tuwmater dams. A total of 387 sockeye were not detected, and for these by using their GSI stock classification, it is possible to determine the stock composition by reach where they went missing (Table 43). The majority of the fish were lost between Bonneville and McNary and heavily weighted towards the Wenatchee stock when compared to the run at-large. PIT tagged sockeye missing between McNary and Priest Rapids dam were more likely to be Okanagan stock**.**

Table 43. Genetic stock classification of sockeye PIT tagged at Bonneville Dam last detected at Bonneville, McNary, Priest Rapids, and Rock Island dams in 2012. (According to GSI, the run at Bonneville Dam was 80.4% Okanagan and 19.6% Wenatchee.)

Reach PIT Tagged Fish Lost Between	N	Okanagan	Wenatchee	Snake River
Bonneville-McNary	266	72.2%	27.8%	0.0%
McNary-Priest Rapids	48	91.7%	8.3%	0.0%
Priest Rapids-Rock Island	65	84.6%	15.4%	0.0%
Rock Island-Rocky Reach/Tumwater	8	75.0%	25.0%	0.0%

A total of 14 Bonneville-tagged sockeye salmon were detected passing Rocky Reach Dam and 4 detected passing Wells Dam before heading downstream and being last detected in the Wenatchee River (Table 44). This comprised 1.3% of all Bonneville-tagged sockeye passing Rocky Reach. Of these fish, two were among the eight adipose clipped sockeye salmon last detected in the Wenatchee River indicating they were from the Eastbank Hatchery program. One of the 14 sockeye was last detected at the Lower Wenatchee array (LWE); the rest passed Tumwater Dam. Four of the six Bonneville-PIT tagged sockeye last detected at the Little Wenatchee River (LWN) spawning grounds were sockeye which had passed Rocky Reach Dam.

Table 44. Number of PIT tagged sockeye salmon passing Rocky Reach and Wells dams which were subsequently detected in the Wenatchee River in 2012.

Tag Site	N Passing Rocky Reach	N and % past Rocky Reach and Wells subsequently Detected in Wenatchee R.		Number of Detections in Upper Wenatchee Basin by Site				
		Rocky Reach Dam	Wells Dam	Tumwater Dam	Little Wenatchee (LWN)	White River (WTL)	Icicle Creek (ICL)	Chiwawa River (CHL)
Bonneville	1027	14 (1.3%)	4	13	4	4	0	0
Priest Rapids	583	11 (1.4%)	3	11	2	4	2	0
Wells Dam	769[29]	--	--	4	0	2	3	0
Juveniles (Varity of Sites	161	44 (27.3%)	15	40	3	11	4	1

A total of 11 Priest Rapids PIT tagged sockeye salmon were detected passing Rocky Reach Dam, 3 of which also passed Wells Dam, before turning around and heading downstream to enter the Wenatchee River. All 11 were detected passing Tumwater Dam, with 4 ultimately detected in the White River and 2 in the Little Wenatchee River.

Sockeye tagged as juveniles were much more likely, than those tagged as adults, to pass Rocky Reach and Wells dams before turning around and entering the Wenatchee River. Of the 161 passing Rocky Reach, 44 (27.3%) were

[29] Number of sockeye tagged at Wells Dam

subsequently detected in the Wenatchee River, 40 of which passed Tumwater Dam.

An additional three Wells Dam and two Priest Rapids Dam-tagged adults were last detected in the Entiat and Methow rivers. Among sockeye tagged as juveniles, seven were last detected in those rivers. No Bonneville-tagged adults were detected in the Entiat or Methow rivers.

A total of 29 sockeye salmon were last detected at the Priest Rapids trap and likely ended up in the Cle Elum sockeye reintroduction program. Five (17.2%) were classified using GSI as Wenatchee and 24 (82.3%) as Okanagan stock.

Our tagging at both Wells and Bonneville dams, in addition to acoustic and temperature tagging at Wells Dam combined with PIT and acoustic detection at OKC offered the opportunity to provide insights on the effect of different tagging regimes on sockeye salmon (Table 45). In 2012, this shows that the more recently tagged sockeye at Wells and Priest Rapids Dam had a higher conversion rate to OKC than those tagged at Bonneville Dam implying there was a benefit from sampling/tagging of 6.5% and 1.0% respectively. This was likely a result of a differential harvest with harvesters downstream of the Canadian border instructed to release externally tagged sockeye salmon. The estimated harvest and release rate upstream of Wells Dam was 4.1% for the tribal fishery and 12.8% for the sport fishery although the degree of adherence to the regulation to release tagged fish in the sport fishery is uncertain. (We had four tags returned to us from sports anglers in 2012.) Bonneville tagged fish, without any external tag, would have been more likely to be retained than sockeye tagged at Wells and Priest Rapids dams with external tags. On the other hand, we have no way to estimate the survival of sockeye salmon caught and released in sports fisheries. If incidental mortality is high from being captured and released by sport fisheries, then the advantage a sockeye externally tagged at Priest Rapids or Wells dam would be from being caught and released would be reduced when compared to a Bonneville tagged fish with no external identification which would presumably be kept and not released.

A better comparison to provide insights on tagging impacts may be comparing Wells Dam-tagged and Priest Rapids-tagged sockeye as both had external marks and would seemingly face similar fishing impacts. This comparison suggests that sockeye tagged at Wells had a 5.2% lower conversion rate to OKC when compared to Priest Rapids-tagged sockeye (44.1% vs. 41.8%, Table 45). Acoustic tagged sockeye, when compared to PIT tagged only sockeye at Wells, had a 7.2% lower conversion rate to OKC (38.8% vs. 41.8%).

Table 45. Conversion rates from Wells Dam to OKC for sockeye tagged at Bonneville, Priest Rapids, and Wells dams and the percent deviation from that of Bonneville-tagged sockeye salmon in 2012.

Tagging Location	Tagging Regime	Wells-OKC Conversion Rate	Deviation from Bonneville-tagged Conversion Rate
Bonneville Dam	PIT tag	41.4%	--
Priest Rapids Dam	PIT plus Floy tag	44.1%	-6.5%
Wells Dam	PIT plus Floy-tag	41.8%	-1.0%
Wells Dam	PIT plus acoustic plus Floy Tag	38.8%	6.3%

The tribal fishery upstream of Wells Dam recorded Floy tag numbers of sockeye captured and released by that fishery (Table 46). A total of 24 Priest Rapids tagged sockeye (out of 562 passing Wells Dam, or 4.3%) were captured and released along with 34 Wells Dam-tagged sockeye (out of 769 released upstream of Wells, or 4.4%). When compared to the Wells-OKC conversion rate of 41.8 to 44.1% (Table 45), the conversion rate of Priest Rapids-tagged sockeye captured and released in the fishery was much greater (66.7%), while that for Wells-tagged sockeye was less (38.2%). Wells Dam-tagged sockeye captured in tribal fisheries were also more likely to be last detected at Zosel Dam though the detection efficiency of this site was low and samples sizes are small. A possible explanation for the difference in survival of the two groups of sockeye may be that the sockeye tagged at Wells Dam were much more recently tagged than the Priest Rapids-tagged sockeye (median of 13.5 days vs 29.0 days between tagging and capture), which may make them less likely to survive the stress of being captured and released. It is more difficult to come up with an explanation as to why Priest Rapids-tagged sockeye captured and released in the fishery had higher survival than those not captured.

Table 46. Last detection site for sockeye recorded as captured and released in tribal fisheries between Wells and Zosel dams by tagging site in 2012.

Last Detection Site	Tagging Site			
	Priest Rapids Dam		Wells Dam	
	N	%	N	%
Wells Dam or Not Detected	7	29.2%	17	50.0%
Zosel Dam	1	4.2%	4	11.8%
OKC	16	66.7%	13	38.2%
Total Number captured and released in fishery	**24**		**34**	

Weekly downloads and summary distributions of acoustic tagged adult sockeye were tested in 2012 as a tool for in-season harvest management by the ONA and DFO. Agencies shared information to validate distribution and provide a conservative estimator of in-season abundance of sockeye stocks in the North Basin, Osoyoos Lake (location of the seine and troll fishery, plus recreational fishery). The acoustic information provided ONA an early indicator of abundance which was integral to the decision to close the fishery on September 1, 2012, two weeks earlier than originally planned (15 September). ONA and DFO estimate that if the fishery had continued for the extra two weeks, it is likely that fishing would have driven escapement well below the 100,000 goal. Having an in-season tool using acoustic data was beneficial for fisheries managers to validate in-season decisions. The tool was used to convince user groups that, despite large catches, harvest needed to be curtailed to provide sufficient escapement.

There are some data suggesting that survival estimates based on acoustic tags may be biased high. First, sockeye salmon mortality was observed in the southern basin of Lake Osoyoos which was not reflected in data from acoustic tagged fish (http://www.osoyoostimes.com/warm-water-bacteria-responsible-for-killing-hundreds-of-sockeye-salmon-in-osoyoos-lake/). Also, PIT tag data suggests that the conversion rate to OKC was somewhat higher on days acoustic tagging was conducted at Wells Dam than other days. For sockeye tagged at Wells Dam, the conversion rate to OKC was 43.8% for days acoustic tags were deployed versus 39.6% for days in which acoustic tags were not deployed. Among Priest Rapids-tagged sockeye passing Wells Dam, the conversion rate from Wells Dam to OKC was 48.9% for days acoustic tags were deployed at Wells Dam compared to 43.1% for days acoustic tags were not deployed. Among Bonneville Dam-tagged sockeye passing Wells Dam, the conversion rate from Wells Dam to OKC was 41.5% for days acoustic tagging occurred at Wells

Dam compared to 41.0% for days in which acoustic tagging did not occur. A possible explanation for the higher conversion rates on days of acoustic tagging may be the several short dips in Okanagan River temperatures that happened to occur a few days after sockeye were acoustic tagged at Wells Dam (Figure 11). Several of these temperature dips apparently were timed that sockeye passing on days that acoustic tagging occurred were able to quickly pass upstream to Osoyoos Lake. Sockeye passing Wells Dam on other days may have missed these narrow windows, resulting in these fish being delayed in Wells Pool where they would have been subject to additional fishing and possible other mortality. As has been the case since 2008, there was not a significant linear relationship between run timing at Bonneville Dam and stock composition. PIT tag studies in 2006 and 2007, as well as several scale pattern studies in past years (e.g. Fryer 1995, 2006); found a significant relationship between run timing and stock composition. These pre-2008 results suggested a higher percentage of the Wenatchee stock migrated in the early portion of the run and a higher percentage of the Okanagan stock migrated in the latter portion of the run. In recent years, the proportion of Okanagan stock sockeye relative to the Wenatchee has increased early in the run.

The rate of sockeye missing detection at mainstem dams was lower in 2012, for most dams, than in other years (Table 5). Rock Island and McNary dams had the highest rate, but the McNary rate of 1.6% was the lower observed since this study began in 2006, while the Rock Island rate of 4.4% was the third lowest. At McNary Dam it is possible that sockeye are using the navigation locks, which are located on the north side of the dam just downstream from the Snake River (which enters the Columbia River from the south side). Rock Island Dam is known for having lower rates of detection than other mainstem dams due to electrical interference (Fryer et al. 2011) at the antennas.

Fallback rates (Table 15) at Rocky Reach Dam, at a minimum of 7.9%, would have inflated visual counts by a similar amount. This same phenomenon could be affecting Snake River counts based on fallback rates estimated from sockeye tagged as juveniles. This is the first year that we have tabulated any data from juveniles so we do not know how this compares with previous years at Snake River dams. It is also unknown how representative these PIT tagged sockeye are of the run in the Snake River. Sockeye tagged as juveniles in the

Upper Columbia were certainly not representative of the run upstream of Priest Rapids Dam as the bulk of these sockeye are Wenatchee stock (including many hatchery) while the majority of the sockeye run is Okanagan stock. The preponderance of Wenatchee stock sockeye, and more specifically Wenatchee hatchery sockeye, explains the high percentage of returning tagged juveniles which pass Rocky Reach and Wells dams before returning to the Wenatchee River.

In 2012, PIT tags from three sockeye salmon tagged at Bonneville Dam and two tagged at Priest Rapids Dam were recovered from the Badger Island Pelican Colony at Columbia River km 512. The two Priest Rapids sockeye were 48.0 and 48.5 cm and both tagged on July 23, 2012 while the Bonneville tagged fish ranged in length between 45.5 and 50.0 cm and were tagged between June 13 and July 9, 2012. Two of the Bonneville-tagged sockeye were last detected at McNary with one last detected at Bonneville. Both Priest Rapids-tagged sockeye were last detected at the upper Priest Rapids Dam antenna.

From 2008 and 2010, this study documented delays in passage at Tumwater Dam that was likely attributable to 24 hour operation of the trap at that facility. The median delay reported was up to 4.6 days (in 2008) and PIT tag detection records suggested that up to 33.3% (in 2010) of sockeye salmon reaching Tumwater Dam never passed over it. Trap operations were changed in 2011 so that passage through the fish ladder was not blocked 24 hours per day. The result was that the median delay dropped to six minutes in 2011 and was again six minutes in 2012. All sockeye salmon detected at Tumwater Dam in 2012 were last detected at the upper antenna suggesting that they all passed upstream of the dam.

This project is proposed to continue and evolve through at least 2017. Past work has created the infrastructure through funding PIT tag antennas at OKC and Zosel Dam as well as acoustic arrays to better determine where losses of Okanagan sockeye salmon are occurring upstream of Wells Dam. However, low sample sizes of acoustic tagged sockeye, possible acoustic tagging impacts, as well as the lack of any PIT tag detection between Wells Dam and Zosel Dam

and OKC still leaves considerable uncertainty in quantifying mortality. This gap should begin to be filled in when the Colville Tribe implements a PIT tag array in the lower Okanagan River beginning in 2014. We hope to work with the Colville Tribe in the future on expanding PIT tag detection in the Okanagan Basin. In addition, we have been investigating possible PIT tag detection at the Highway 3 bridge in Osoyoos between the north and central basins of Osoyoos Lake. It is hoped that better PIT tag detection at some of these sites could eliminate the need for acoustic tags providing considerable savings which could be better applied elsewhere.

We also expect to continue with Wenatchee acoustic trawl surveys and limnological work to better estimate the production and productive potential of Wenatchee sockeye salmon. Acoustic trawl surveys in both Lake Wenatchee and Osoyoos Lake are also being used in Columbia Basin run forecasting. There are several unanswered questions regarding Lake Wenatchee sockeye that we hope to address for this project. A primary question is why Lake Wenatchee sockeye have not increased in relative abundance as much as Okanagan sockeye, or even Snake River sockeye, in recent years. Our limnology and ATS work will help in answering this question, but it is also uncertain what the optimal spawning escapement goal is for this stock. An optimal escapement analysis is being done, using other funding, for Osoyoos and Skaha sockeye and we plan to consider this for the Wenatchee stock.

Another unanswered question is how current production for both Osoyoos and Wenatchee sockeye salmon compares to historical production. Peak historical Columbia Basin sockeye runs have been estimated at 2.6 million to 4.3 million (Chapman 1986, NPPC 1986, Fryer 1995); however the 2012 run of over 510,000 sockeye salmon with less than 5% of historical Columbia Basin habitat available (Fryer 1995) makes those peak estimates appear conservative. To answer this question, we plan to work with the Okanagan Nation, Department of Fisheries and Oceans Canada, and Grant, Chelan, and Douglas Public Utility District to fund paleolimnological work in Wenatchee, Osoyoos, Skaha, and Okanagan lakes beginning in 2014.

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APPENDIX A

Table A1. Probability of detection at PIT tag detectors by antenna at mainstem Columbia Basin fish ladders, and the overall probability of detection, for sockeye salmon in 2012.

Dam, Site, Tag Type, and Number		Antenna and Probability of Detection at Antenna				Overall Detection Probability
Bonneville	**N**	**1**	**2**	**3**	**4**	
BO1	16	100.0	100.0	100.0	93.8	100.0
BO4	1573	98.9	98.7	99.4	99.0	100.0
McNary	**N**	**1**	**2**	**3**		
MC1 (Oregon)	677	98.8	97.9			100.0
MC2 (Washington)	647	97.7	99.4	90.6		100.0
Priest Rapids	**N**	**Upper**	**Lower**			
West	158	99.4	100.0			100.0
East	1103	97.6	99.9			100.0
Rock Island	**N**	**Upper**	**Lower**			
Left	491	98.8	99.6			100.0
Middle	77	98.7	100.0			100.0
Right	539	89.1	89.1			98.8
Rocky Reach	**N**	**Upper**	**Lower**			
Right	1020	99.6	98.0			100.0
Wells	**N**	**Upper**	**Lower**			
Left-	746	99.6	100.0			100.0
Right	259	99.3	99.3			100.0
Tumwater	**N**	**Upper**	**Lower**			
12.5	194	100.0	100.0			100.0

Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank.

Table A2. Distribution of sockeye salmon by fish ladder for dams with multiple fish ladders as estimated by PIT tag detections of sockeye tagged at Bonneville Dam in 2012.

Dam	Right Bank	Left Bank	Center
Bonneville	99.0%	1.0%	
McNary	48.9%	51.1%	
Priest Rapids	87.4%	12.6%	
Rock Island	51.6%	41.9%	6.6%
Wells	25.8%	74.2%	

Right or left is determined by looking downstream at the dams, thus the right bank at Wells would be the west bank, at McNary it would be the Washington shore.

Table A3. Harvest by fishery for Columbia Basin sockeye salmon in 2012.

Location	Fishery Type	Source	Totals
Zone 1-5	Sport and Commercial	TAC	4,321
Zone 6	Commercial, Ceremonial and Subsistence	TAC	45,747
	Sport	TAC	434
Priest Rapids Tailrace	Wanapum Ceremonial and Subsistence	TAC	44
Lake Wenatchee	Sport	WDFW	12,107
Priest Rapids to Chief Joseph Dam	Sport	DFO	27,500
Colville Harvest (Lake Pateros and Okanogan River)	Colville Tribal Net	DFO	1,532
	Colville Tribal Purse Seine	DFO	12,826
	Chief Joseph Tailrace	DFO	57
	Tribal anglers and net	DFO	1,262
Canada Okanagan Basin	Okanagan Nation Alliance Communal	DFO	5,225
	Okanagan Nation Alliance Economic Demo	DFO	778
	Recreational	DFO	439
Priest Rapids Dam	Yakama Broodstock Removals[30]	YN	10,000

[30] Although not a true "harvest", the Yakima Nation collect live, adult sockeye salmon at Priest Rapids Dam each year and place them in Cle Elum and Cooper Lakes to spawn. This sockeye reintroduction project was initiated in 2009.

Table A4. Information on interrogation sites for detection of PIT tags in the Columbia Basin.

Site Code	Site Name	Site Description
ACB	Asotin Cr. at Cloverland Brdg.	Mainstem of Asotin Creek above the George Creek confluence, underneath the Cloverland Bridge, 4.6 km upstream from the mouth of Asotin Creek.
ACM	Asotin Creek near mouth	Near the mouth of Asotin Creek 50 m upstream of the Highway 129 bridge spanning the mainstem of Asotin Creek in two serial sets of two antennas.
B2J	Bonneville PH2 Juvenile	Bonneville Dam PH2 Juvenile Bypass and Sampling Facility
BBT	Touchet River at Bolles Bridge	The Bolles Bridge site is located about 200 feet above the State HWY 124 bridge on the Touchet River, near Bolles Road, at River Kilometer 65.2.
BCC	BON PH2 Corner Collector	Bonneville Dam 2nd Powerhouse Corner Collector Outfall Channel
BGM	Burlingame Dam and Canal	Burlingame Diversion Dam is located on the lower Walla Walla River.
BHL	Adult Fishway at BONH	In-stream detection system located in Bonneville Hatchery Ladder.
BO1	Bonneville Bradford Is. Ladder	Bradford Island Adult Fishway at Bonneville Dam
BO2	Bonneville Cascades Is. Ladder	Cascades Island Adult Fishway at Bonneville Dam
BO3	Bonneville WA Shore Ladder/AFF	Washington Shore Adult Fishway and AFF at Bonneville Dam; replaces B2A and BWL
BO4	Bonneville WA Ladder Slots	Washington Shore Fishway Vertical Slots at Bonneville Dam
BSC	Big Sheep Creek ISA at km 6	In-stream detection system located in Big Sheep Creek at river km 6 (N 45.50649, W -116.85067).
CAL	Carson NFH Adult Return Ladder	Hatchery adult spring Chinook return ladder from the Wind River to Carson NFH.
CHL	Lower Chiwawa River	Chiwawa River rkm 1, located between the Chiwawa smolt trap and the Chiwawa Acclimation Ponds.
CHU	Upper Chiwawa River	Chiwawa River rkm 12, located above the Forest Road 62 bridge and below Alder Creek.
CRT	Crooked River Satellite Fac.	Ladder of the Crooked River Satellite Facility. The Crooked River is a tributary to the South Fork Clearwater River. The array consists of two overflow antennas.
CRW	Chewuch River above Winthrop	Chewuch River at river km 1, above Winthrop, WA.
DRM	Deschutes River mouth	Mouth of the Deschutes River in the west channel at Moody Island (rkm 0.46).
DWL	Dworshak NFH adult trap	Located at the terminus of the Dworshak National Hatchery adult fish ladder in the North Fork Clearwater River.
ENA	Upper Entiat River at rkm 17.1	The site is located approximately 400 meters above the mouth of the Mad River near the township of Ardenvoir at river kilometer 17.1
ENF	Upper Entiat River at rkm 40.6	The site is located approximately 600 meters below the beginning of Forest Service Property within the upper portion of the Entiat River at rkm 40.6.
ENL	Lower Entiat River	Entiat River rkm 2, located immediately upstream of Entiat, WA.
ENM	Middle Entiat River	Entiat River rkm 26, below the McKenzie Diversion Dam.
ENS	Upper Entiat River at rkm 35.7	The site is located approximately 4.3 km above Stormy Creek at river kilometer 35.7 and near the entrance of the Riverwood subdivision.
ESJ	Easton Acc. Pond	Easton Acclimation Pond Outfall
ESS	EFSF Salmon River at Parks Cr.	East Fk South Fk Salmon River (rkm 21) near Parks Creek.
FDD	Feed Diversion Dam	Feed Diversion Dam, at Umatilla River rkm 47.
GLC	Gold Creek, Methow River	Gold Creek, Methow River Basin
GOJ	Little Goose Dam Juvenile	Little Goose Dam Juvenile Fish Bypass/Transportation Facility
GRA	Lower Granite Dam Adult	Lower Granite Dam Adult Fishway and Fish Trap
GRJ	Lower Granite Dam Juvenile	Lower Granite Dam Juvenile Fish Bypass/Transportation Facility
HRM	Hood River Mouth	Mouth of the Hood River against the west side jetty just inside the bar where the Hood River meets the Columbia River.
HYC	Hayden Creek In-stream Array	Lower section of Hayden Creek, in the Lemhi River Basin.
ICH	Ice Harbor Dam (Combined)	Ice Harbor Dam Adult Fishways (both) and Full Flow Bypass
ICL	Lower Icicle Instream Array	Located at rkm 0.4 on Icicle Creek (Wenatchee River Basin), near Leavenworth, WA.
IR1	Lower Imnaha River ISA @ km 7	Lower Imnaha River at river km 7 (N 45.761162, W -116.750658).
IR2	Lower Imnaha River ISA @ km 10	Lower Imnaha River at river km 10 (N 45.742839 W -116.764563).
IR3	Upper Imnaha River ISA @ km 41	Upper Imnaha River at river km 41 (N 45.49004 W 116.80393).
JD1	John Day River, McDonald Ferry	John Day River in-stream detection, near McDonald Ferry at RM 20
JDJ	John Day Dam Juvenile	John Day Dam Juvenile Fish Bypass and Sampling Facility
JOC	Joseph Creek ISA @ km 3	Joseph Creek, Grande Ronde basin at river km 3 (N 46.030016, W -117.016042).
KRS	SF Salmon River at Krassel Cr.	Krassel Creek at rkm 65 on the South Fork Salmon River.
LC1	Lower Lolo Creek at rkm 21	Lolo Creek, a tributary to the Clearwater River located at river km 522.224.087.021 (N 46.294434 W -115.976119).
LC2	Upper Lolo Creek at rkm 25	Lolo Creek, a tributary to the Clearwater River located at river km 522.224.087.025 (N 46.290562 W -115.934153.
LFF	Lyle Falls Fishway	The Lyle Falls Fishway in Klickitat River
LLC	Loup Loup Creek Instream Array	Loup Loup Creek trib of the Okanogan River at RKM 27.2, within the city of Malott, WA. The LLC site is located 0.42 km from the confluence with the Okanogan River.
LLR	Lower Lemhi River	Lower Lemhi River in Salmon, ID.
LMJ	Lower Monumental Dam Juvenile	Lower Monumental Dam Juvenile Fish Bypass/Transportation Facility
LMR	Lower Methow River at Pateros	Lower Methow River near the WDFW 'Miller Hole' access site on the lower Methow River immediately upstream of Pateros, WA.
LNF	Leavenworth NFH Adult Ladder	Located in the Leavenworth National Fish Hatcheries adult ladder and holding pond.
LRW	Lemhi River Weir	Lemhi River above the mouth of Hayden Creek and below the IDFG weir.
LTR	Lower Tucannon River	Near the mouth of the Tucannon River. The upstream array group was located at an abandoned railroad bridge abutment upstream of Hwy 261 on the Tucannon River downstream from Starbuck. The CO in-stream array was relocated below the Hwy 261 bridge on Sept. 29, 2010.
LWD	Lowden Diversion Dam	At the entrance to the fish ladder at Lowden Diversion Dam. Lowden Dam is located at rkm 51 on the Walla Walla River.
LWE	Lower Wenatchee River	Wenatchee River rkm 2.
LWL	Ltl. White Salmon NFH returns	Adult fish ladder allowing passage from the Little White Salmon River into the adult holding ponds at Little White Salmon NFH.
LWN	Little Wenatchee River	Little Wenatchee River rkm 4, located at the old fish weir site.
MAD	Mad River, Entiat River Basin	Mad River rkm 1, located at Ardenvoir, WA.
MC1	McNary Oregon Shore Ladder	Oregon Shore Adult Fishway at McNary Dam
MC2	McNary Washington Shore Ladder	Washington Shore Adult Fishway at McNary Dam
MCD	Mill Creek Diversion Project	Fish bypass and passage facilities at the (Bennington) Diversion Dam and the first Division Works in the Mill Creek Diversion Project in the Walla Walla Basin.

Table A5. Table A4 continued.

Site Code	Site Name	Site Description
MCJ	McNary Dam Juvenile	McNary Dam Juvenile Fish Bypass/Transportation Facility
MCL	Lower Mission Creek Instream	Located at rkm 0.7 on Mission Creek (Wenatchee River Basin), near Cashmere, WA.
MRT	Methow River at Twisp	Methow River at river km 67, above the Twisp River.
MRW	Methow River at Winthrop	Methow River. During 2009 and early 2010, the array was located at river km 81, above Winthrop, WA near Winthrop National Fish Hatchery. In Sept. 2010 it was moved upstream to its new location below Wolf Creek on the mainstem Methow River, at river km 85.
MSH	Methow Fish Hatchery Outfall	Outlet of the Washington Department of Fish and Wildlifes (WDFW) Methow Hatchery located on the Methow River at Rk 82.3 from the confluence with the Columbia River.
MTR	Middle Tucannon River	The Middle Tucannon River site is located about 250 feet above the River Ranch Ln bridge on the Tucannon River, at River Kilometer 19.5.
MWC	Maxwell Canal	Maxwell Canal is located at rkm 24 on the Umatilla River.
MWE	Middle Wenatchee River	Wenatchee River rkm 50 above Tumwater Dam, consisting of a single antenna array floated off the bottom spanning the river.
NAL	Lower Nason Creek	Nason Creek rkm 1, located within Lake Wenatchee State Park.
NAU	Upper Nason Creek	Nason Creek rkm 19 (Wenatchee River Basin).
NBA	Nursery Bridge Adult	Nursery Bridge Dam Fishways (both), Walla Walla River at Milton-Freewater, OR.
NFW	North Fork Walla Walla River	North Fork Walla Walla River approximately 267 meters upstream from the confluence with the South Fork Walla Walla River.
OKC	Okanagan Channel at VDS-3	The OKC site is located in the Okanagan (Canadian spelling) Channel at 310th Avenue/Road 18 upstream from Osoyoos Lake.
OMK	Omak Creek Instream Array	Omak Creek enters the Okanogan River at RKM 51.5, approximately 1 km upstream from the city of Omak, WA. The OMK site is located on Omak Creek, 0.24 km from the confluence with the Okanogan River.
ORB	Oasis Road Bridge	In-stream arrays at Oasis Road Bridge, lower Walla Walla River
PRA	Priest Rapids Adult	Priest Rapids Dam Adult Fishways (both)
PRH	Priest Rapids Hatchery Outfall	Priest Rapids Hatchery outfall channel. The site is located just upstream of the typical point of inundation in the channel.
PRO	Prosser Diversion Dam Combined	Adult Fishways (all three) and Juvenile Bypass/Sampling Facility at Prosser Dam
PRV	Walla Walla R at Pierce RV Prk	Lower Walla Walla River at Pierce Green Valley RV Park.
RCL	Rock Creek (WA) at rkm 5	Rock Creek (WA) at rkm 5 near the Yakama Nation Longhouse.
RCS	Rock Creek (WA) at rkm 14	Rock Creek (WA) at rkm 14 at the confluence of Rock and Squaw Creeks.
RIA	Rock Island Adult	Rock Island Dam Adult Fishways (all three)
ROZ	Roza Diversion Dam (Combined)	Roza Dam Smolt Bypass.
RPJ	Rapid River Hatchery Pond	Rapid River Hatchery (IDFG) outfall
RRF	Rocky Reach Fishway	Rocky Reach Dam Adult Fishway
RRJ	Rocky Reach Dam Juvenile	Juvenile Fish Bypass Surface Collector.
RRT	Red River Satellite Facility	Ladder of the Red River Satellite Facility. The Red River is a tributary to the South Fork Clearwater River.
SC1	Lower SF Clearwater R at rkm 1	Lower South Fork Clearwater River at river km 0.9 (N 46.13685 W -115.98091).
SC2	Lower SF Clearwater R at rkm 2	Lower South Fork Clearwater River at river km 2 (N 46.12749 W -115.97730).
SCL	Spring Creek NFH Adult Ladder	Fish ladder allowing passage from the Columbia River into the adult holding ponds at Spring Creek NFH.
SCP	Spring Creek Acclimation Pond	Juvenile releases from and adults returning to Winthrop National Fish Hatchery.
SFG	SF Salmon at Guard Station Br.	Located at rkm 30 near the lower South Fork Salmon River Guard Station on the South Fork Salmon River.
STL	Sawtooth Hatchery Adult Trap	Ladder of the Sawtooth Hatchery adult fish trap.
STR	SF Salmon Satellite Facility	Ladder of the South Fork Salmon River adult fish trap.
SWK	Lower Swauk Creek	Located at rkm 0.5 on lower Swauk creek, just above the highway 10 bridge.
TAY	Big Creek at Taylor Ranch	Centered around the bridge at Taylor Ranch, Big Creek, ID.
TD1	The Dalles East Fish Ladder	East Fish Ladder at The Dalles Dam
TD2	The Dalles North Fish Ladder	North Fish Ladder at The Dalles Dam
TMF	Three Mile Falls Dam Combined	Adult Fishway and Juvenile Bypass/subsampling facility at Three Mile Falls Dam
TRC	Trout Creek, Wind River	Trout Creek located at river km 2 on Trout Creek, in the Wind River (WA.) Basin above Hemlock Lake.
TUF	Tumwater Dam Adult Fishway	Adult Fishway at Tumwater Dam
TWR	Lwr Twisp Rvr near MSRF Ponds	Lower Twisp River adjacent to the Methow Salmon Recovery Foundation Ponds.
TWX	Estuary Towed Array (Exp.)	The TWX experimental trawl detector is typically deployed in the Columbia River estuary, at and above Jones Beach (rkm 75).
UGR	Upper Grande Ronde at rkm 155	Grand Ronde River located at river km 522.271.155 (45. 593338, -117.903124).
USE	Upper Salmon River at rkm 437	Located in the Salmon River at river km 522.303.437 (N45.028939 W-113.915892).
USI	Upper Salmon River at rkm 460	Located in the mainstem Salmon River at river km 522.303.460 (N44.890380 W-113.962575).
UTR	Upper Tucannon River	The Upper Tucannon River site is located about 200 yards above Don Howards House on the Tucannon River, at River Kilometer 53.2.
UWE	Upper Wenatchee River	Located at rkm 81.2 on the Wenatchee River, near Plain, WA.
VC1	Valley Creek, Upstream Site	Located on Valley Creek at Stanley, ID., in the Upper Salmon River.
VC2	Valley Creek, Downstream Site	Located on Valley Creek below Stanley, ID., in the Upper Salmon River.
WEA	Wells Dam, DCPUD Adult Ladders	Wells Dam Adult Fishways (both)
WFC	Wolf Creek, Methow River	Wolf Creek, Methow River Basin
WHC	Lwr White Creek, Klickitat Bsn	White Creek (Klickitat River Basin) approximately 150 meters upstream from the mouth.
WSH	Warm Springs Hatchery	Adult Fishway at Warm Springs NFH
WTL	White River, Wenatchee Basin	White River rkm 4, located at the old fish weir site.
WW1	Harris Bridge S F Walla Walla	Harris County Park Bridge, South Fork Walla Walla River
WW2	SF Walla Walla at Bear Creek	Bear Creek, South Fork Walla Walla River
YFK	Yankee Fork Salmon River	The site is located 3.14 river kilometers upstream from the confluence with the Salmon River at an elevation of 1855m.
ZEN	Secesh River at Zena Cr. Ranch	Near the Zena Creek Ranch
ZSL	Zosel Dam Adult Fishways	Zosel Dam is located at Okanogan River km 132, approximately 3 km downstream from the outlet of Lake Osoyoos in the town of Oroville, Washington.

APPENDIX B

Juvenile Sockeye Population Status and Environmental Conditions in Lake Wenatchee, WA and Osoyoos Lake, B.C. in 2012.

K. D. Hyatt, R. Ferguson, D. McQueen and D. P. Rankin

Fisheries and Oceans Canada
Salmon in Regional Ecosystems Program
Salmon and Regional Ecosystems Section
Science Branch
Pacific Biological Station
Nanaimo, B.C.
V9T 6N7

Juvenile Salmon Index Data System Reports (JSIDS SRe.'s) facilitate timely exchange of information and results on assessments of juvenile salmon abundance, their biological traits and associated habitat variables, in response to requests from a variety of "clients" both within and external to the Department of Fisheries and Oceans. Information contained in status reports is often preliminary in nature and contact with the authors is recommended to clarify any uncertainties associated with interpretation or use of status report contents.

Citable As:

Hyatt, K. D., R. Ferguson, D. McQueen and D. P. Rankin. 2013. Lake Wenatchee, WA: Juvenile Nerkid Abundance Status Report. Report to file: JSIDS - SRe 01-2013. Salmon and Regional Ecosystems Division, Fisheries and Oceans Canada, Nanaimo, B.C., V9T 6N7

Distribution (as of 21, Nov., 2013)

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3. Dr. Jeff Fryer, Columbia River Intertribal Fishery Commission, 700 NE Multnomah Street, Suite 1200, Portland Oregon, 97232. Telephone 503-238-0667.

4. Mr. Dennis Beich, Regional Director, Washington Department of Fish and Wildlife, 1550 Alder Street NW, Ephrata, WA, 98823-9699. Telephone: (509) 754-4624.

Lake Wenatchee, WA: Juvenile Nerkid Abundance Status Report.

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Survey Type: [X] acoustics and trawl, [ ] spawning ground, [ ] other.

Survey Rationale:

1. Regional Salmon Stock Assessment activities
2. Requested by the regional director of the Washington Department of Fish and Wildlife, Mr. Dennis Beich, to survey Lake Wenatchee.
3. Only 2 self-sustaining stocks of sockeye salmon are left in the Columbia/Okanagan Rivers, Osoyoos Lake and Lake Wenatchee (Hyatt and Rankin, 1999). The Salmon In Regional Ecosystems Program (SIRE-P) has been monitoring the Osoyoos Lake sockeye stock for 12 years, and assisting the Okanagan Nation Alliance Fisheries Department in their attempts to extend the range of Okanagan sockeye into Skaha Lake. In order to better understand the production dynamics and relative carrying capacity of nursery lakes used by the 2 stocks, basic data are required from Lake Wenatchee using standard assessment techniques employed by SIRE-P.
4. This work is endorsed by the Okanagan Nation Alliance Fisheries Department and by the Columbia River Intertribal Fisheries Commission.

Survey Resources.

All direct costs associated with the surveys, survey instrumentation, sample analysis, data assembly, data analysis and reporting were covered through a collaborative agreement between the Okanagan Nation Alliance Fisheries, Department and **SIRE-P**. **SIRE** supported surveys with approximately 9 days of time for survey support and analysis (R. Ferguson, 8d; K. Hyatt, 1d).

<u>Survey Subjects</u>:

Abundance of juvenile nerkids, zooplankton and water quality parameter measurements in Lake Wenatchee (Figure 1).

Fish Survey Dates:

2011: 20September, 01November
2012: 25June, 18September
(Limnology survey dates are shown in Table 1)

Survey Crew(s):

Rick Ferguson, Jeff Fryer, Paul Rankin, Jeff Till

Survey Status:

All surveys were completed. Weather conditions during the 25Jun2012 were marginal (see STR attached). The weather was good except for the full moon which probably reduced the trawl catch. Summary figures, forms and tables are attached: (i.) types of samples and records obtained during surveys (Table 1); (ii.) acoustic (Biosonics 200kHz DTX) and trawl based estimates of fish abundance (Tables 2&3). Figures and tables attached in Appendix 1 include (1.) survey location, (2) fall weight vs. average density in Osoyoos and Wenatchee and (3) limnological parameters.

Status of Samples:

Acoustic records, biological samples and survey observations will be incorporated (yes [X], no [ ]) into sample inventories or databases maintained by **SIRE-P** at **PBS** for future reference.

Status of Sample Analysis*:*

Acoustic records have been processed using Sonar5 Pro v 6.0.1 to provide population estimates reported in Table 2. Additional sample analysis will be completed (yes [X], no [ ]) in support of a report identified below. Sample types from which additional information **may** be extracted include juvenile sockeye size, zooplankton and water chemistry.

Status of Data Analysis and Reporting:

Additional data analysis and/or reporting will be completed (yes [**X**], no [ ]) as time and annual work plan assignments permit. Such data will be managed as part of our multi-year, juvenile sockeye index data sets (**JSIDS**) for incorporation into future stock assessment and research publications on interactions between sockeye/kokanee stocks in coastal British Columbia lakes.

Preliminary Conclusions or Recommendations:

1. Year 2012 late summer estimates of limnetic fish abundances in Wenatchee and Osoyoos Lakes averaged 2,800 and 3,494 fish/ha respectively. Within-sample, between-transect confidence intervals equaled 25 and 10% respectively. Lake Wenatchee trawl catches

consisted entirely of juvenile nerkids. No other fish were caught in the limnetic zone.

2. The Lake Wenatchee juvenile sockeye population was estimated to be 2,100,000 (2011) and 2,800,000 (2012). The Osoyoos Lake juvenile sockeye population was estimated to be 4,500,000 (2011) and 3,260,000 (2012).
3. Lake Wenatchee juvenile sockeye caught in the trawl on 18 September 2012, averaged 56 mm in length and 1.89g wet weight (Table 2. Figure 3). Osoyoos Lake juvenile sockeye grew more quickly. Osoyoos Lake juveniles caught in the trawl on 11 September 2012, averaged 60 mm and 2.4 and on 11 October 2012, averaged 66 mm and 3.1 g. (Table 3, Figure 3).
4. Wenatchee juvenile sockeye sit below the "density growth" trajectory represented by Osoyoos Lake (Figure 3). This is not surprising given the location of the lake (572 m, elevation) and the surrounding land use patterns when compared to those in the Okanagon valley around Osoyoos (278m, elevation).
5. In Lake Wenatchee during 2012, the entire water column had water temperatures and oxygen concentrations that were within the preference limits for juvenile sockeye (i.e. > 4 ppm and cooler than 17 ^{O} C (Table 4). In Osoyoos Lake, September epilimnetic temperatures >17°C extended down to 14 m and September hypolimnetic oxygen concentrations <4 ppm extended up to 19 m leaving only a mid-depth 4 m band of water with optimal conditions (i.e <17 ^{O} C and > 4ppm) for juvenile sockeye salmon (Tables 5, 6).
6. In Lake Wenatchee during 2012, average water chemistry conditions included (Tables 4, 7): Secchi depths 5.9 m, epilimnetic total phosphorus (TP) 5.9 µg/L and epilimnetic chlorophyll a 1.0 µg/L. Hypolimnetic TP averaged 7.5 µg/L. In Osoyoos Lake nutrients were higher and Secchi depths lower averaging (Table 8): Secchi depth 3.2 m, epilimnetic total phosphorus (TP) 11.2 µg/L, epilimnetic chlorophyll a 2.5µg/L. Hypolimnetic TP 10.8 µg/L.
7. Alkalinity and calcium are measures of buffering capacity. Laboratory work has suggested that when calcium concentrations are less than approximately 2 µg/L, cladocerans such as *Daphnia* may have difficulty producing carapace material. Lake Wenatchee had less calcium than some coastal British Columbia lakes, but was above the "carapace restriction" limit (Table 9).
8. In Lake Wenatchee, almost all of the available phytoplankton were "edible" by zooplankton. In Osoyoos Lake, total algal biomasses were much higher but many species were large and/or gelatinous and could not be consumed by zooplankton (Figure 4). The result was that both lakes had similar biomasses of edible algae.
9. Lake Wenatchee zooplankton biomasses were only 50% as high as they were in Osoyoos Lake and there were differences in zooplankton species composition. Both lakes had *Daphnia* and *Bosmina* but *Diaphanosoma* was found only in Osoyoos Lake. Both lakes had *Diacyclops bicuspidatus*,

but Osoyoos Lake had *Leptodiaptomus ashlandi* while Lake Wenatchee had *Hesperodiaptomus kenai* which is large-bodied and a very important target for juvenile sockeye.

10. In general, lower Lake Wenatchee total zooplankton biomasses suggest that Wenatchee sockeye should have grown at about half the rate of Osoyoos Lake juvenile sockeye. However, the presence of *Hesperodiaptomus* likely allowed Lake Wenatchee sockeye to hunt with greater efficiency (energy return per feeding strike was higher), suggesting a smaller than expected difference in Lake Wenatchee and Osoyoos Lake sockeye growth rates. In fact during 2012, both Wenatchee and Osoyoos sockeye had similar lengths and weights in June and by September, Lake Wenatchee sockeye were only 20% smaller than Osoyoos Lake sockeye.

11. Consideration of the biomass of fall fry produced at similar abundance levels (i.e. comparisons restricted to an abundance range of 1500-3500 fry/ha) over multiple years, as a relative sockeye production indicator suggests that Lake Wenatchee is about 63% as productive as Osoyoos Lake. Thus, within the specified abundance range, Wenatchee and Osoyoos lakes have exhibited average biomasses of fall fry of 4.7 and 7.5 kg/ha respectively.
12. The maximum fall fry biomass observed to date occurred in Osoyoos Lake in 2009 when fall fry achieved weights of about 3.5 g at a record abundance level of in excess of 7500 fry/ha (Figure 3) equating to production of about 26 k/ha.
13. It is premature to make any statements about the potential maximum carrying capacity of Lake Wenatchee for sockeye fry in the absence of any observations for sizes of fall fry or subsequent smolts associated with abundance levels greater than 3000/ha.

Completed By: Kim Hyatt, Rick Ferguson, Don McQueen and Paul Rankin
Date: Nov. 16, 2013

References

Hyatt, K.D. and D.P. Rankin. 1999. A habitat based evaluation of Okanagan sockeye salmon escapement objectives. Canadian Stock Assessment Secretariat Research Document 99/181.

Table 1: Lake Wenatchee summer 2012 survey dates and samples collected.

Date Surveyed	Water chemistry average 1,3,5 and 25 m	Temperature and Oxygen	Secchi Depth m	Phytoplankton average 1,3,5 m water depth	Zooplankton 0-30 m water depth	Acoustic sampling	Fish trawling
04-Jun-12		x	x	x	x		
25-Jun-12	x	x	x	x		x	x
05-Jul-12		x	x	x	x		
08-Aug-12		x	x	x	x		
10-Sep-12				x	x		
18-Sep-12		x	x	x		x	x
06-Oct-12	x	x	x	x	x		

Table 2: Lake Wenatchee 2012 juvenile "nerkid" population estimates. To facilitate comparisons,
data from 2010 and 2011 are also shown.

Date Surveyed	Juvenile "nerkid" Abundance	Total Fish Density (#/hectare)	95% CI (%)	Mean length (mm)/fresh standard wt (g)	Comment #
21-Sep-2010	1,637,000	1,600	26%	58mm/2.02g	1
20-Sep-2011	2,300,000	2,300	29%	56mm/1.74g	1
01-Nov-2011	2,000,000	2,000	23%	62mm/2.69g	2
25-Jun-2012	1,700,000	1,700	25%	31mm/.27g	3
18-Sep-2012	2,800,000	2,800	25%	56mm/1.89g	1

1. No other fish were caught.

2. 2% of trawl catch (105) were clipped.
3. 2% (based on size) of trawl catch (102) were 1+.

Table 3: Osoyoos Lake juvenile nerkid population estimates during the 2012 survey year.

Survey date	Juvenile nerkid abundance per lake	Total fish density (per ha)	Mean length (cm)	Mean weight (g)
14-Jun-12	3,713,573	3,980	3.98	0.58
24-Jul-12	3,959,197	4,244	4.83	1.12
11-Sep-12	3,998,044	4,285	6.06	2.35
11-Oct-12	2,867,774	3,074	6.56	3.05
17-Nov-12	2,213,428	2,372	7.11	3.72
15-Feb-13	2,310,465	2,476	7.60	4.10

Appendix 1

Figures and additional tables

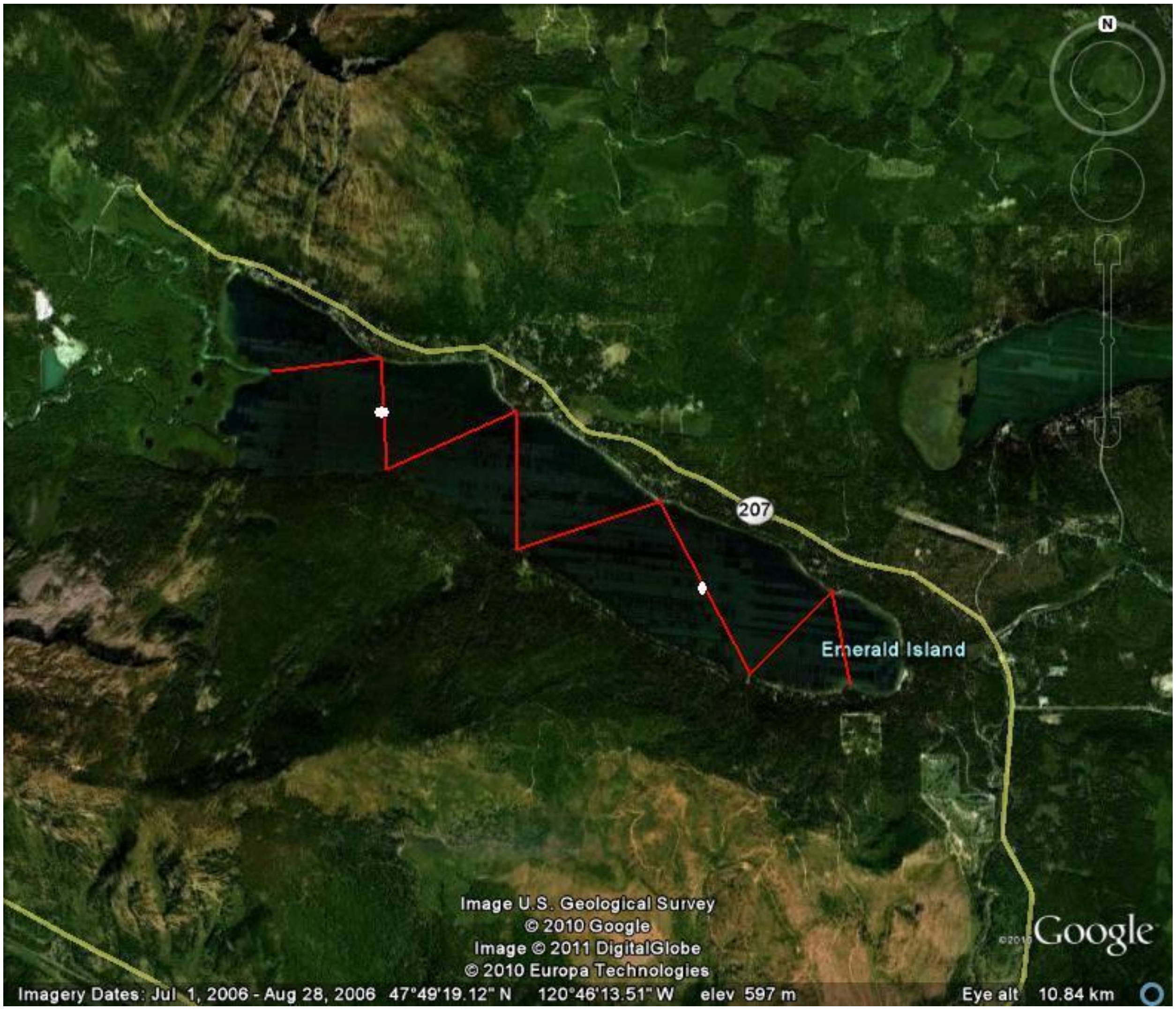

Figure 1: Google Earth map of Lake Wenatchee showing acoustic transects (red) and water/zooplankton sampling stations (white circles)

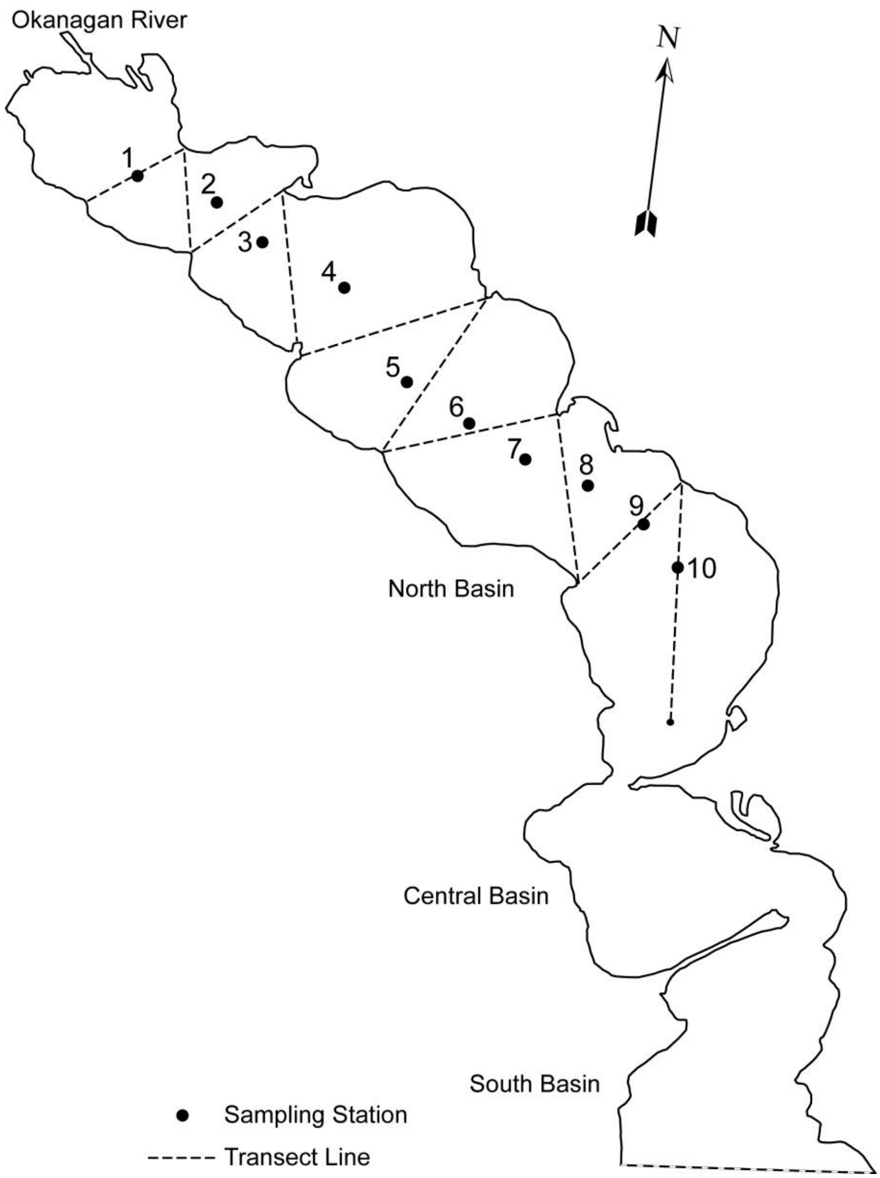

Figure 2: Osoyoos Lake North Basin, showing echosounding transects and water chemistry sampling stations

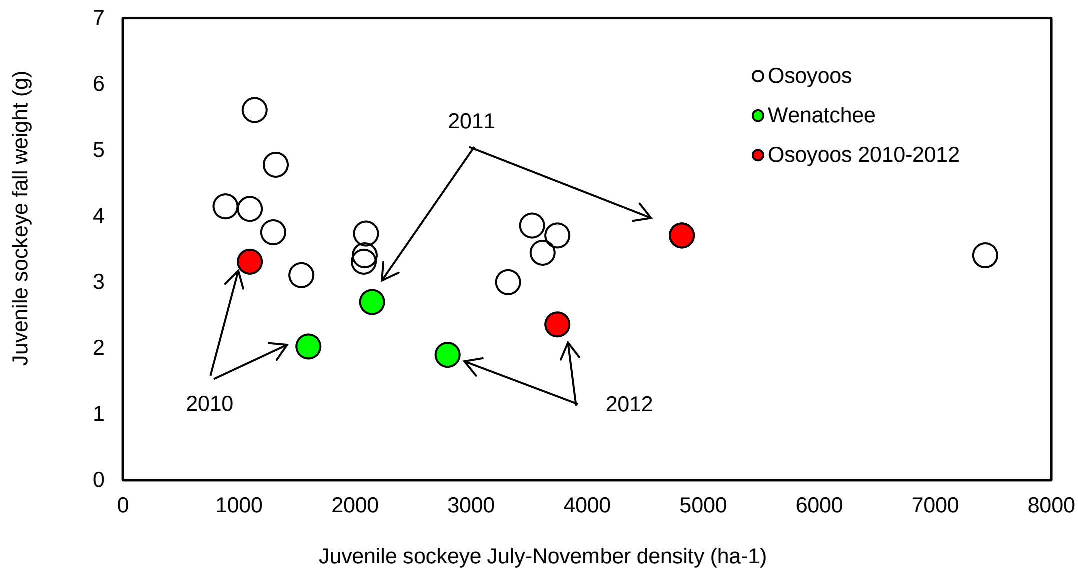

Figure 3: Lake Wenatchee 2010-2012 juvenile nerkid fall weights and Osoyoos Lake 1994-2012 juvenile nerkid fall weights. The Osoyoos Lake data (open symbols) were collected in November of each year and demonstrate that at juvenile densities between 1000-8000 fish ha^{-1}, density had little influence on growth rate. The Wenatchee fish were usually collected earlier in the fall (2010 = 21 September, 2011 = 01 November, and 2012 = 18 September). In order to achieve direct date-for-date comparisons the red symbols show juvenile sockeye weights in Osoyoos Lake on 02 October 2010, 28 November 2011, and 11 Sept 2012). Arrows indicate direct date-for-date and lake-to-lake comparisons for 2010, 2011 and 2012. During these years, Osoyoos Lake sockeye had fall weights that were 38%, 27% and 20% higher than comparable Lake Wenatchee juvenile sockeye.

Table 4: Lake Wenatchee Oxygen and temperature profiles. On all dates, the entire water column had water with oxygen concentrations > 4 ppm and cooler than 17 ^{O} C. These are the preference limits for juvenile sockeye suggesting that on all dates, the entire Lake Wenatchee water column was suitable for use by juvenile sockeye salmon.

Lake Wenatchee water temperature 2012

Water depth (m)	04-Jun-12	25-Jun-12	05-Jul-12	09-Aug-12	18-Sep-12	06-Oct-12
1	8.1	8.2	10.6	14.2	16.4	13.8
2	7.7	8.2	10.2	14.2	16.1	13.8
3	7.6		10.0	14.2		13.7
4	7.5	8.0	9.5	14.2	15.6	13.7
5	7.3		9.3	14.2		13.7
6	7.3	8.1	9.2	14.2	15.5	13.7
7	7.2		9.1	14.0		13.7
8	7.2	8.1	9.0	13.9	15.3	13.6
9	7.2		8.8	13.7		13.6
10	7.1	8.0	8.6	13.6	15.1	13.6
11	7.1		8.6	13.5		13.6
12	7.1	7.7	8.5	13.5	14.8	13.6
13	7.0		8.4	13.4		13.6
14	6.9	7.4	8.4	13.4	14.5	13.6
15	6.9		8.3	13.3		13.6
16	6.8	7.4	8.2	12.9	14.2	13.6
17	6.8		8.0	12.8		13.6
18	6.7	7.4	7.9	12.8	14.0	13.6
19	6.7		7.8	12.7		13.5
20	6.7	7.4	7.8	12.3	13.8	13.4
24	6.5	7.2	7.5	10.5	12.3	13.2
28	6.4	7.1	7.4	9.5	11.6	11.1
32	6.3		7.2	8.9		8.6
36	6.3		7.1	8.5		7.9
40	6.2		7.0	7.9		7.5
44	6.1		6.9	7.6		7.4
48	6.1		6.8	7.3		7.2
52	6.0		6.7	7.1		7.1
	5.8	5.5	5.9	4.3	6.5	7.2

Lake Wenatchee Oxygen concentrations (ppm) 2012

Water depth (m)	04-Jun-12	05-Jul-12	09-Aug-12	06-Oct-12
1	10.2	12.8	9.9	10.0
2	10.2	13.0	10.0	10.0
3	10.2	13.1	10.0	10.0
4	10.2	13.2	10.0	9.9
5	10.2	13.3	10.0	9.8
6	10.2	13.3	10.0	9.8
7	10.3	13.4	10.0	9.7
8	10.3	13.5	10.0	9.7
9	10.3	13.5	10.0	10.2
10	10.3	13.5	10.0	9.7
11	10.3	13.6	10.0	9.7
12	10.3	13.6	10.0	9.6
13	9.4	13.6	10.0	9.6
14	10.5	13.4	9.9	9.6
15	10.4	13.7	9.9	9.6
16	10.3	13.7	10.0	9.6
17	10.2	13.8	10.0	9.6
18	10.3	13.8	10.0	9.5
19	10.2	13.8	9.9	9.5
20	10.0	13.9	10.0	9.5
24	6.0	13.9	10.2	9.4
28	6.6	14.0	10.3	9.8
32	6.9	14.0	10.3	10.1
36	7.1	14.0	10.3	9.9
40	7.1	14.0	10.4	9.8
44	7.1	14.2	10.4	9.7
48	7.1	14.2	10.4	9.7
52	7.2	14.2	10.4	9.7

Table 5: Osoyoos Lake 2012 temperature profiles. Profiles were averaged from data collected at the North End and Monashee sites. The shaded area approximates water temperatures >17°C and thus avoided by juvenile sockeye.

Water depth (m)	11-Jun-12	16-Jul-12	26-Jul-12	07-Aug-12	13-Aug-12	20-Aug-12	27-Aug-12	04-Sep-12	11-Sep-12	17-Sep-12	24-Sep-12	30-Sep-12	11-Oct-12
1	14.9	22.5	22.4	23.8	23.8	24.4	21.9	20.2	19.0	18.6	18.6	18.0	15.6
2	14.6	22.5	22.0	23.6	23.8	24.4	21.9	20.1	19.2	18.6	18.6	18.0	15.6
3	14.6	22.4	21.9	23.2	23.6	24.4	21.9	20.0	19.0	18.5	18.6	18.0	15.4
4	14.0	22.2	21.8	23.0	23.3	24.4	21.9	20.0	19.1	18.5	18.5	18.0	15.3
5	13.9	21.8	21.8	22.4	23.2	24.3	21.9	19.9	19.1	18.5	18.5	17.9	15.3
6	13.7	21.6	21.6	22.0	22.8	24.3	21.9	19.9	19.1	18.4	18.4	17.8	15.2
7	13.5	20.3	21.3	21.8	22.5	24.0	21.8	19.9	19.1	18.4	18.3	17.8	15.2
8	13.5	18.6	21.1	21.6	22.4	23.7	21.8	19.8	19.0	18.3	18.2	17.8	15.2
9	13.4	17.6	20.6	21.4	22.2	22.8	21.8	19.8	18.9	18.2	18.1	17.8	15.2
10	13.4	16.7	20.0	20.3	20.7	22.0	21.7	19.7	18.9	18.2	18.0	17.7	15.1
11	12.8	16.1	18.9	19.3	18.6	19.8	21.6	19.6	18.7	18.0	18.0	17.7	15.1
12	12.4	15.5	17.0	18.0	17.2	16.2	19.9	19.3	18.5	17.8	17.8	17.6	15.0
13	11.4	13.7	15.3	15.4	15.8	13.8	14.9	18.2	17.4	17.7	17.7	17.3	14.9
14	11.0	12.8	14.0	13.5	13.3	11.4	12.2	16.1	15.2	17.0	17.2	16.8	14.9
15	9.4	11.3	12.8	12.6	11.8	10.2	11.1	11.8	12.6	14.8	15.7	16.3	14.7
16	8.8	9.8	11.6	11.5	10.1	9.5	9.6	10.5	10.6	11.6	11.7	14.6	14.0
17	8.2	9.1	10.3	10.1	9.3	9.0	9.1	9.7	9.4	10.3	10.0	12.3	12.9
18	7.9	8.7	9.5	9.5	8.8	8.7	8.9	8.9	9.2	9.7	9.4	10.1	11.3
19	7.7	8.4	9.1	8.9	8.5	8.5	8.7	8.6	9.0	9.2	9.0	9.4	10.5
20	7.6	8.2	8.7	8.5	8.3	8.4	8.4	8.5	8.8	8.9	8.8	9.0	9.5
24	7.3	7.8	8.0	8.1	8.1	8.1	8.1	8.2	8.5	8.5	8.5	8.5	8.9
28	7.3	7.6	7.8	7.9	7.9	8.0	8.0	8.1	8.4	8.4	8.4	8.4	8.6
32	7.2	7.5	7.7	7.8	7.9	7.9	7.9	8.0	8.3	8.2	8.3	8.3	8.4
36	7.2	7.5	7.7	7.8	7.8	7.8	7.9	8.0	8.2	8.2	8.3	8.3	8.5
40	7.2	7.5	7.7	7.7	7.8	7.8	7.9	8.0	8.2	8.2	8.2	8.2	8.5
44	7.2	7.5	7.6	7.7	7.8	7.8	7.9	7.9	8.2	8.2	8.2	8.2	8.4
48	7.1	7.5	7.6	7.6	7.7	7.7	7.8	7.9	8.2	8.2	8.2	8.2	8.4
52	7.1	7.4	7.5	7.6	7.7	7.7	7.8	7.9	8.1	8.2	8.2	8.1	8.4

Table 6: Osoyoos Lake 2012 oxygen profiles. Profiles are averaged from data collected at the North End and Monashee sites. The shaded area approximates oxygen concentrations < 4 ppm and thus avoided by juvenile sockeye.

Water depth (m)	11-Jun-12	26-Jul-12	07-Aug-12	13-Aug-12	20-Aug-12	27-Aug-12	04-Sep-12	11-Sep-12	17-Sep-12	24-Sep-12	30-Sep-12	11-Oct-12
1	11.1	8.5	8.7	8.8	8.9	8.7	8.8	9.0	9.2	9.7	9.7	10.1
2	11.0	8.4	8.7	8.9	8.9	8.7	8.7	8.8	9.2	9.7	9.6	10.0
3	11.0	8.3	8.6	8.9	9.0	8.7	8.6	8.8	9.2	9.8	9.6	10.1
4	10.9	8.2	8.6	8.9	9.0	8.8	8.6	8.8	9.2	9.8	9.6	10.0
5	10.7	8.3	8.6	8.9	9.1	8.7	8.6	8.8	9.2	9.7	9.5	10.0
6	10.5	8.3	8.4	8.7	9.1	8.7	8.5	8.8	9.1	9.7	9.4	9.9
7	10.5	8.0	8.3	8.6	9.0	8.7	8.5	8.8	9.1	9.7	9.2	9.8
8	10.5	8.0	8.1	8.5	9.0	8.7	8.4	8.7	9.1	9.3	9.2	9.8
9	10.5	7.8	7.9	8.2	8.6	8.7	8.2	8.6	8.9	9.0	9.1	9.7
10	10.4	7.7	7.6	7.2	8.1	8.7	8.2	8.5	8.8	8.7	9.0	9.6
11	10.5	7.5	7.0	6.0	7.6	8.6	8.3	8.3	8.7	8.6	9.0	9.5
12	10.4	7.1	6.6	5.6	5.9	8.0	8.2	8.2	8.5	8.5	9.0	9.4
13	10.4	6.8	6.2	5.6	5.5	5.5	7.5	7.5	8.4	8.3	8.8	9.3
14	10.1	6.6	6.3	5.7	5.5	5.2	5.9	5.5	7.5	8.0	8.3	9.2
15	10.0	6.6	6.2	5.8	5.6	5.1	5.2	5.2	6.2	7.2	7.7	9.1
16	10.0	6.7	6.2	6.1	5.7	5.3	4.8	4.8	4.6	6.6	6.7	8.7
17	10.1	6.7	6.4	6.2	5.9	5.5	4.8	4.5	4.2	4.6	5.2	8.2
18	10.1	6.8	6.4	6.3	6.0	5.5	4.9	4.4	4.1	4.2	4.1	6.8
19	10.1	6.8	6.5	6.3	6.1	5.6	5.0	4.4	4.1	4.1	3.6	5.1

20	10.1	6.8	6.5	6.3	6.1	5.6	5.0	4.4	4.1	4.0	3.5	4.1
24	10.0	6.7	6.5	6.2	6.1	5.6	4.9	4.4	4.1	3.9	3.5	3.6
28	10.0	6.7	6.5	6.1	5.9	5.4	4.8	4.4	4.1	3.8	3.5	3.2
32	9.8	6.7	6.3	5.9	5.7	5.2	4.6	4.3	4.0	3.6	3.2	2.8
36	9.8	6.3	6.2	5.9	5.7	5.1	4.4	4.2	3.8	3.8	3.5	2.9
40	9.8	6.3	6.1	5.8	5.7	5.0	4.2	4.1	3.8	3.7	3.4	2.7
44	9.8	6.2	6.0	5.7	5.7	4.9	4.2	4.1	3.8	3.7	3.4	2.6
48	9.6	6.2	6.0	5.7	5.5	4.9	4.2	4.0	3.8	3.7	3.3	2.6
52	9.6	6.1	5.9	5.6	5.4	4.9	4.2	4.0	3.8	3.6	3.1	2.5

Table 7: Lake Wenatchee 2012 Water chemistry on 25 June and 18 September 2012. Secchi depths (Table 4) averaged 5.9 m, epilimnetic total phosphorus (TP) averaged 5.9 µg/L and epilimnetic chlorophyll a averaged 1.0 µg/L. Hypolimnetic TP averaged 7.5 µg/L.

Date	Lake	Stations	Depth	Nitrate (µg/L)	TP (µg/L)	Chl a (µg/L)
25-Jun-12	Wenatchee	1	1,3,5 Epi	68.9	6.5	0.9
18-Sep-12	Wenatchee	Mean 1,2	1,3,5 Epi	0.4	5.2	1.2
25-Jun-12	Wenatchee	1	25 Hypo	71.3	7.4	
18-Sep-12	Wenatchee	Mean 1,2	25 Hypo	20.3	7.5	

Table 8: Osoyoos Lake 2012 water chemistry. Epi = epilimnetic data were derived from samples collected at 2 stations and averaged from water collected at 1,5,10 m. Hypo = hypolimnetic samples from water collected at 2 stations and averaged over 20, and 34m or 20 and 45m depending on station depth. Averages based on June and September data (comparable to the Wenatchee data): Secchi depth 3.2 m, epilimnetic total phosphorus (TP) 11.2 µg/L, epilimnetic chlorophyll a 2.5µg/L. Hypolimnetic TP 10.8 µg/L.

Sampling dates 2012	Stations	Epi TP (µg/L)	Epi TN (µg /L)	Chla (µg/L)	Secchi (m)	Hypo TP (µg/L)	Hypo TN (µg /L)
12-May-12	average 1,6	11.9	267	2.1	2.3	11.4	298
11-Jun-12	average 1,6	13.5	258	3.0	2.7	12.7	292
16-Jul-12	average 1,6	11.3	268	2.3	2.4	14.2	294
13-Aug-12	average 1,6	6.6	217	2.8	4.4	18.6	308
24-Sep-12	average 1,6	8.8	245	2.1	3.7	20.7	298
29-Oct-12	average 1,6	12.6	429	4.3	4.2	23.6	474

Table 9: Lake Wenatchee 2012 alkalinity and calcium concentrations compared with similar measures from three British Columbia oligotrophic, coastal lakes. Alkalinity and calcium are measures of buffering capacity. Laboratory work has suggested that when calcium concentrations fall below approximately 2 µg/L, cladocerans such as *Daphnia* may have difficulty producing carapace material. Lake Wenatchee had less calcium than the coastal lakes, but was above the “carapace restriction” limit.

Lake Wenatchee

Date	Lake	Stations	Depth		Total alkalinity µg/L	Na µg/L	Mg µg/L	Calcium µg/L
25-Jun-12	Wenatchee	1	1,3,5	Epi	12.84	0.81	0.62	2.52

British Columbia Coastal Lakes

Date	Lake	Stations	Depth		Total alkalinity µg/L	Na µg/L	Mg µg/L	Calcium µg/L
25-Jun-12	Sproat	Mean 1,2	1,3,5	Epi	31.7	1.0	0.7	9.5
25-Jun-12	Great Central	Mean 1,2	1,3,5	Epi	17.7	0.8	0.5	5.3
25-Jun-12	Henderson	Mean 1,2	1,3,5	Epi	11.2	12.9	1.7	3.4

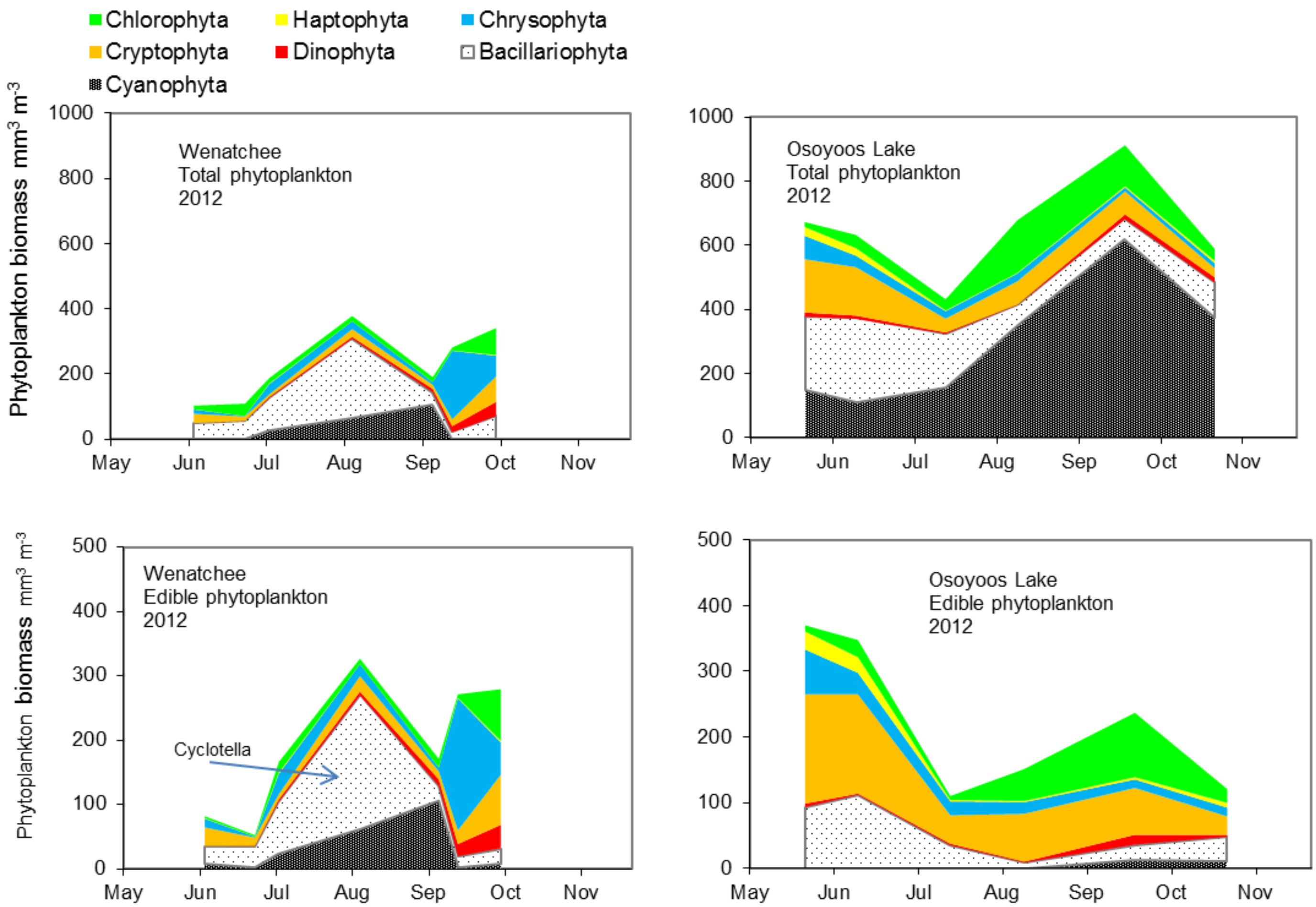

Figure 4: Lake Wenatchee total and edible phytoplankton (left-hand panels). **Osoyoos Lake total and edible phytoplankton** (right-hand panels). The goal of our phytoplankton counting procedure was to assess the relative availabilities of edible (grazable) and non-edible (non-grazable) algae. Edible algae comprise phytoplankton taxa that can be easily consumed by most zooplankton. In both lakes the dominant divisions were diatoms (Bacillariophyta), green algae (Chlorophyta), Chyrsophyta, and blue-green algae (Cyanophyta). In Osoyoos Lake, many of the diatom and blue-greens and some of the green algae were too large or too gelatinous to be consumed by zooplankton. In Lake Wenatchee, almost all of the available (i.e. total) phytoplankton were edible. Given that Lake Wenatchee total phosphorus concentrations were much lower than comparable Osoyoos Lake concentrations, Lake Wenatchee had an unexpectedly high abundance of phytoplankton suitable for consumption by zooplankton.

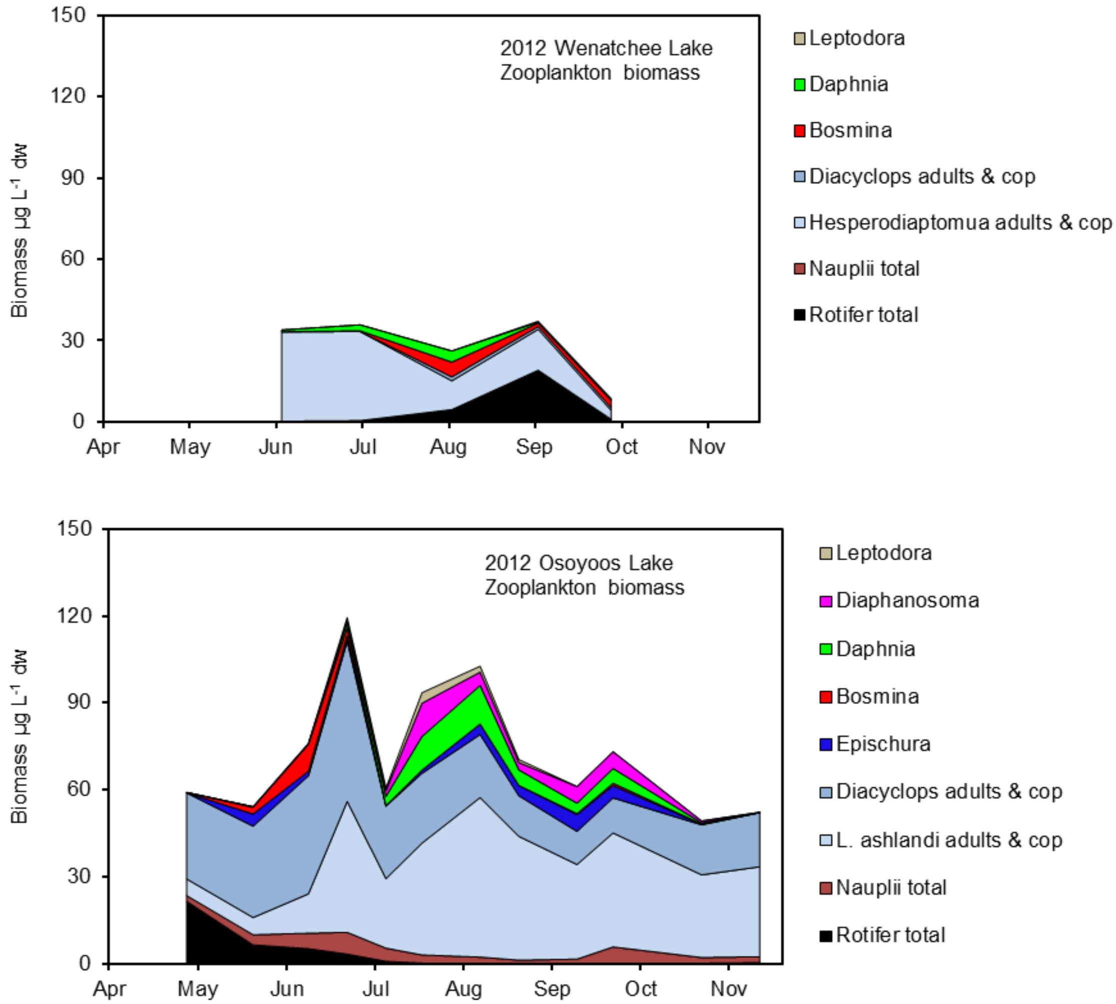

Figure 5: Wenatchee and Osoyoos Lake 2012 zooplankton biomass. The Osoyoos Lake biomasses were more than twice as high as the Lake Wenatchee biomasses. Among the cladocerans, both lakes had *Daphnia* and *Bosmina* but *Diaphanosoma* was found only in Osoyoos Lake. Among the copepods, both lakes had *Diacyclops bicuspidatus*, but Osoyoos Lake had *Leptodiaptomus ashlandi* while Lake Wenatchee had *Hesperodiaptomus kenai*. This single species substitution represents a major difference in the availability of zooplankton for fish. On average, *Leptodiaptomus* copepodids and adults weigh 2.5 µg dry weight and measure less than 1 mm in body length. The average weight for *Hesperodiaptomus* is >30 µg dry weight and the average body length is about 2 mm. This makes *Hesperodiaptomus* and important target for juvenile sockeye. In general, lower Lake Wenatchee total zooplankton biomasses suggest that Wenatchee sockeye should have grown at about half the rate of Osoyoos Lake juvenile sockeye. However, the presence of *Hesperodiaptomus* likely allowed Lake Wenatchee sockeye to hunt with greater efficiency (energy return per feeding strike was higher), suggesting a smaller than expected difference in sockeye growth rates. In fact during 2012, both Wenatchee and Osoyoos sockeye had similar lengths and weights in

June and by September, Lake Wenatchee sockeye were only 20% smaller than Osoyoos Lake sockeye.

APPENDIX C

Brood Year 2011 – Sockeye Smolt Out of Basin Survival Pilot Study in q'awsitk^{w} (Okanagan River)

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November 2013

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EXECUTIVE SUMMARY

Since 2003, the Okanagan Nation Alliance has conducted an experimental Sockeye Salmon (*Oncorhynchus nerka*) re-introduction into q'awst'ik'ʷt[1] (Skaha Lake). One main unanswered question is out of basin survival of both hatchery and natural Okanagan smolts. The Okanagan Basin Technical Working Group (COBTWG), conducted a pilot juvenile out of basin study to evaluate Juvenile Salmonid Acoustic Telemetry System (JSATS) and Passive Integrated Transponder (PIT) technology to test the methodology, efficiency of the system, and survival and travel time of smolts as the migrate out of the basin.

We deployed Lotek Wireless® WHS 4000 JSATS receivers in q'awsitkʷ (Okanagan River) at sx̌wəx̌wnikw (Town of Okanagan Falls) below the Skaha Lake Outlet Dam, Vertical Drop Structure 3 near the Town Oliver, suwiẇs (Osoyoos Lake), Zosel Dam at the outlet of suwiẇs in Washington State, and at Monse Bridge upstream of the nxˇʷəntkʷitkʷ (Columbia River) confluence. Each site was tested for receiver range and efficiency. From 24 April to 1 May 20, 2012 we captured and surgically implanted 68 smolts from q'awst'ik'ʷt and suwiẇs with JSATS transmitters. Tagged smolts were grouped into three release groups: q'awst'ik'ʷt (lake), suwiẇs (lake), and sx̌wəx̌wnikw (river). Following release, receivers detected outmigrating tagged smolts to Monse Bridge. Travel time to Monse for all smolts ranged from 5 – 31 days. Tagging mortality rate for the suwiẇs release group was highest (50%). Survival to Monse was highest in the sx̌wəx̌wnikw group (54%), followed by the suwiẇs group (11%), then the q'awst'ik'ʷt group (8%). The reason for the differential survival is not known, but could be related to stress due to capture method, lower survival for smolts passing through Skaha Lake Outlet Dam, size difference between hatchery and wild smolts, or premature expiration of the transmitter battery. Each site had varying levels of range and detection efficiency. Main recommendations include: repeating the pilot study for an additional year, then waiting until JSATS technology evolves to enable programmable tags with time-delay activation to conserve battery life; decrease stress on pre-smolts by decreasing time in the trawl net, and eliminate sites with poor detection efficiency and double receivers in a gate configuration at other sites.

From 24 April to 2 May, 2012, we implanted 559 smolts from q'awst'ik'ʷt with PIT tags. Overall survival to nxˇʷəntkʷitkʷ estuary was 14.9%, ranging from 27.5% to 115.5% for all dam locations (Rocky Reach, McNary, John Day, and Bonneville dams). Capture probabilities ranged from 0.06 to 0.31. Overall travel time to the estuary was 15 days. Although the sample size was low, results indicate a potentially powerful tool for estimating smolt out of basin survival. The main recommendation was to increase the sample size to a minimum of 5,000 tagged smolts, to improve the capacity to tag this number of smolts, and to increase the tagging study design to include suwiẇs smolts.

[1] throughout this report the proper Okanagan name written in N'Syilxcen will be used to identify locations

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Grant and Chelan Public Utility Districts (GCPUD and CCPUD), the Columbia River Inter Tribal Fisheries Commission (CRITFC) and the Bonneville Power Administration through the Columbia Basin Accords provided funding for this project. Dr. Kim Hyatt (Fisheries and Oceans Canada) provided direction for the study design. Mark Timko, Audrey Thompson, and Michael Meagher (Blue Leaf Environmental) provided valuable JSATS technical training and database support. Josh Murauskas (CCPUD) conducted the PIT queries and provided analysis of PIT results.

TABLE OF CONTENTS

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LIST OF OKANAGAN NAMES

Okanagan Place Names (Okanagan-English Translation)	
nx̆ʷəntkʷitkʷ	Columbia River
q̓awsitkʷ	Okanagan River
suwiw̓s	Osoyoos Lake
q̓awst'ik'ʷt, also known as t̓iwcən	Skaha Lake
akspaqmix	Vaseux Lake
nʕaylintən	McIntyre Dam
sx̌wəx̌wnikw	Okanagan Falls

1.0 INTRODUCTION

1.1 Project Background

In response to concerns over declining Sockeye Salmon (*Oncorhynchus nerka*) stocks in the Okanagan Basin, the Okanagan Nation Alliance (ONA) commenced sockeye salmon re-introduction into q'awst'ik'ʷt (Skaha Lake) beginning in 2003 (Wright and Smith 2003). Sockeye eggs collected from q'awsitkʷ (Okanagan River) broodstock are hatchery reared then released into q'awst'ik'ʷt, where they rear for one year before migrating to nx̌ʷəntkʷitkʷ (Columbia River) and the Pacific Ocean as smolts (Benson et al. 2011a; 2011b). One main unanswered question is out of basin survival of both hatchery and natural Okanagan smolts. The tri-partite research group comprised of the Columbia River Inter-Tribal Fish Commission (CRITFC), ONA, and the Canadian Department of Fisheries and Oceans (DFO) are mutually interested in determining the limiting factors affecting the abundance of Okanagan Sockeye. Broadly, the factors of concern are the freshwater outmigration, marine survival, and freshwater migratory return.

The Okanagan Basin Technical Working Group (COBTWG), consisting of DFO, ONA, and the Ministry of Forests, Lands, and Natural Resource Operations has proposed a pilot study to evaluate Juvenile Salmonid Acoustic Telemetry System (JSATS) technology to test the methodology, efficiency of the system, and survival and travel time of smolts as the migrate out of basin. Concurrently, a Passive Integrated Transponder (PIT) tagging pilot study will be conducted to assess methods for a larger scale PIT study.

Recent advances in technology have resulted in smaller acoustic transmitters and supported an increase in the use of acoustic telemetry to study juvenile salmonids. Based on the limitations of the existing technology in 2001, the Portland District of the U.S. Army Corps of Engineers (USACE) began development of a new acoustic telemetry system that would use an active transmitter small enough for implantation in the majority of the size distribution of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) emigrating through the Columbia Estuary. JSATS consists of microacoustic transmitters, receiving systems, and data management and processing applications (McMichael et al. 2010)

PIT tag technology has been used as a tool by researchers and fisheries managers in nx̌ʷəntkʷitkʷ Basin to mark and track anadromous fish since 1987. Currently, a comprehensive network of PIT arrays, tagging programs, and a data repository is operational in the Basin. The system is managed by the Pacific States Marine Fisheries Commission and funded by Bonneville Power Administration (BPA) (PTAGIS 1999). In 2009, CRITFC and ONA installed a PIT antenna in q'awsitkʷ upstream of suwiẁs (Osoyoos Lake) in order to track adults tagged at Wells Dam to the spawning grounds (Fryer et al. 2012). The existing PIT network will allow us to track tagged smolt survival rates and travel times during outmigration to evaluate the success of the PIT pilot study.

1.2 Study Area

q’awsitkʷ is a major tributary to nx˘ʷəntkʷitkʷ and has an approximate length of 185 km (37 km Canadian portion, 148 km US portion). q’awst’ik’ʷt smolts leave the lake and pass through Skaha Lake Outlet Dam located at sx̌wəx̌wnikw (Town of Okanagan Falls), then migrate down q’awsitkʷ through akspaqmix (Vaseux Lake), nʕaylintən (McIntyre Dam), and suwiw̓s (Figure 1). Sockeye that rear in the North Basin of suwiw̓s begin outmigration at similar times as q’awst’ik’ʷt sockeye smolts. Both travel downstream and pass through the Osoyoos Lake Narrows, a part of the lake that connects the Central and North Basin of the lake. From suwiw̓s the q’awsitkʷ flows south through the Okanogan County, past Okanogan and Omak. q’awsitkʷ enters nx˘ʷəntkʷitkʷ from the north, 8 km east of Brewster, between the Wells Dam (downstream) and the Chief Joseph Dam (upstream). The reservoir behind Wells Dam, into which q’awsitkʷ empties, is called Lake Pateros. Smolts must migrate through nine hydroelectric dams to reach the Pacific Ocean.

Figure 1. q’awsitk^{w} juvenile out of basin study site showing node locations.

1.3 Project Objectives

The main objective was to test the feasibility of JSATS and PIT tagging as methods to determine Sockeye smolt out of basin survival and travel time. The ultimate goal was to conduct a small scale study and assess methods in order to expand on a larger scale study in the future. Specific objectives included:

1. PIT tag up to 600 hatchery-origin smolts as they migrate from q’awst’ik’^{w}t.

2. Monitor PIT tagged smolt survival and travel rates to the nx̌^{w}əntk^{w}itk^{w} estuary.

3. Surgically implant a total of 70 Lotek® micro-transmitters into both q’awst’ik’^{w}t and suwiw̓s smolts just prior to outmigration.

4. Monitor and compare the survival of both acoustic-tag groups post-surgery.

5. Configure five receiver stations using Lotek JSATS receivers at various strategic locations on the q’awsitk^{w}. Test the range and efficiency of each location to determine optimal placement and configuration.

6. Download and manage receiver data and develop a streamlined method and database. Estimate survival and travel rates for implanted fish.

7. Synthesize an efficient study design and data management protocol that will address out of basin survival.

2.0 METHODS

2.1 JSATS Receiver Equipment, Site Selection, and Range Testing

We used six Lotek Wireless® JSATS compatible WHS 4000 autonomous data logging acoustic node receivers (Photo Plate 1). The WHS 4000 is a compact, lightweight, submersible data logging receiver that operates for 100 days with two D-cell lithium batteries and allows researchers to use the smallest acoustic tags available (0.25 g). The WHS 4000 is Lotek’s beta version JSATS node. Due to budgetary constraints and the experimental nature of the pilot study, the WHS 4000 was chosen as an appropriate system to field test.

Photo Plate 1. JSATS receiver.

We chose five station locations based on geography and accessibility. Beginning upstream, the site locations are the following (Figure 1):

1. sx̌wəx̌wnikw, below Skaha Lake Dam
2. Vertical Drop Structure (VDS) 3
3. Osoyoos Lake Narrows, at the Highway 3 Bridge
4. Upstream of Zosel Dam, Washington
5. Monse Bridge, Washington

We used three methods to deploy receivers. For shallow sites, the receiver was zap-strapped to a piece of rebar that was cemented with epoxy into the centre hole of a 25 cm x 25 cm pyramid shaped concrete block (Photo Plate 2). Once deployed, the block rested on the substrate while the receiver remained perpendicular. The hydrophone was typically 0.5 m or less below the water surface. Once in place, a rope was attached to the block and tied to the bank to prevent loss. A second method employed a custom made aluminum frame (1 m X 1 m base, 1.3 height) with the receiver attached at the top (Photo Plate 3). The frame was weighted with four pieces of angle iron. For both methods, we tied the anchoring device to the bank with a rope to prevent loss during high flows. The third method was used for the deepest locations. Two ten-pound mushroom anchors were attached to one end of a rope, and a buoy was attached to the other end. The receiver was then attached slightly below the buoy using zap-straps (Photo Plate 4). Once deployed the receiver hydrophone was within 1 m of the water surface.

Photo Plate 2. Pyramid block receiver configuration

Photo Plate 3. Aluminum frame receiver configuration.

Photo Plate 4. Anchor line receiver configuration.

A general approach for range testing was conducted at all five sites prior to smolt release. We launched the node at a potential location, and then placed an activated tag at a specific distance from the node for a set amount of time, typically for one hour. A second phase of the range test involved attaching an active tag to a weighted rope, then randomly traversing the vicinity of the node in a kayak or pontoon boat with the tag just below the water surface for a set time period. Following the field test, we would estimate a maximum number of tag pings (tag ping rate X total time tag was in water = max tag pings). The number of detections from each receiver was then divided by the maximum number of pings to estimate efficiency at each node location.

We tested tag battery life at three locations: sx̌wəx̌wnikw, VDS 3, and Monse Bridge. During receiver deployment, we attached an active transmitter directly above the hydrophone. The transmitter was placed in a plastic bag filled with river water, then taped to the rebar or anchor line with electrical tape. The purpose of this test was to obtain a more accurate estimate of battery life which would be affected by ambient river temperature.

2.2 Surgical Implantation

We employed two types of JSATS transmitter tags. The L-AMT-2.1 measured 11.8 mm (length), 5.1 mm (width), 3.8 mm (depth) and weighed 0.43 g in air. The estimated battery life was 33 days (5 second burst rate) to 46 days (7 second burst rate). The L-AMT-1.1 measured 11.2 mm (length), 5.1 mm (width), 2.9 mm (depth) and weighed 0.30 g in air. The estimated battery life was 22 days (5 second burst rate). For the *in situ* battery life test, both types were deployed.

Fish from q'awst'ik'ʷt and suwiw̓s were captured after sunset using short (10-30 minute) trawls and held at the lake foreshore using perforated aluminum kitoi boxes for 12-15 hrs before tagging. Surgical tagging was performed by experienced personnel using procedures outlined by LGL Limited (2011) and Warman and Bussanich (2011). Tagged fish were held for 8-12 hrs post-surgery to monitor recovery before being transported after sunset to the pelagic zone of their respective lake and released. Fish showing any signs of morbidity were not released. For quality assurance and control (QA/QC), a receiver was placed in the holding box for several hours prior to release to verify each tag was transmitting and being detected. In addition, a receiver was placed in the lake at the location of release and held for a minimum of 30 minutes, followed by mobile tracking, to verify detection in the lake and potentially monitor movement immediately after release.

We removed tags from mortalities and re-implanted them into a third group of smolts. We captured 37 fish with rotary screw traps (RSTs) at sx̌wəx̌wnikw and held them in an area of low flow in the same aluminum boxes for approximately 24 hrs prior to tagging. Tagging procedures, post-surgery holding, release, and QA/QC followed the same procedure described above, except the fish were released into an eddy in the river and mobile tracking was not conducted.

2.3 Data Filtering and Management

JSATS tags transmit a four character hexadecimal code in order to reduce the size of the tag for use in juvenile salmonids. A major disadvantage is that the system is susceptible to background noise and false detections. The WHS 4000 has a filter that can be set at a specific time interval to reduce background noise and false detections. We tested two receivers simultaneously at Monse, one without the filter, one set for 15 seconds. In order to detect and log signals, multiple signals needed to be greater than 15 seconds apart.

As part of the QA/QC component, we sent downloaded data to Blue Leaf Environmental Inc. (Ellensburg, WA) for data processing. Blue Leaf was able to filter out potential false detections using parameters such as transmitter pulse rate, number of contiguous detections, and filter interval. In addition, we manually sorted and processed all raw data to compare with Blue Leaf's output.

2.4 PIT Tagging Procedures

q'awst'ik'^{w}t smolts were captured downstream of Skaha Lake Outlet Dam during the smolt outmigration monitoring program (Benson and Warman 2012). Two RST's were set for 12-hour periods from 27 March to 20 April, 2012, then 24-hour periods from 20 April to 2 May, 2012. We checked live wells once or twice per day depending on peak outmigration. During morning checks, a sub-sample of captured smolts were kept in aluminum kitoi boxes positioned in the river downstream of the RSTs until tagging was complete.

We used procedures outlined by PTAGIS (1999) and Biomark (2012) for marking smolts. We deployed BIOMARK HPT 12 PIT tags (134.2 kHz) measuring 12.5 mm in length. The MK10 implanter manufactured by Biomark® was used for implanting tags. Fish were removed from kitoi boxes and placed in a 19-L (5-gal) pail containing a 5 mg/l solution of clove oil dissolved in ethanol. Fish were kept in the solution until they lost equilibrium. Smolts were then measured for fork length and general body condition was recorded. The tagging needle was inserted on the left side between the dorsal fin and lateral line, then the plunger was depressed until the tag was inserted into the incision hole. The tagged smolt was scanned and logged using an FS 2001 F-ISO reader (Destron Fearing™). Each PIT number was also recorded manually on data sheets. In addition, all PIT marked smolts were externally marked with an upper caudal fin clip. Following processing, each tagged fish was placed in a bucket of aerated water until fully recovered. All tagged smolts were returned to the kitoi boxes and released back into river the same day, typically between 22:00 and 24:00. Fish were released downstream of the Skaha Lake Outlet Dam and upstream of the RSTs.

3.0 RESULTS

3.1 Site Selection and Range Testing

Channel cross sections are presented (Figures 2-6). The depth data label indicates the approximate location of node deployment. Note that the scale differs for each figure.

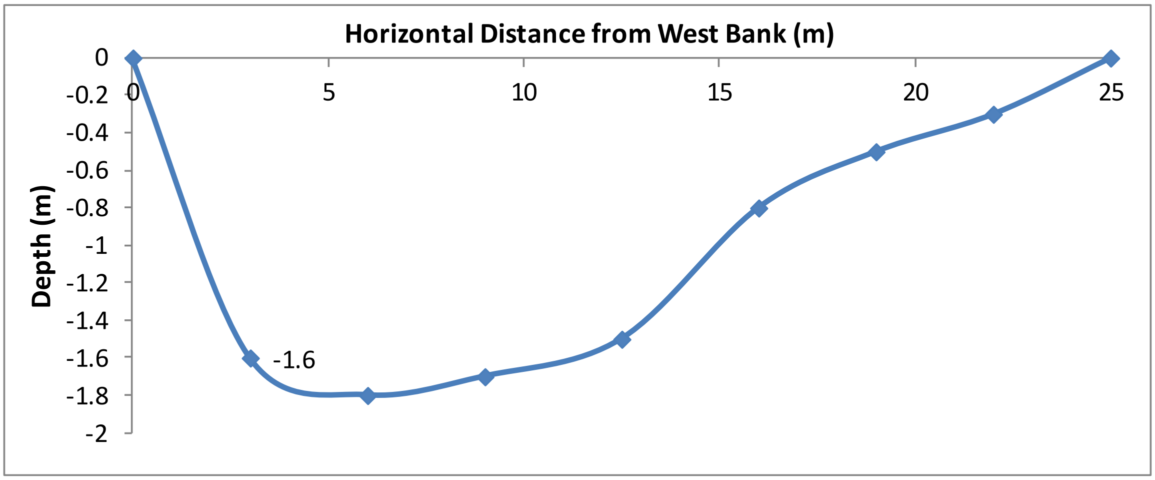

Figure 2. Cross-sectional profile of sx̌wəx̌wnikw site.

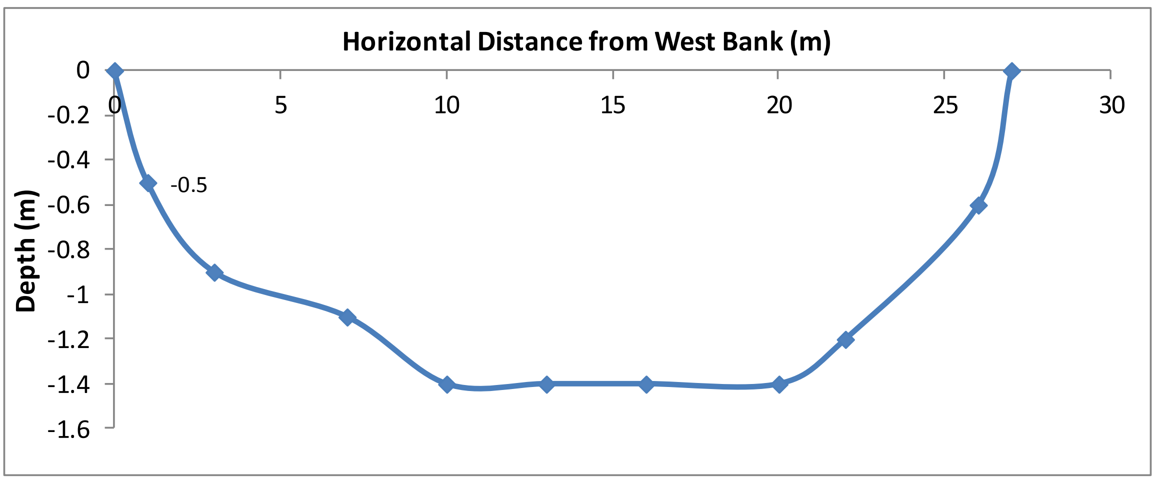

Figure 3. Cross-sectional profile of VDS 3 site.

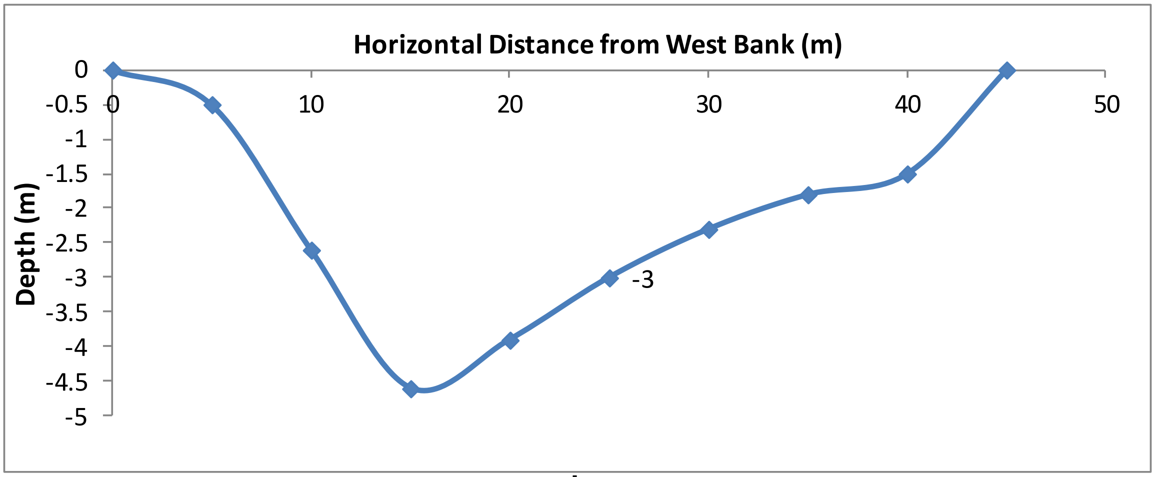

Figure 4. Cross-sectional profile of suwiw̓s site.

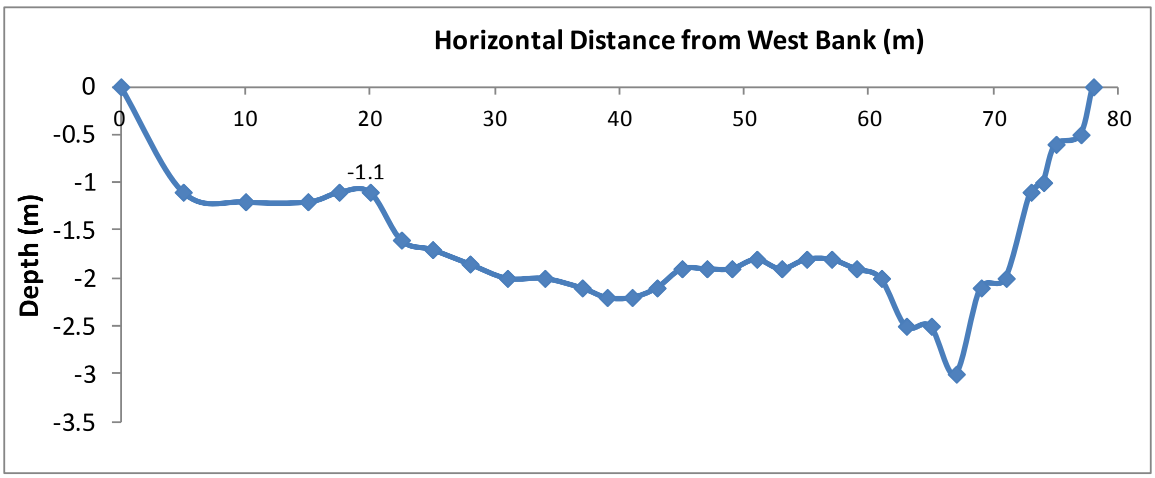

Figure 5. Cross-sectional profile of Zosel Dam site.

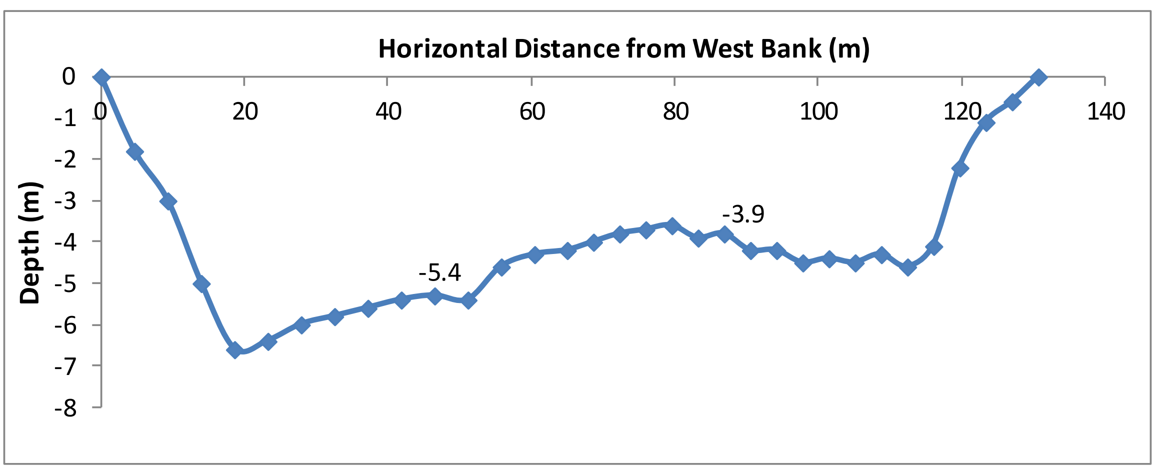

Figure 6. Cross-sectional profile of Monse Bridge site.

We successfully range tested one location at sx̌wəx̌wnikw, VDS 3, and suwiw̓s. Two successful locations were tested at Zosel Dam and Monse Bridge. Range tests were

conducted on 4 April (VDS 3), 5 April (sx̌wəx̌wnikw), 11 April (Zosel Dam), 12 April (Monse Bridge), and 25 April (suwiw̓s). Results of range tests are summarized (Table 1).

Table 1. Summary of q’awsitk^{w} JSATS range testing.

Site Name	Test distance (m)	Test efficiency (%)	(No filter)	Stream Width (m)
sx̌wəx̌wnikw	10.8	0.0%		25 m
	9.3	0.7%		
	20.0	0.0%		
VDS 3	52.9	0.0%		27 m
	26.4	41.6%		
	15.1	12.9%		
suwiw̓s	31.7	11.1%		45 m
	76.0	1.3%		
Zosel Dam	28.3	22.7%		78 m
	10.0	81.7%		
	21.8	28.0%		
	23.9	10.3%		
	11.2	10.2%		
	37.3	14.5%		
Monse Bridge	31.2	47.1%	43.6%	130 m
	52.6	0.0%	0.0%	
	45.3	51.8%	47.5%	
	34.4	22.6%		
	52.5	0.0%		
	58.8	13.7%		

Based on the field and pre-deployment lab tests, the 15-second filter reduced the false signals, sometimes by up to three orders of magnitude. More importantly, the filter increased the efficiency of detections, possibly by significantly reducing background noise (Table 1). Sites with the greatest efficiency were Zosel Dam, Monse Bridge, and VDS 3 (Table 1). Although reception efficiency is site dependant (substrate composition, water depth, noise and turbulence), the maximum effective range appears to be less than 50 m.

3.2 Surgical Implantation

We originally implanted 36 smolts from suwiw̓s and 14 from q’awst’ik’^{w}t. Following post surgery recovery, 18 from Osoyoos and 13 from Skaha were still alive (Table 2). Several days following pelagic smolt releases, 37 additional smolts from q’awst’ik’^{w}t

were tagged and released, with no mortalities following post-surgery (Table 2). Survival did not seem to be affected by tag type (L-AMT-1.1 vs. L-AMT-2.1).

Table 2. Spring 2012 Okanagan Sockeye smolt acoustic tagging summary.

Sockeye Smolt Origin	Capture Method/ Location	Capture Date	Taggin g Date	Water Temp (°C)	# Tagged Fish Released	Tagging Mortality Rate	Release Date	Release Location
Osoyoos (Wild)	Trawl suwiw̓s	24-Apr	25-Apr	12.6	18	50%	25-Apr	suwiw̓s Pelagic
Skaha (Hatchery)	Trawl q'awst'ik'ʷt	25-Apr	26-Apr	8.5	13	7%	26-Apr	q'awst'ik'ʷt Pelagic
Skaha (Hatchery)	RST at sx̌wəx̌wnikw	30-Apr	1-May	8.4	37	0%	1-May	sx̌wəx̌wnikw River

3.3 Data Filtering, Tag Fate, and Migration Timing

Blue Leaf's filtering protocol tended to be more conservative than our own manual filtering. For example, five contiguous detections are counted as three valid detections. The criteria worked for many solitary pings that were likely background noise and false detections. However, on several instances numerous detections were present within a two minute time span, yet were filtered out because there were not enough contiguous detections. Considering the potential noise level in many node locations, missed pings seemed probable. It is possible that an actual tagged smolt passed the node in a short time period, but was filtered out because there were several missed consecutive pings (e.g. over a two-minute period, there could be five to seven pings. This was likely a real fish, but would not be registered as a legitimate detection). The false detection issue was further complicated by the WHS 4000 filter set at 15 seconds.

The 37 river smolts were released in close proximity to the sx̌wəx̌wnikw receiver. Once in the eddy, smolts were allowed to enter the stream thalweg under their own volition. This explains the range of detections (1-1478) at the sx̌wəx̌wnikw receiver on May 1-2 (Table 3).

Results of the node detections by date are summarized (Tables 3 and 4). We assume that fish detected in Monse successfully made it out of the basin into nx̌ʷəntkʷitkʷ. The sx̌wəx̌wnikw release group appeared to have the highest survival, with 20 (54%) detected near at Monse Bridge (Table 3). The next highest survival was the suwiw̓s release group, with 2 (11%) detected at Monse (Table 4). The lowest survival was the q'awst'ik'ʷt release Group, with only one (8%) detected at Monse (Table 4).

Table 3. Summary of sx̌wəx̌wnikw Sockeye smolt release group detection history. Numbers is parentheses indicate the number of detections at each node. (n=37)

Tag ID	Release Location	Release Date	Detection Date by Node				
			sx̌wəx̌wnikw	VDS 3	suwiw̓s	Zosel Dam	Monse Bridge
FC84	OK Falls	1-May	1-May (23)		4-May (5)		7-May (5)
0EFD	OK Falls	1-May	1-May (128)		4-May (3)	7-May (9)	8-May (11)
AD01	OK Falls	1-May	1-May (659)		4-May (2)		8-May (6)
7713	OK Falls	1-May	1-May (9)		5-May (2)		8-May (4)
0A4B	OK Falls	1-May	1-May (214)		5-May (11)		
BE82	OK Falls	1-May	1-May (1)		5-May (3)		
B1CB	OK Falls	1-May	1-May (31)		7-May (4)	10-May (3)	11-May (2)
FE22	OK Falls	1-May	1-May (1)		7-May (3)		
1333	OK Falls	1-May	1-May (42)				
A35B	OK Falls	1-May	1-May (1)				
6E1B	OK Falls	1-May	1-May (42)				
9ADC	OK Falls	1-May	1-May (17)				
CA8D	OK Falls	1-May	1-May (91)				
98B3	OK Falls	1-May	1-May (80)		5-May (2)		6-May (3)
5420	OK Falls	1-May	1-May (201)	4-May (2)	5-May (3)		8-May (9)
7A6E	OK Falls	1-May	1-May (15)				
F332	OK Falls	1-May	1-May (73)				
7570	OK Falls	1-May	1-2 May (776)		6-May (8)		
8075	OK Falls	1-May	1-2 May (1478)			6-May (2)	7-May (2)
3374	OK Falls	1-May	1-2 May (506)				
8EB5	OK Falls	1-May			4-May (5)		6-May (3)
CC8C	OK Falls	1-May			4-May (7)		6-May (4)
DE0D	OK Falls	1-May			4-May (5)	5-May (3)	6-May (3)
0465	OK Falls	1-May			4-May (12)	5-May (9)	6-May (12)
A029	OK Falls	1-May			4-May (4)		6-May (3)
BF3B	OK Falls	1-May			4-May (2)		6-May (5)
B4C3	OK Falls	1-May			4-May (2)		7-May (3)
D96C	OK Falls	1-May			4-May (2)		7-May (2)
3089	OK Falls	1-May			4-May (8)	7-May (8)	8-May (12)
48A8	OK Falls	1-May			4-May (7)		
9979	OK Falls	1-May			5-May (10)		8-May (3)
57D5	OK Falls	1-May					6-May (18)
9455	OK Falls	1-May					9-May (19)
65CB	OK Falls	1-May					
30C3	OK Falls	1-May					
E4DC	OK Falls	1-May					
0351	OK Falls	1-May					

Table 4. Summary of suwiw̓s and q'awst'ik'ʷt Sockeye smolt release groups detection history. Numbers is parentheses indicate the number of detections at each node. (n=31)

Tag ID	Release Location	Release Date	Detection Date by Node: sx̌wəx̌wnikw	VDS 3	suwiw̓s	Zosel Dam	Monse Bridge
7C91	Osoyoos L	25-Apr			30-Apr (104)		
9F58	Osoyoos L	25-Apr			6-May (4)		
8291	Osoyoos L	25-Apr			10-May (4)		22-May (3)
500C	Osoyoos L	25-Apr			29-Apr to 1-May (19)		
E96A	Osoyoos L	25-Apr			2-4 May (24)		
505D	Osoyoos L	25-Apr					
AC81	Osoyoos L	25-Apr					
E3AE	Osoyoos L	25-Apr					
7310	Osoyoos L	25-Apr					
8069	Osoyoos L	25-Apr					
3D1D	Osoyoos L	25-Apr					
5F8E	Osoyoos L	25-Apr					
64A1	Osoyoos L	25-Apr					
8A77	Osoyoos L	25-Apr					
9DE3	Osoyoos L	25-Apr					
AB5C	Osoyoos L	25-Apr					
BA78	Osoyoos L	25-Apr					
C65B	Osoyoos L	25-Apr					26-May (2)
ACD0	Skaha L	26-Apr					10-May (4)
8753	Skaha L	26-Apr					
35EE	Skaha L	26-Apr					
43F4	Skaha L	26-Apr					
48BA	Skaha L	26-Apr					
508B	Skaha L	26-Apr					
6AA7	Skaha L	26-Apr					
BB3E	Skaha L	26-Apr		25-Apr (2)			
BDBE	Skaha L	26-Apr					
BEF0	Skaha L	26-Apr					
CA31	Skaha L	26-Apr					
DB47	Skaha L	26-Apr					
F1BF	Skaha L	26-Apr					

The out of basin travel time varied between the three groups. For the sx̌wəx̌wnikw group, average time from release to detection at Monse was 6.2 days (range 5-10 days). The two smolts from the suwiw̓s group had travel times of 27 and 31 days. The only q'awst'ik'ʷt smolt detected had a travel time of 14 days.

3.4 PIT Tagging Results

In total, 559 smolts were tagged during three tagging sessions: 24 April (n = 120), 30 April (n = 143), and 2 May (n = 296). Twenty eight smolts died immediately after surgery or in recovery tanks before release. Ten smolts were subsequently recaptured in the RST, euthanized, then bio-sampled. Complete tagging data has been summarized (Appendix A).

Mean overall survival from release to Bonneville Dam was 0.15 (SE 0.08) (Table 5, Figure 7). Mean survival between reaches ranged from 1.16 (Rocky Reach Dam to McNary Dam) to 0.28 (John Day Dam to Bonneville Dam) (Table 5, Figure 7). Mean overall travel time from release to Bonneville Dam was 15.5 days (Table 5, Figure 8). Capture probabilities ranged from 0.33 to 0.06 (Table 6).

Table 5. Mean survival and travel time for PIT tagged q'awst'ik'ʷt Sockeye smolts.

Period	Survival	SE	Travel time	SE
Release to Rocky Reach	0.5365	0.0768	7.79	0.20
Rocky Reach to McNary	1.1556	0.4376	3.92	0.22
McNary to John Day	0.8765	0.6464	2.33	0.18
John Day to Bonneville	0.2750	0.2360	1.47	0.06
Overall	0.1494	0.0844	15.52	0.62

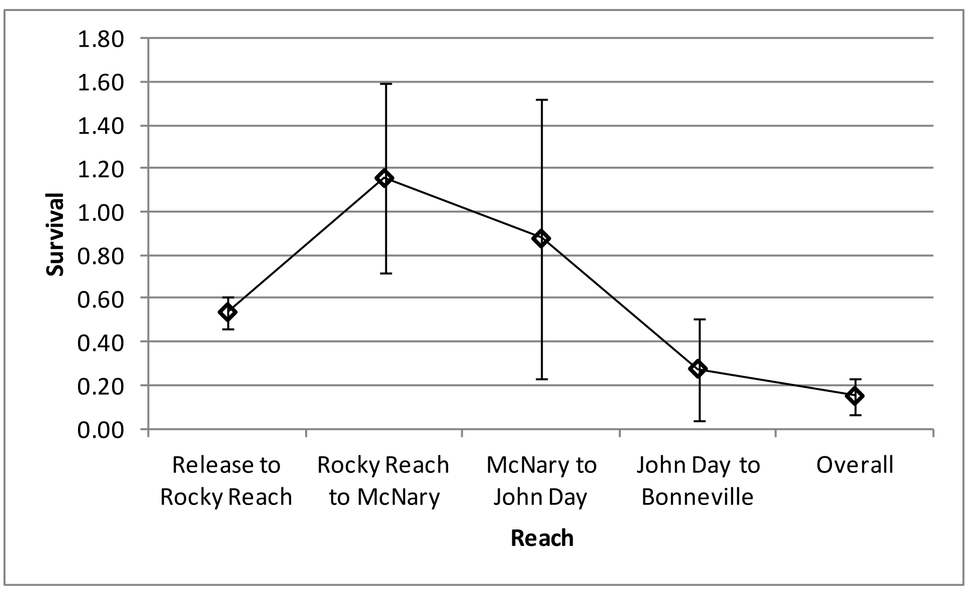

Figure 7. Mean survival for PIT tagged q'awst'ik'ʷt Sockeye smolts.

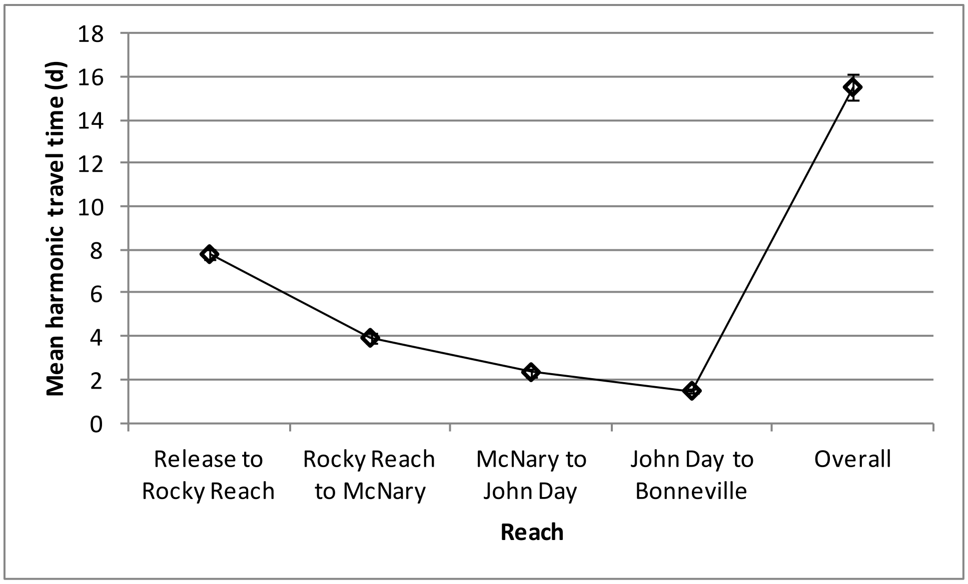

Figure 8. Mean travel time for PIT tagged q'awst'ik'ʷt Sockeye smolts.

Table 6. Capture Probabilities for PIT tagged q'awst'ik'ʷt Sockeye smolts.

Occasion	Capture Probability	SE
Rocky Reach	0.3095	0.0504
McNary	0.1250	0.0477
John Day	0.0645	0.0441
Bonneville	0.3333	0.1925

4.0 DISCUSSION AND RECOMMENDATIONS

JSATS is a promising new tool to study juvenile salmonid behavior and life history. The system has potential for further trial and implementation in the Okanagan Basin. This pilot study identified areas for improvement. Typically, the WHS 4000 receivers work best in deep water (A. Thompson, Blue Leaf Environmental Inc., *pers. comm.*). This explains the poor efficiency documented at sx̌wəx̌wnikw (Table 1) and VDS 3 (Table 3 and 4). This is also evident in the increased efficiency at the deeper Zosel Dam site (Table 1, Figure 5). Detection results indicate suwiw̓s and Monse Bridge had the greatest detection efficiency (Tables 3 and 4).

The suwiw̓s and q'awst'ik'ʷt release groups had the lowest survival based on post-surgery holding tests and overall detections following release. The reason for differential survival is not known and could be due to several reasons:

1. Pre-smolts may experience higher mortality because of stress due to trawling or being held in still water following surgery. However, the same methods were employed in 2011 and resulted in less than 1% mortality (Warman and Bussanich 2011). Water flow through the kitoi boxes (by placing boxes in the river or providing artificial flow in the lake) may increase post-surgery survival.

2. Survival rates of smolts through Skaha Lake Outlet Dam have not been documented and may explain the higher apparent mortality of the q'awst'ik'ʷt release group vs. the sx̌wəx̌wnikw release group. The node at sx̌wəx̌wnikw had low detection efficiency, and it is likely that tagged smolts migrating from q'awst'ik'ʷt were not detected.

3. suwiw̓s wild smolts are typically smaller than q'awst'ik'ʷt hatchery smolts (Benson et al. 2011b.), which may explain initial low survival following surgery due to higher relative tag burden.

4. Typically, peak smolt migration occurs near the beginning of May for both q'awst'ik'ʷt and suwiw̓s, but some smolt outmigrants can be detected until the beginning of June, particularly for suwiw̓s smolts (Benson et al. 2011b). It is possible that the approximately 30-day battery life (from 24-25 April) expired before smolts were detected by receivers.

Based on the most successful treatment group, out of basin survival was as high as 54%. The pooled survival for all three groups was 33.8%. The survival metrics are *ad hoc* (number detected / number tagged), and do not have statistical theory to estimate variance or confidence intervals. If detection efficiency can be increased to nearly 100%, we can use a maximum likelihood estimator and known fate model to estimate survival probability (Conroy et al. 1989; Bunck and Pollock 1993). Site efficiency can be increased by eliminating the shallow sites (sx̌wəx̌wnikw and VDS 3), and using the receivers to configure a gate-like positioning (two adjacent receivers spaced evenly to maximize coverage). Continue to range test sites with the new configuration to document node efficiency.

The program *SampleSize* (Columbia Basin Research, School of Aquatic & Fishery Sciences, University of Washington) was used to develop confidence intervals for a single-release survival estimates of juvenile Sockeye Salmon through the Columbia River Basin (Figure 9). Estimates require an assumed survival and detection probability at downstream locations. Lake Wenatchee-origin sockeye smolts were used to generate capture probabilities at McNary, John Day, and Bonneville; spring Chinook smolts released above Wells Dam were used to generate detection probabilities at Rocky Reach Dam. Survival probabilities were generated from spring Chinook releases above Wells Dam. Average values from these observations were used as assumptions in the program. Based on the sample size analysis, a minimum of 5,000 PIT tags would be optimal for estimating survival (Figure 9).

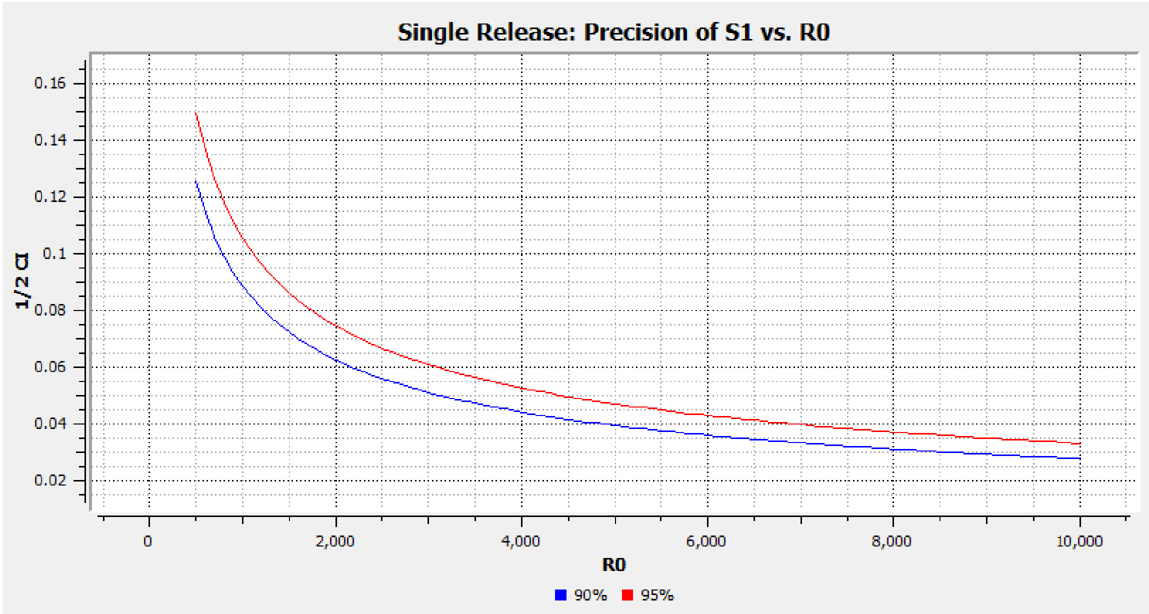

Figure 9. Estimated one-half confidence intervals (1/2 CI) vs. release size (R0) of smolts released above Rocky Reach Dam.

We propose the following recommendations for the 2012 study:

- Decrease the stress on trawled smolts by decreasing time in the trawl net and by placing caught fish in a current (either in the river or artificially).
- In order to decrease the ambiguity of false detections, use less conservative filtering criteria, such as a minimum number of pings in a two minute time span.
- The aluminum kitoi boxes are not suitable for QA/QC and post-surgical mortality monitoring due to reflection of signals in a confined space (H.Tam, LOTEK Wireless, *pers. comm.*). An alternate net pen that does not reflect signals should be used to hold smolts following surgery.
- Do not launch sx̌wəx̌wnikw and VDS 3 receivers and double up receivers at suwiw̓s, Zosel Dam, and Monse Bridge.
- Current JSATS technology limitations do not allow for programmable transmitters with time-delay activation. Such a feature would enable us to implant a transmitter, QA/QC to ensure tags are transmitting, then have the tag shut off temporarily. After a set amount of time, tags will activate before smolts leave the system and allow for tracking as they outmigrate. This configuration will conserve battery life and allow for longer tracking. We recommend continuing the pilot study for one more year, then waiting until JSATS technology can develop time-delay activation tags.
- Status quo for PIT methodologies with additional site validation trials.

- Increase the number of PIT tagged smolts (n = 5,000), and add suwiw̓s as a tagging site. Develop the logistics and capacity to enable tagging the recommended sample size.

5.0 REFERENCES

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APPENDIX A. Sockeye smolt PIT tagging biological data

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
24-Apr-12	1	Missing		10.9	Note: Started to record tag no's only in wand and planned to download later, but at fish no. 6 decided to record by hand as back up. Data from PIT reader was lost. Tag numbers recorded manually therefore some risk of transcription error.
24-Apr-12	2	Missing		11.4	
24-Apr-12	3	Missing		12.8	
24-Apr-12	4	Missing		11.5	
24-Apr-12	5	Missing		11.0	
24-Apr-12	6	3D9.1C2D		11.4	
24-Apr-12	7	3D9.1C2D	B6A372	11.0	
24-Apr-12	8	3D9.1C2D	B72A0C	12.2	
24-Apr-12	9	3D9.1C2D	B71408	11.2	SCALE LOSS
24-Apr-12	10	3D9.1C2D	B69EED	11.4	
24-Apr-12	11	3D9.1C2D	B6BAC7	10.7	
24-Apr-12	12	3D9.1C2D	B506D7	13.0	
24-Apr-12	13	3D9.1C2D	B6EAC5	12.3	
24-Apr-12	14	3D9.1C2D	B514D2	11.1	
24-Apr-12	15	3D9.1C2D	B30251	12.3	
24-Apr-12	16	3D9.1C2D	B71A82	11.4	
24-Apr-12	17	3D9.1C2D	B5472C	11.9	
24-Apr-12	18	3D9.1C2D	B52EC2	11.9	
24-Apr-12	19	3D9.1C2D	B6A598	10.9	
24-Apr-12	20	3D9.1C2D	B6D038	11.4	
24-Apr-12	21	3D9.1C2D	B70683	12.8	
24-Apr-12	22	3D9.1C2D	B7237D	11.5	
24-Apr-12	23	3D9.1C2D	B771C7	11.9	
24-Apr-12	24	3D9.1C2D	AC3D0F	9.7	
24-Apr-12	25	3D9.1C2D	B6DD0B	10.9	
24-Apr-12	26	3D9.1C2D	B7334E	10.5	
24-Apr-12	27	3D9.1C2D	B7209C	12.4	
24-Apr-12	28	3D9.1C2D	B69F4E	12.2	
24-Apr-12	29	3D9.1C2D	B6FEDB	10.6	
24-Apr-12	30	3D9.1C2D	B7347A	11.2	
24-Apr-12	31	3D9.1C2D	B69F53	11.7	
24-Apr-12	32	3D9.1C2D	B6E1D2	12.1	
24-Apr-12	33	3D9.1C2D	B5F484	10.4	
24-Apr-12	34	3D9.1C2D	B6C7C5	12.4	
24-Apr-12	35	3D9.1C2D	B6D81A	12.0	
24-Apr-12	36	3D9.1C2D	B7CBD1	10.2	
24-Apr-12	37	3D9.1C2D	B6F57A	12.6	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
24-Apr-12	38	3D9.1C2D	B6AEF2	11.1	
24-Apr-12	39	3D9.1C2D	B6DA8D	11.5	
24-Apr-12	40	3D9.1C2D	B70C7E	11.7	
24-Apr-12	41	3D9.1C2D	B7346A	11.4	
24-Apr-12	42	3D9.1C2D	B71B46	10.3	
24-Apr-12	43	3D9.1C2D	B71A3F	11.1	
24-Apr-12	44	3D9.1C2D	B4FB12	11.3	
24-Apr-12	45	3D9.1C2D	B6C154	11.3	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
24-Apr-12	46	3D9.1C2D	B724A1	10.6	
24-Apr-12	47	3D9.1C2D	B73237	11.9	
24-Apr-12	48	3D9.1C2D	BC30C4	11.5	
24-Apr-12	49	3D9.1C2D	B72DC3	12.1	
24-Apr-12	50	3D9.1C2D	B6AA22	12.1	
24-Apr-12	51	3D9.1C2D	B700C8	11.4	
24-Apr-12	52	3D9.1C2D	B70E72	11.6	
24-Apr-12	53	3D9.1C2D	B72EE8	12.4	
24-Apr-12	54	3D9.1C2D	B6125F	11.6	
24-Apr-12	55	3D9.1C2D	B5971A	10.8	
24-Apr-12	56	3D9.1C2D	B6F847	12.0	
24-Apr-12	57	3D9.1C2D	B6C5FA	13.2	SCALE LOSS
24-Apr-12	58	3D9.1C2D	B6C903	12.0	
24-Apr-12	59	3D9.1C2D	B6C18E	11.2	
24-Apr-12	60	3D9.1C2D	B72513	13.2	
24-Apr-12	61	3D9.1C2D	B5E59A	10.8	
24-Apr-12	62	3D9.1C2D	B6BC02	11.1	
24-Apr-12	63	3D9.1C2D	B7335C	11.6	
24-Apr-12	64	3D9.1C2D	B69F57	12.0	
24-Apr-12	65	3D9.1C2D	B61ED0	11.3	
24-Apr-12	66	3D9.1C2D	B70CB1	11.7	
24-Apr-12	67	3D9.1C2D	B72586	11.2	
24-Apr-12	68	3D9.1C2D	B520B6	11.3	
24-Apr-12	69	3D9.1C2D	B69EAF	11.9	
24-Apr-12	70	3D9.1C2D	B72A55	12.3	
24-Apr-12	71	3D9.1C2D	B4F7B6	11.6	
24-Apr-12	72	3D9.1C2D	B24DB4	12.1	BRIEFLY DROPPED
24-Apr-12	73	3D9.1C2D	BC47C9	12.1	
24-Apr-12	74	3D9.1C2D	B70D6A	11.0	
24-Apr-12	75	3D9.1C2D	B79C9A	12.8	
24-Apr-12	76	3D9.1C2D	B732CB	10.9	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
24-Apr-12	77	3D9.1C2D	B1AACD	12.4	
24-Apr-12	78	3D9.1C2D	B71A47	11.1	
24-Apr-12	79	3D9.1C2D	B71326	11.9	
24-Apr-12	80	3D9.1C2D	B69E50	12.6	
24-Apr-12	81	3D9.1C2D	B706BF	11.2	
24-Apr-12	82	3D9.1C2D	B72037	10.3	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
24-Apr-12	83	3D9.1C2D	B6B5F7	11.9	
24-Apr-12	84	3D9.1C2D	B5F439	10.9	
24-Apr-12	85	3D9.1C2D	B30CD8	11.4	
24-Apr-12	86	3D9.1C2D	AC10DE	11.7	
24-Apr-12	87	3D9.1C2D	B6BB70	12.0	
24-Apr-12	88	3D9.1C2D	B6B827	13.4	
24-Apr-12	89	3D9.1C2D	B6F22D	10.7	
24-Apr-12	90	3D9.1C2D	B507B4	11.2	
24-Apr-12	91	3D9.1C2D	B6DEFB	11.7	
24-Apr-12	92	3D9.1C2D	B4EB03	13.1	
24-Apr-12	93	3D9.1C2D	B6A5E4	10.4	
24-Apr-12	94	3D9.1C2D	B6AA31	9.3	
24-Apr-12	95	3D9.1C2D	B6EDCF	11.1	
24-Apr-12	96	3D9.1C2D	B6C291	12.3	TAG POSITIONED SLIGHTLY ANTERIOR
24-Apr-12	97	3D9.1C2D	B4FADE	12.4	
24-Apr-12	98	3D9.1C2D	B53D43	12.0	
24-Apr-12	99	3D9.1C2D	AD77E8	10.8	MORTALITY
24-Apr-12	100	3D9.1C2D	B6E73A	10.8	
24-Apr-12	101	3D9.1C2D	B727C5	10.8	
24-Apr-12	102	3D9.1C2D	B1BD7E	10.7	
24-Apr-12	103	3D9.1C2D	B00251	11.8	
24-Apr-12	104	3D9.1C2D	B30EBB	11.9	SCALE LOSS
24-Apr-12	105	3D9.1C2D	B71C54	12.6	
24-Apr-12	106	3D9.1C2D	B4FB0E	11.1	
24-Apr-12	107	3D9.1C2D	B6C353	11.1	
24-Apr-12	108	3D9.1C2D	B63965	10.2	
24-Apr-12	109	3D9.1C2D	B4D331	11.8	
24-Apr-12	110	3D9.1C2D	B53C28	11.4	BLED A LITTLE
24-Apr-12	111	3D9.1C2D	B2837D	10.7	
24-Apr-12	112	3D9.1C2D	B00F04	11.9	
24-Apr-12	113	3D9.1C2D	B6A2A0	12.6	
24-Apr-12	114	3D9.1C2D	BD4FB9	10.7	
24-Apr-12	115	3D9.1C2D	B7CC73	11.2	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
24-Apr-12	116	3D9.1C2D	B6BC7F	11.7	
24-Apr-12	117	3D9.1C2D	B02977	11.8	
24-Apr-12	118	3D9.1C2D	B6C1DB	11.7	
24-Apr-12	119	3D9.1C2D	ADA5C6	11.7	
24-Apr-12	120	3D9.1C2D	B01757	12.7	
30-Apr-12	1	3D9.1C2D	_AD926	11.6	
30-Apr-12	2	3D9.1C2D	B74927	11.2	
30-Apr-12	3	3D9.1C2D	B4D426	10.9	
30-Apr-12	4	3D9.1C2D	B51342	11.1	
30-Apr-12	5	3D9.1C2D	__8364	10.4	
30-Apr-12	6	3D9.1C2D	AFD5B7	10.8	
30-Apr-12	7	3D9.1C2D	B4C74E	13.5	
30-Apr-12	8	3D9.1C2D	B2A2F9	11.4	
30-Apr-12	9	3D9.1C2D	AFF09F	10.7	
30-Apr-12	10	3D9.1C2D	B00A21	10.7	
30-Apr-12	11	3D9.1C2D	B547B8	11.5	
30-Apr-12	12	3D9.1C2D	B4F894	12.5	
30-Apr-12	13	3D9.1C2D	B4DCD1	12.1	
30-Apr-12	14	3D9.1C2D	B6FB91	12.1	
30-Apr-12	15	3D9.1C2D	B54642	11.0	
30-Apr-12	16	3D9.1C2D	B1A709	10.4	
30-Apr-12	17	3D9.1C2D	B0210A	10.9	
30-Apr-12	18	3D9.1C2D	B02816	12.1	
30-Apr-12	19	3D9.1C2D	B5125C	11.2	
30-Apr-12	20	3D9.1C2D	AFD241	10.1	
30-Apr-12	21	3D9.1C2D	B1F32D	10.0	
30-Apr-12	22	3D9.1C2D	AFDB1A	13.0	
30-Apr-12	23	3D9.1C2D	B014C3	12.1	
30-Apr-12	24	3D9.1C2D	B53C83	12.3	
30-Apr-12	25	3D9.1C2D	B0193C	11.0	
30-Apr-12	26	3D9.1C2D	B4FB2C	11.4	
30-Apr-12	27	3D9.1C2D	B1ACD6	11.4	
30-Apr-12	28	3D9.1C2D	B71695	10.9	
30-Apr-12	29	3D9.1C2D	AFF191	11.6	
30-Apr-12	30	3D9.1C2D	B6FA49	11.4	
30-Apr-12	31	3D9.1C2D	B7203B	11.4	
30-Apr-12	32	3D9.1C2D	B51509	11.8	
30-Apr-12	33	3D9.1C2D	AD55C0	12.5	
30-Apr-12	34	3D9.1C2D	B5469C	12.2	
30-Apr-12	35	3D9.1C2D	B00EBC	12.4	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
30-Apr-12	36	3D9.1C2D	B02107	12.4	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
30-Apr-12	37	3D9.1C2D	AC24FA	11.3	
30-Apr-12	38	3D9.1C2D	B02010	12.2	
30-Apr-12	39	3D9.1C2D	B520B3	9.5	
30-Apr-12	40	3D9.1C2D	B52EDE	12.5	
30-Apr-12	41	3D9.1C2D	B10357	11.9	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
30-Apr-12	42	3D9.1C2D	AFE8C7	11.9	
30-Apr-12	43	3D9.1C2D	B4C869	11.1	
30-Apr-12	44	3D9.1C2D	ADA5B0	10.8	
30-Apr-12	45	3D9.1C2D	B53A07	11.5	
30-Apr-12	46	3D9.1C2D	AFD4AA	10.9	
30-Apr-12	47	3D9.1C2D	B4D32B	10.8	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
30-Apr-12	48	3D9.1C2D	B022ED	11.9	
30-Apr-12	49	3D9.1C2D	B515CF	10.9	
30-Apr-12	50	3D9.1C2D	B028F3	11.5	
30-Apr-12	51	3D9.1C2D	B1290A	12.1	
30-Apr-12	52	3D9.1C2D	AD7939	11.5	
30-Apr-12	53	3D9.1C2D	B78047	13.4	
30-Apr-12	54	3D9.1C2D	B7289B	10.5	
30-Apr-12	55	3D9.1C2D	AFD4D7	10.5	
30-Apr-12	56	3D9.1C2D	AFF9FB	11.2	
30-Apr-12	57	3D9.1C2D	B5079B	11.6	
30-Apr-12	58	3D9.1C2D	AFC3BF	10.4	
30-Apr-12	59	3D9.1C2D	B24614	11.2	
30-Apr-12	60	3D9.1C2D	B5B181	10.8	
30-Apr-12	61	3D9.1C2D	AD3AF7	11.5	
30-Apr-12	62	3D9.1C2D	AFDF31	11.8	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
30-Apr-12	63	3D9.1C2D	AFFE2B	11.4	
30-Apr-12	64	3D9.1C2D	B4DCFC	11.3	
30-Apr-12	65	3D9.1C2D	AFC1C2	11.4	
30-Apr-12	66	3D9.1C2D	ADA3C8	11.6	
30-Apr-12	67	3D9.1C2D	B4EA30	10.7	
30-Apr-12	68	3D9.1C2D	B2DFB5	11.7	
30-Apr-12	69	3D9.1C2D	B73281	10.6	
30-Apr-12	70	3D9.1C2D	B6D33E	11.2	
30-Apr-12	71	3D9.1C2D	B72BBF	11.2	
30-Apr-12	72	3D9.1C2D	B6E71B	10.9	
30-Apr-12	73	3D9.1C2D	B24D17	12.3	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
30-Apr-12	74	3D9.1C2D	B49129	14.1	
30-Apr-12	75	3D9.1C2D	B72386	11.4	
30-Apr-12	76	3D9.1C2D	B7549F	11.0	
30-Apr-12	77	3D9.1C2D	B7B366	12.2	
30-Apr-12	78	3D9.1C2D	B7B7ED	12.3	
30-Apr-12	79	3D9.1C2D	B62C80	11.4	
30-Apr-12	80	3D9.1C2D	B1DEEE	11.4	
30-Apr-12	81	3D9.1C2D	B6C247	12.1	
30-Apr-12	82	3D9.1C2D	B6C1F9	10.2	
30-Apr-12	83	3D9.1C2D	ADA5B4	10.9	
30-Apr-12	84	3D9.1C2D	B6C914	14.1	
30-Apr-12	85	3D9.1C2D	B70ABA	11.2	
30-Apr-12	86	3D9.1C2D	AC081E	10.8	
30-Apr-12	87	3D9.1C2D	B7171A	12.3	
30-Apr-12	88	3D9.1C2D	B7151D	11.1	
30-Apr-12	89	3D9.1C2D	B61E94	10.8	
30-Apr-12	90	3D9.1C2D	AC08BB	10.3	
30-Apr-12	91	3D9.1C2D	B6C824	10.3	
30-Apr-12	92	3D9.1C2D	B6FD86	10.5	
30-Apr-12	93	3D9.1C2D	B522F4	12.3	
30-Apr-12	94	3D9.1C2D	B507A6	11.1	
30-Apr-12	95	3D9.1C2D	B23F64	11.5	
30-Apr-12	96	3D9.1C2D	B6AFFD	9.3	
30-Apr-12	97	3D9.1C2D	B69C81	11.6	
30-Apr-12	98	3D9.1C2D	B6A555	11.4	
30-Apr-12	99	3D9.1C2D	B6EAF9	10.9	
30-Apr-12	100	3D9.1C2D	B7237A	11.4	
30-Apr-12	101	3D9.1C2D	B5C745	11.3	
30-Apr-12	102	3D9.1C2D	B6C630	11.4	
30-Apr-12	103	3D9.1C2D	AD78D6	10.6	
30-Apr-12	104	3D9.1C2D	B732B4	11.0	
30-Apr-12	105	3D9.1C2D	B53B3E	10.5	
30-Apr-12	106	3D9.1C2D	B6B55C	11.6	
30-Apr-12	107	3D9.1C2D	B6F8C4	12.3	
30-Apr-12	108	3D9.1C2D	B7347C	12.4	
30-Apr-12	109	3D9.1C2D	B72055	11.7	
30-Apr-12	110	3D9.1C2D	B6B914	10.1	
30-Apr-12	111	3D9.1C2D	B6D0CE	11.6	
30-Apr-12	112	3D9.1C2D	B70D9D	11.7	
30-Apr-12	113	3D9.1C2D	B6DECC	9.9	RECAPTURED IN RST + TAKEN FOR

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
					BIOSAMPLING
30-Apr-12	114	3D9.1C2D	B01FEF	11.4	
30-Apr-12	115	3D9.1C2D	B27775	11.5	
30-Apr-12	116	3D9.1C2D	B6B876	10.5	
30-Apr-12	117	3D9.1C2D	B7519C	9.5	
30-Apr-12	118	3D9.1C2D	B733A6	12.5	
30-Apr-12	119	3D9.1C2D	B78E61	11.3	
30-Apr-12	120	3D9.1C2D	B7AFB4	11.3	
30-Apr-12	121	3D9.1C2D	B6AFF2	11.6	
30-Apr-12	122	3D9.1C2D	B71395	10.4	
30-Apr-12	123	3D9.1C2D	B6B668	11.0	
30-Apr-12	124	3D9.1C2D	B71FBF	12.1	
30-Apr-12	125	3D9.1C2D	B72F81	10.9	
30-Apr-12	126	3D9.1C2D	B6A359	11.4	
30-Apr-12	127	3D9.1C2D	B724F7	11.7	
30-Apr-12	128	3D9.1C2D	B6AF0D	12.2	
30-Apr-12	129	3D9.1C2D	B52F5E	10.5	
30-Apr-12	130	3D9.1C2D	B7355B	11.6	
30-Apr-12	131	3D9.1C2D	B6F1F5	11.3	
30-Apr-12	132	3D9.1C2D	B24E4F	10.5	
30-Apr-12	133	3D9.1C2D	B32C25	10.9	
30-Apr-12	134	3D9.1C2D	B1BA67	10.7	
30-Apr-12	135	3D9.1C2D	B6A129	11.5	
30-Apr-12	136	3D9.1C2D	B6FEE6	11.4	
30-Apr-12	137	3D9.1C2D	B7323E	11.7	
30-Apr-12	138	3D9.1C2D	B6D117	10.6	
30-Apr-12	139	3D9.1C2D	B6B01C	10.7	
30-Apr-12	140	3D9.1C2D	B6E349	11.3	
30-Apr-12	141	3D9.1C2D	B6B678	11.0	
30-Apr-12	142	3D9.1C2D	B53D78	11.9	
30-Apr-12	143	3D9.1C2D	B2E5FC	11.2	
2-May-12	1	3D9.1C2D	B7BF0E	11.9	
2-May-12	2	3D9.1C2D	B6C897	11.6	
2-May-12	3	3D9.1C2D	B6B4DE	10.0	
2-May-12	4	3D9.1C2D	B7CCED	11.0	
2-May-12	5	3D9.1C2D	B729A9	11.3	
2-May-12	6	3D9.1C2D	B6C537	11.3	
2-May-12	7	3D9.1C2D	B6B6AC	10.8	
2-May-12	8	3D9.1C2D	B71B41	11.6	DROPPED
2-May-12	9	3D9.1C2D	B6AA13	12.1	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	10	3D9.1C2D	B4F7BE	11.4	DROPPED
2-May-12	11	3D9.1C2D	B69F41	11.7	
2-May-12	12	3D9.1C2D	B6AADC	12.6	
2-May-12	13	3D9.1C2D	B24E2C	11.2	
2-May-12	14	3D9.1C2D	B3199C	10.7	
2-May-12	15	3D9.1C2D	AC1166	11.2	
2-May-12	16	3D9.1C2D	B72F16	12.1	
2-May-12	17	3D9.1C2D	B6E194	11.0	
2-May-12	18	3D9.1C2D	B700BC	10.7	ONE TAG
2-May-12	19	3D9.1C2D	B7D54A	10.6	
2-May-12	20	3D9.1C2D	B6DEC4	11.2	
2-May-12	21	3D9.1C2D	B24110	12.8	
2-May-12	22	3D9.1C2D	AFC56C	12.0	
2-May-12	23	3D9.1C2D	AFC171	11.3	
2-May-12	24	3D9.1C2D	AFC0C4	11.3	
2-May-12	25	3D9.1C2D	AFE3E4	11.3	
2-May-12	26	3D9.1C2D	AEC218	13.0	
2-May-12	27	3D9.1C2D	AFDFB0	10.6	
2-May-12	28	3D9.1C2D	AFE48E	11.8	
2-May-12	29	3D9.1C2D	AFBB77	11.9	
2-May-12	30	3D9.1C2D	B01534	11.4	
2-May-12	31	3D9.1C2D	AFC85E	11.1	
2-May-12	32	3D9.1C2D	B02727	9.0	
2-May-12	33	3D9.1C2D	AFD159	12.1	
2-May-12	34	3D9.1C2D	AFBE81	10.5	
2-May-12	35	3D9.1C2D	AFDFDA	11.2	
2-May-12	36	3D9.1C2D	AFE2ED	10.9	
2-May-12	37	3D9.1C2D	AFD1D7	11.7	
2-May-12	38	3D9.1C2D	AFC487	10.3	
2-May-12	39	3D9.1C2D	AFCF65	11.3	
2-May-12	40	3D9.1C2D	AFDA93	10.6	
2-May-12	41	3D9.1C2D	AFD5DE	11.3	
2-May-12	42	3D9.1C2D	B12FFF	10.1	
2-May-12	43	3D9.1C2D	B01F3B	10.3	
2-May-12	44	3D9.1C2D	AEC0FE	11.8	
2-May-12	45	3D9.1C2D	AEC3CE	11.3	
2-May-12	46	3D9.1C2D	B02702	11.6	
2-May-12	47	3D9.1C2D	B0107E	10.3	
2-May-12	48	3D9.1C2D	AC62EA	11.1	
2-May-12	49	3D9.1C2D	AFE301	11.6	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	50	3D9.1C2D	B014C2	12.1	
2-May-12	51	3D9.1C2D	B12400	10.8	
2-May-12	52	3D9.1C2D	AFD5EF	11.3	
2-May-12	53	3D9.1C2D	B01E5D	10.6	
2-May-12	54	3D9.1C2D	AFE405	10.5	
2-May-12	55	3D9.1C2D	AFD93A	11.1	
2-May-12	56	3D9.1C2D	AFC486	10.9	
2-May-12	57	3D9.1C2D	AFC0EF	11.7	
2-May-12	58	3D9.1C2D	B00983	11.6	
2-May-12	59	3D9.1C2D	B00B21	10.6	
2-May-12	60	3D9.1C2D	AFEDD3	11.4	
2-May-12	61	3D9.1C2D	B01AB8	10.6	
2-May-12	62	3D9.1C2D	B020A2	12.7	
2-May-12	63	3D9.1C2D	AFEBCB	10.6	
2-May-12	64	3D9.1C2D	B02928	10.7	
2-May-12	65	3D9.1C2D	AFCD8E	10.8	
2-May-12	66	3D9.1C2D	AFEBF2	10.7	
2-May-12	67	3D9.1C2D	AFEF09	10.5	
2-May-12	68	3D9.1C2D	AFCCD7	11.2	
2-May-12	69	3D9.1C2D	AFCDF5	10.7	
2-May-12	70	3D9.1C2D	AE98D2	11.1	
2-May-12	71	3D9.1C2D	AFEB3E	11.7	RECAPTURE:B02107
2-May-12	72	3D9.1C2D	AFF01E	10.7	
2-May-12	73	3D9.1C2D	AFE401	10.3	
2-May-12	74	3D9.1C2D	AFF0F3	10.8	
2-May-12	75	3D9.1C2D	B024BE	11.4	
2-May-12	76	3D9.1C2D	AFEA92	11.1	
2-May-12	77	3D9.1C2D	B003A3	12.3	
2-May-12	78	3D9.1C2D	B01D30	12.1	
2-May-12	79	3D9.1C2D	AFEEEC	10.9	
2-May-12	80	3D9.1C2D	B02333	11.1	
2-May-12	81	3D9.1C2D	AFEFB6	11.0	
2-May-12	82	3D9.1C2D	AFCD09	9.5	
2-May-12	83	3D9.1C2D	AC6196	9.7	
2-May-12	84	3D9.1C2D	AFC7F2	13.2	
2-May-12	85	3D9.1C2D	AFFA5C	11.4	
2-May-12	86	3D9.1C2D	AED31D	10.7	FOUND ON GROUND MORT
2-May-12	87	3D9.1C2D	AFDEF0	11.4	
2-May-12	88	3D9.1C2D	AFC98B	10.4	
2-May-12	89	3D9.1C2D	AFCC41	11.5	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	90	3D9.1C2D	B01107	11.3	
2-May-12	91	3D9.1C2D	B149BA	10.6	
2-May-12	92	3D9.1C2D	AFE0C9	10.7	DIED IN RECOVERY
2-May-12	93	3D9.1C2D	B005D7	11.8	
2-May-12	94	3D9.1C2D	AFEF65	11.5	DIED IN RECOVERY
2-May-12	95	3D9.1C2D	B0043D	10.4	
2-May-12	96	3D9.1C2D	AFDAD4	11.5	
2-May-12	97	3D9.1C2D	B0096A	12.3	
2-May-12	98	3D9.1C2D	B03D1	11.5	
2-May-12	99	3D9.1C2D	B00456	10.3	DIED IN RECOVERY
2-May-12	100	3D9.1C2D	AFF041	10.5	
2-May-12	101	3D9.1C2D	AFE3E9	11.0	
2-May-12	102	3D9.1C2D	AFDFF6	12.3	
2-May-12	103	3D9.1C2D	AFEA65	10.1	
2-May-12	104	3D9.1C2D	B003A6	10.9	
2-May-12	105	3D9.1C2D	AEAEB3	11.8	
2-May-12	106	3D9.1C2D	AFC8CO	10.6	
2-May-12	107	3D9.1C2D	AE9F48	10.7	
2-May-12	108	3D9.1C2D	AFEAC3	10.9	
2-May-12	109	3D9.1C2D	AFEF07	11.0	
2-May-12	110	3D9.1C2D	B0290C	12.4	
2-May-12	111	3D9.1C2D	B01BF3	11.1	
2-May-12	112	3D9.1C2D	B026E6	10.7	
2-May-12	113	3D9.1C2D	AFDEFF	11.5	
2-May-12	114	3D9.1C2D	B01E14	11.6	
2-May-12	115	3D9.1C2D	AFC57E	13.0	
2-May-12	116	3D9.1C2D	AFF6AD	11.0	
2-May-12	117	3D9.1C2D	AFE470	10.8	
2-May-12	118	3D9.1C2D	AFC104	12.0	
2-May-12	119	3D9.1C2D	BFBFBB	9.8	
2-May-12	120	3D9.1C2D	AC5D03	10.5	DIED IN RECOVERY
2-May-12	121	3D9.1C2D	B022CD	10.7	
2-May-12	122	3D9.1C2D	B4FB42	12.3	
2-May-12	123	3D9.1C2D	B521C3	10.3	
2-May-12	124	3D9.1C2D	B54768	10.3	
2-May-12	125	3D9.1C2D	B766A0	10.7	
2-May-12	126	3D9.1C2D	B6B816	12.3	
2-May-12	127	3D9.1C2D	B7C272	11.4	
2-May-12	128	3D9.1C2D	B53058	10.3	
2-May-12	129	3D9.1C2D	AFE614	11.4	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	130	3D9.1C2D	AFBB7B	10.6	
2-May-12	131	3D9.1C2D	B50493	11.5	
2-May-12	132	3D9.1C2D	B4D121	10.5	
2-May-12	133	3D9.1C2D	B69EDB	11.0	
2-May-12	134	3D9.1C2D	B00D89	10.9	
2-May-12	135	3D9.1C2D	AFCBCB	10.8	
2-May-12	136	3D9.1C2D	AFDB34	10.3	
2-May-12	137	3D9.1C2D	B10AC6	11.6	
2-May-12	138	3D9.1C2D	B28FD1	11.8	
2-May-12	139	3D9.1C2D	AD9251	10.6	
2-May-12	140	3D9.1C2D	B7C95E	12.7	
2-May-12	141	3D9.1C2D	B52EE0	12.2	
2-May-12	142	3D9.1C2D	AD3F77	12.3	
2-May-12	143	3D9.1C2D	AFFF44	11.9	
2-May-12	144	3D9.1C2D	B740F5	11.9	
2-May-12	145	3D9.1C2D	AFF1FB	11.5	
2-May-12	146	3D9.1C2D	AFCB49	12.0	
2-May-12	147	3D9.1C2D	B009A7	10.8	
2-May-12	148	3D9.1C2D	AD7943	11.2	
2-May-12	149	3D9.1C2D	B00F25	11.8	
2-May-12	150	3D9.1C2D	AFFD2F	11.0	
2-May-12	151	3D9.1C2D	B726A9	11.3	
2-May-12	152	3D9.1C2D	B53C47	11.3	
2-May-12	153	3D9.1C2D	B6D016	11.2	
2-May-12	154	3D9.1C2D	B10181	11.5	
2-May-12	155	3D9.1C2D	B4ECA5	11.8	
2-May-12	156	3D9.1C2D	AFD0CB	10.2	
2-May-12	157	3D9.1C2D	AFC132	10.4	
2-May-12	158	3D9.1C2D	B- 00B57	12.0	
2-May-12	159	3D9.1C2D	B00F39	9.6	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
2-May-12	160	3D9.1C2D	B7B644	10.3	DIED IN RECOVERY
2-May-12	161	3D9.1C2D	B74014	12.0	
2-May-12	162	3D9.1C2D	AFBDAF	11.5	
2-May-12	163	3D9.1C2D	B0017D	10.3	
2-May-12	164	3D9.1C2D	B4D0E0	11.6	
2-May-12	165	3D9.1C2D	B716F7	11.7	
2-May-12	166	3D9.1C2D	AFEA1E	12.0	
2-May-12	167	3D9.1C2D	B30703	12.0	
2-May-12	168	3D9.1C2D	B530C0	10.2	DIED IN RECOVERY

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	169	3D9.1C2D	B00218	10.2	RECAPTURED IN RST + TAKEN FOR BIOSAMPLING
2-May-12	170	3D9.1C2D	B4DF62	11.3	
2-May-12	171	3D9.1C2D	B70C91	10.4	
2-May-12	172	3D9.1C2D	B73362	10.5	
2-May-12	173	3D9.1C2D	B52E53	12.4	
2-May-12	174	3D9.1C2D	AFC3E7	11.3	
2-May-12	175	3D9.1C2D	B53C5A	11.3	
2-May-12	176	3D9.1C2D	B00256	11.5	
2-May-12	177	3D9.1C2D	B2A3EC	9.6	
2-May-12	178	3D9.1C2D	B6E70B	11.4	
2-May-12	179	3D9.1C2D	B4BFE0	11.5	
2-May-12	180	3D9.1C2D	B5CDCC	11.0	
2-May-12	181	3D9.1C2D	B4D30A	10.3	
2-May-12	182	3D9.1C2D	B52E30	11.4	
2-May-12	183	3D9.1C2D	B5BF2C	11.4	BLEEDING HEAVILY
2-May-12	184	3D9.1C2D	B53C79	12.0	
2-May-12	185	3D9.1C2D	B6BEF4	10.9	
2-May-12	186	3D9.1C2D	B6E9FB	11.8	
2-May-12	187	3D9.1C2D	B54880	10.9	
2-May-12	188	3D9.1C2D	AD58ED	11.5	
2-May-12	189	3D9.1C2D	B6A197	10.4	
2-May-12	190	3D9.1C2D	B52E5D	11.9	
2-May-12	191	3D9.1C2D	B6A5B4	10.8	
2-May-12	192	3D9.1C2D	B5460A	10.7	
2-May-12	193	3D9.1C2D	B14201	10.6	
2-May-12	194	3D9.1C2D	B4DBD9	11.8	
2-May-12	195	3D9.1C2D	B521AE	11.7	
2-May-12	196	3D9.1C2D	AD76D7	10.7	
2-May-12	197	3D9.1C2D	AD60A5	11.8	
2-May-12	198	3D9.1C2D	B7A8D7	12.3	
2-May-12	199	3D9.1C2D	AC24AA	10.8	
2-May-12	200	3D9.1C2D	AD762D	11.1	
2-May-12	201	3D9.1C2D	B8026A	11.4	
2-May-12	202	3D9.1C2D	B14D07	11.6	
2-May-12	203	3D9.1C2D	B4DD16	10.6	
2-May-12	204	3D9.1C2D	AFE583	11.1	
2-May-12	205	3D9.1C2D	AFBE22	11.2	
2-May-12	206	3D9.1C2D	B7139E	11.5	
2-May-12	207	3D9.1C2D	B15ECA	10.8	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	208	3D9.1C2D	B6AE83	10.3	
2-May-12	209	3D9.1C2D	B3460A	11.9	
2-May-12	210	3D9.1C2D	B4C81B	12.1	
2-May-12	211	3D9.1C2D	B53BB7	11.9	
2-May-12	212	3D9.1C2D	B0165F	11.0	
2-May-12	213	3D9.1C2D	AD6A2F	12.2	
2-May-12	214	3D9.1C2D	AFBE44	12.3	SLIGHT SCALE LOSS
2-May-12	215	3D9.1C2D	AFBE48	10.1	
2-May-12	216	3D9.1C2D	B4D434	11.5	
2-May-12	217	3D9.1C2D	B6B903	11.3	
2-May-12	218	3D9.1C2D	B7351B	10.4	
2-May-12	219	3D9.1C2D	B6A70E	11.6	
2-May-12	220	3D9.1C2D	B51387	9.8	
2-May-12	221	3D9.1C2D	B506E5	12.0	
2-May-12	222	3D9.1C2D	B727CD	11.2	
2-May-12	223	3D9.1C2D	B6ACAA	11.3	
2-May-12	224	3D9.1C2D	B2DF90	11.6	
2-May-12	225	3D9.1C2D	B74422	11.3	
2-May-12	226	3D9.1C2D	AC3B20	11.0	
2-May-12	227	3D9.1C2D	AC2EE8	11.5	
2-May-12	228	3D9.1C2D	B5CC05	10.9	
2-May-12	229	3D9.1C2D	B6EDD2	11.3	
2-May-12	230	3D9.1C2D	B6D5CB	11.5	
2-May-12	231	3D9.1C2D	B6BC70	11.7	
2-May-12	232	3D9.1C2D	B6AF89	11.9	
2-May-12	233	3D9.1C2D	B56F6B	11.9	
2-May-12	234	3D9.1C2D	B78347	10.7	
2-May-12	235	3D9.1C2D	B7146A	?	
2-May-12	236	3D9.1C2D	AD75EE	12.0	
2-May-12	237	3D9.1C2D	B6DA40	10.9	
2-May-12	238	3D9.1C2D	B6BC07	10.4	
2-May-12	239	3D9.1C2D	B706CB	11.1	
2-May-12	240	3D9.1C2D	B6CFB3	11.5	
2-May-12	241	3D9.1C2D	B72000	11.3	
2-May-12	242	3D9.1C2D	B28497	10.3	
2-May-12	243	3D9.1C2D	B7938B	10.3	
2-May-12	244	3D9.1C2D	B77D82	11.3	
2-May-12	245	3D9.1C2D	B51F64	10.4	
2-May-12	246	3D9.1C2D	B6F91C	11.1	
2-May-12	247	3D9.1C2D	B6B804	11.8	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	248	3D9.1C2D	B6A5EF	10.7	
2-May-12	249	3D9.1C2D	B6EC06	12.8	
2-May-12	250	3D9.1C2D	B26EAB	11.9	
2-May-12	251	3D9.1C2D	B72A5C	10.0	
2-May-12	252	3D9.1C2D	B7002F	11.1	
2-May-12	253	3D9.1C2D	B52186	11.4	
2-May-12	254	3D9.1C2D	B332D1	10.8	
2-May-12	255	3D9.1C2D	B5465D	12.1	
2-May-12	256	3D9.1C2D	B6FB7D	10.9	
2-May-12	257	3D9.1C2D	B69D46	11.8	
2-May-12	258	3D9.1C2D	B721BC	11.2	
2-May-12	259	3D9.1C2D	B71951	10.7	
2-May-12	260	3D9.1C2D	B6D470	11.2	
2-May-12	261	3D9.1C2D	B7437C	12.7	
2-May-12	262	3D9.1C2D	B29D48	11.4	SCALE LOSS
2-May-12	263	3D9.1C2D	B6EA0C	11.8	
2-May-12	264	3D9.1C2D	B6CC09	11.7	
2-May-12	265	3D9.1C2D	B70DC4	11.8	
2-May-12	266	3D9.1C2D	B4D0EA	10.9	
2-May-12	267	3D9.1C2D	B52395	10.6	
2-May-12	268	3D9.1C2D	B72BA3	13.1	
2-May-12	269	3D9.1C2D	B31FA0	12.2	
2-May-12	270	3D9.1C2D	B6FB85	10.8	
2-May-12	271	3D9.1C2D	B6E6E0	10.1	
2-May-12	272	3D9.1C2D	B53D48	11.0	
2-May-12	273	3D9.1C2D	B6B08B	11.7	
2-May-12	274	3D9.1C2D	B6ABB3	11.7	
2-May-12	275	3D9.1C2D	B51290	11.9	
2-May-12	276	3D9.1C2D	B6E704	11.6	
2-May-12	277	3D9.1C2D	B7EAA8	11.1	
2-May-12	278	3D9.1C2D	B6D717	11.0	
2-May-12	279	3D9.1C2D	B78668	11.2	
2-May-12	280	3D9.1C2D	B7BF80	10.5	
2-May-12	281	3D9.1C2D	B70B3A	11.5	
2-May-12	282	3D9.1C2D	B4DCFE	10.5	
2-May-12	283	3D9.1C2D	B28432	11.6	
2-May-12	284	3D9.1C2D	B523D8	11.5	
2-May-12	285	3D9.1C2D	B30EC7	11.0	
2-May-12	286	3D9.1C2D	B67FAA	10.2	
2-May-12	287	3D9.1C2D	B6A5AE	10.5	

Date Tagged + Released	Fish No.	Tag No.		Fork Length (cm)	Comments
2-May-12	288	3D9.1C2D	AC5CFF	11.1	
2-May-12	289	3D9.1C2D	B6A4A8	11.5	
2-May-12	290	3D9.1C2D	B700C1	11.0	
2-May-12	291	3D9.1C2D	B6DA33	10.6	
2-May-12	292	3D9.1C2D	B2F7D5	11.2	
2-May-12	293	3D9.1C2D	B77158	10.9	
2-May-12	294	3D9.1C2D	B6BAC5	11.1	
2-May-12	295	3D9.1C2D	B6C525	10.4	
2-May-12	296	3D9.1C2D	B24DB6	10.8	